Systematically Gathering Clinician Opinions on Health Care Technology

BY

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DISSERTATION
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This dissertation is dedicated to my husband, Christopher Jones, who has managed to keep my standards and spirits high through his love and support.

This dissertation is also dedicated to my parents, Ira and Sheila Naiman, who raised me to have the discipline and intellectual curiosity necessary to embark on this journey to start with.
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A multi-level study of healthcare technology innovation and adoption was conducted in a large, suburban Emergency Department. The goal of the study was to develop and implement a new survey instrument based on Q-methodology that will allow hospital administrators to efficiently incorporate clinician preferences into strategic planning efforts.

Qualitative techniques were used to identify key features and clinical scenarios in which adopting radical health technology would be most beneficial. The final instrument consisted of 43 generic statements that 40 clinicians ranked based on which they felt were most likely to most unlikely to improve care (a Q sort). Analysis of the Q sorts revealed four innovation profiles: Speed, Holism, Acuity, and Information. Each profile reflects a unique group of opinions regarding which technologies are most likely to improve care.

Analysis across the four innovation profiles revealed nine technologies that were ranked as likely to improve care and six technologies that were ranked unlikely to improve care across all four groups. Seven technologies were considered highly controversial across the groups, including patient records contained in a Health Information Exchange. Taken together, these results provide a new mechanism by which hospital administrators can include clinician opinions during technology assessment efforts and change management planning.
I. INTRODUCTION

A. Background

Innovation is increasingly important to health care organizations. Each year, billions of dollars are spent to acquire new technologies and conduct research (both on projects that will inspire new technologies or those that explore the efficacy and efficiency of technologies currently in use). In 2001, the purchase of new technology, including Information Technology (IT) and major medical equipment, reached 51 percent of all hospital capital spending (1). In 2003, the medical device sector (including commodity supplies such as sutures and bandages) exceeded $165 billion in global revenues (2). In 2004, hospital investment in IT alone reached $26 billion and approximately 2% of operating budgets were allocated to all technology (1). The Centers for Medicare & Medicaid Services project that the medical sector will invest $129.9 billion in equipment and infrastructure during 2011 (3). Literally hundreds of individual decisions will commit much of the available capital in the health care sector for years or decades ahead (1).

Healthcare organizations are motivated to seek and implement innovations, even when innovation increases health care costs (4-6). Clinical performance (improving patient care and increasing treatment options), financial benefit (favorable reimbursement rates, grant funding, or general cost savings), and cultural expectations (a means to attract talent or to enhance organizational prestige) are among the most commonly cited reasons to innovate. A hospital’s decision to adopt a new technology (or many new technologies) is a symbolic action, and provides outside entities with information about the organization. The presence or absence of
technology can reflect the culture of the organization and the connectedness of the organization with its stakeholders (6).

The technology adoption literature distinguishes between two types of innovations: iterative and radical (7). Iterative innovations are defined as minor changes to a previously adopted technology that are intended to improve function in some way. Examples in the healthcare sector might include an infusion pump with an improved user interface or the repackaging of sterile equipment so that it is easier to open or store. Radical innovations refer to major departures from standard practice that may change workflow or professional roles. In the healthcare sector, examples could include using handheld ultrasound devices during an abdominal examination, point-of-care diagnostics to replace laboratory-based tests, or utilizing an electronic stethoscope to record and analyze heart sounds. Both types of innovation are important to improving the provision of care in a hospital department. Most hospitals currently have established assessment protocols for iterative innovations, but do not have a process to identify and prioritize radical innovations. This study seeks specifically to explore opinions regarding radical innovation (defined in this study as the initiation, acceptance, and implementation of a new medical device for the first time within an organizational setting) that may change workflow or professional roles.

In practice, either a “top-down” or “bottom-up” mechanism typically drives the introduction of radical healthcare innovations. In a “top down” scenario, organizational will drives innovation, usually to gain some financial or political benefit. One example of such a scenario would be a hospital seeking and receiving Federal funds to implement a new Electronic
Medical Record system. “Bottom-up” scenarios are characterized by a champion (usually a clinician, most likely a physician) bringing an innovation to administrators and pushing for implementation. Both scenarios rely heavily on vendors to make potential adopters aware of innovation opportunities and provide information to support a use case. So, while innovation occurs, each innovation is treated as an isolated business decision rather than as a component of an overarching plan to meet strategic goals of the organization.

Disregarding clinician opinions as part of a radical innovation strategy has two disadvantages: 1) there is an increased chance that clinical users will be dissatisfied with the technology investment decisions; and 2) the organization will miss opportunities to assess and implement innovations of which it was not aware. The second case is particularly likely if the organization relies, as many do, on a clinician champion to alert administration to innovation opportunities. As a result, there may be either no input from clinical staff or the over-representation of the opinions of a dominant personality. Both scenarios place the organization in an unfavorable position for technology adoption because key variables that mediate organizational innovation include trust, diversity of opinion sources, communication networks, and communication pathways.

One major difficulty that hospital leaders face as part of the investment decision is that usually at the time point when investment would be most strategically advantageous, very little data are available to assess the clinical significance or operating costs of a medical technology at the organizational level (4). Therefore, hospital leaders must consider three major risks: 1) the lack of objective clinical information can lead to selection of a technology that actually does
not improve (or worse, negatively influences) patient outcomes; 2) the lack of sufficient
financial data, such as maintenance and training costs, can lead to operational costs that far
exceed expectations; and 3) unfavorable clinician interactions with the technology can lead to
suboptimal performance and inability to obtain full value from the investment (by any metric of
importance to the organization). The first two risks are difficult to mitigate. Clinical trials and
meta-analyses that support the efficacy of a given innovation take time to complete and will
likely be available well after the timeframe when adoption would lead to the greatest amount
of competitive advantage. Likewise, data on actual operating costs will not be available.
Leveraging current knowledge of individual adoption theory can minimize the third risk factor.
Individuals incorporate a technology into the organization (8). People, not the hardware or
software, are most often associated with an organization’s failure to obtain full value from a
technologic investment. So, while technology provides a unique platform to leverage the
performance of individuals in pursuit of the mission of a hospital (6), hospitals can also
accumulate many technology assets without increasing their capabilities (9).

Many agencies concerned with health technology prioritization (also referred to as
health technology assessment) have developed models and frameworks to aid healthcare
organizations with decision-making. Taken together, 11 agencies in the U.S. and Europe have
proposed a total of 12 frameworks representing 59 unique assessment criteria (10). In the
United States, one of the highest profile frameworks is the 7-step process developed by the
Institute of Medicine (IOM) Committee on Priorities for Assessment and Reassessment of
Health Care Technologies. The IOM was charged with designing a prioritization strategy for
health technology assessment at a national level that would ultimately be performed by the Office of Health Technology Assessment within the Agency for Health Care Policy and Research (now the Agency for Healthcare Research and Quality, or AHRQ). Though the specific process was developed for AHRQ and its infrastructure, the principles were intentionally framed so that they would be relevant to any organization (11). The second step in the recommended process is: “Solicit nominations of candidates for technology assessment.” The IOM goes on to recommend that the solicitation be open to as broad an audience as possible (11). Strategies previously employed by other agencies included similar guidance; for example, the Clinical Efficacy and Assessment Program sponsored by the American College of Physicians and the Diagnostic and Therapeutic Technology Assessment program sponsored by the American Medical Association actively solicited members and other interested groups for assessment topics.

The IOM report explicitly encourages other health organizations to implement their framework when evaluating new technologies, but it does not provide specific guidance on gathering or analyzing opinions in the context of a hospital or other care provider (11). The purpose of the AHRQ assessment is to inform policy of the government’s Health Care Financing Administration. The method employed in the IOM report for soliciting opinions (any member of the public can nominate a topic through the AHRQ website or via email) is probably inappropriate for a single hospital or even a large hospital system. In addition, the AHRQ framework does not directly address issues of clinical user adoption, which would be of great
significance to hospital leadership. Whether clinical providers adopt the recommended technologies is not studied by the IOM or AHRQ.

Thus, the existing priority frameworks aid in assessing the technology itself, but do not provide insight about the context into which the technology will be placed. Knowledge of the social climate is imperative to the strategic planning that surrounds technology implementation. An administrator cannot evaluate risk or opportunity based solely on technical specifications. Systematically gathering clinician opinions about radical technologies provides an opportunity to simultaneously gain insight into end user preferences as well as variations in underlying values between clinicians within a department. Such information could prove especially valuable when attempting to introduce radical innovations into highly diverse departments, such as the emergency department.

Emergency medicine is associated with fast-paced and high risk decision making; providers must be prepared to recognize and address a wide range of clinical conditions in a relatively short amount of time. In this setting, technology can provide critical data that support the initiation of life-saving interventions or the avoidance of unnecessary procedures and patient risk. While many clinical specialties utilize a relatively small assortment of tools during patient care for a generally predictable set of conditions, emergency medicine relies on a broad array of technologies assembled to provide flexibility in treatment options. As such, emergency departments provide an interesting context in which to study innovation and adoption. Outcomes of this study will include a series of factors that describe opinion sets among physicians and nurses across the ED. These opinion sets will help identify several classes
of health care technologies that clinical staff feel will improve care in the ED. Other EDs can use the survey instrument, developed in this study, to help establish technology investment strategies.

If successful in the ED, it is likely that this methodology would be useful in other areas of a hospital, other health care organizations, and organizations where individuals from diverse professional backgrounds perform a large number of complicated, interconnected tasks. Once hospital leadership determines priorities for evaluating a class of medical devices, there is usually infrastructure in place to assess options within a given area. Many hospitals establish an evaluation team to compare similar devices from different vendors in order to determine which vendor product should be acquired (4, 10, 12-15). This team is generally composed of clinicians, engineers, and business managers, who collect and synthesize data from different sources. These committees collect clinical input in a variety of ways, ranging from side-by-side comparisons during an in-service (16) to formal observational human factors study (17). Based on case studies and published reports, these evaluation teams are generally attuned to usability issues, but no literature describes a mixed-methods approach to gathering clinician opinion data for strategic purposes. There appears to be a gap, therefore, between healthcare technology assessment theory and practice at the hospital level, which this study seeks to fill.

B. **Statement of the Problem**

Specifically, this study explores opinions regarding radical innovation (defined in this study as the initiation, acceptance, and implementation of a new medical device for the first time within an organizational setting) that may change workflow or professional roles. New
medical devices and health IT products will reach the market at an increased pace. Likewise, new revelations in medical science will require clinicians and health care organizations to embrace new practices and technologies that significantly depart from traditional thinking. Both of these realities require health care providers to optimize the manner in which radical innovations are recognized and identified at the organizational level. Combining an established prioritization framework that applies what is known from research about how individuals and organizations adopt innovations (18, 19) will likely aid hospital administrators in developing a solid investment strategy and mitigate the risk of technology rejection. While several prioritization frameworks recommend soliciting opinions from clinical users to focus technology assessment efforts, a systematic method to gather and analyze these opinions at the hospital level has not been established.

An additional challenge in identifying and prioritizing radical innovations at the hospital level is that the needs, cultures, and opportunities for radical innovation vary across departments. Generally speaking, the greater the number of relevant and attractive options, the harder it is to prioritize them. Since most hospitals provide budget lines to each department, it is logical to focus opinion gathering at the departmental level. However, not every department will face the same prioritization challenges. Therefore, it is most meaningful to test a new prioritization framework in a context where many radical innovations could be adopted and prioritization is difficult. Emergency departments are, on average, innovation rich environments. Emergency rooms must be prepared to address a wide range of health issues. From a technology perspective, this means adopting devices and equipment associated with
many different specialties. From a cognitive perspective, clinicians must be prepared to recognize and treat patients whose needs range from primary care through life-threatening disease states or trauma. The unique operating parameters of the ED make it likely that the preferences and perceptions of ED clinicians are likely to hold true in other contexts. For example, ED treatment rooms are equipped with the same ophthalmoscopes and otoscopes as primary care physicians. It is likely those ED clinicians’ opinions regarding design flaws would be shared by other users.

C. **Purpose of the Study**

The purpose of this research is to develop and test a methodology that will aid health care administrators in systematically gathering and analyzing opinions regarding healthcare technology in order to identify radical innovations and prioritize their implementation. When clinical workflow dictates frequent interaction with a technology, the failure to adopt an innovation may result in user dissatisfaction, productivity losses, and other negative consequences. The goal of this study is to provide guidance on the solicitation of end user opinions, which can serve as the basis for technology selection and implementation. Using Q-methodology to collect clinician opinions will provide two levels of data that will be valuable to administrators. First, studying trends across independent opinion groups will allow hospital leaders to determine which radical innovations clinicians collectively favor at the departmental level. Second, studying trends within each opinion group will allow hospital leaders to construct “innovation profiles” of clinicians in the department which can inform change management strategies that will facilitate implementation and ultimately adoption.
D. **Significance of the Problem**

Approximately 50% of health technology implementation efforts fail (20). Despite massive effort and government incentives, the Office of the National Coordinator estimates only 35% of hospitals had adopted electronic health records by 2011 (21). Literature and case studies describing clinician rejection of new technologies, as well as inventive workarounds, is abundant (22-24). Continuing the practice of selecting technology without clinician input will only exacerbate this trend, especially as health technology begins to reflect major departures from traditional medical practice that are being uncovered in basic and translational research. New methods to efficiently and effectively obtain and incorporate clinician opinions regarding health technology are imperative if we are to decrease the number of clinician rejection.

E. **Research Questions**

This research focuses on designing and implementing a new methodology that hospital administrators could utilize to solicit clinician opinions regarding radical healthcare technology, a key phase of healthcare innovation. These opinions can then be applied to the identification of radical innovations candidates and to prioritize the candidates according to clinician preference. Q method uses the task of sorting as a means of documenting the self-reported, self-referenced opinion surrounding potential radical innovations. Three benefits accrue in the use of Q method rather than an open solicitation format (as in the AHRQ process). First, administrators can limit the topics to areas in which the organization will reasonably explore radical technology implementation, thus reducing the chances that clinical users will perceive their opinions as ignored. Second, Q method brings quantitative analytic tools (correlation
coefficients and factor analysis) to bear on qualitative data. This facilitates opinion ranking, which can refine the overall prioritization exercise. Third, Q allows each participant’s opinion to have equal weight during data analysis.

Specifically, this study explores opinions regarding radical innovation (defined in this study as the initiation, acceptance, and implementation of a new medical device for the first time within an organizational setting) that may change workflow or professional roles. Radical innovation is explored through two theories of technology adoption: the Task-Technology Fit model and the Technology Adoption Model. Both theories are well established in the literature (25, 26) and have been used extensively in health care settings; however, these theories are usually applied to predicting the acceptance and adoption of single technologies. In this study, they will be used to inform a market review of multiple radical health care technologies intended for use in the ED.

1. **Identifying Radical Health Care Technologies**

Research Question 1: Can a method be developed by which clinicians can characterize those technological innovations most beneficial to their provision of care? The medical device and health IT industries have steadily grown over the last two decades, often achieving double-digit growth from year to year. As a result, the market often contains several technological solutions to a given clinical problem; however, the design of these solutions does not necessarily reflect clinician preferences or workflow. Two theoretical perspectives provide insight into the relationships between users and technology that influence adoption. First, clinicians are more likely to adopt technologies that are easy to use or serve a clear purpose.
The Technology Adoption Model proposes that Perceived Ease of Use and Perceived Usefulness are two variables describing technology characteristics that influence adoption behavior. Using this framework to guide clinician interviews about health technology will establish a refined definition of “easy to use” and “usefulness” within the context of that specific department and operational experience. This refined definition of technology characteristics can then be applied to initial assessments of radical innovations that could be deployed in the future.

Second, clinicians are more likely to adopt innovations when these innovations address a perceived need. Based on the Task Technology Fit framework, exploring the relationship between clinical tasks (i.e., diagnosis, treatment, and management of various clinical conditions) and health technology will reveal instances where current technology does not “fit.” The purpose of this measurement is to identify clinical conditions for which providers feel that entirely new approaches to care, using new technology, could be of greatest benefit. By exploring clinical conditions, rather than specific devices, there is greater opportunity for health care leaders to identify areas for radical innovation. Focusing on a specific technology too early in the selection process hinders creativity in several ways. First, by putting forward a device for consideration, leaders are signaling a strong preference or that a decision has already been made. Faced with this situation, most employees perceive expressing an alternative or contradictory opinion as going against their own self-interest. Second, framing a discussion of radical innovation in terms of specific technologies inherently limits the conversation only to those technologies participants are aware of. Just as it is impossible to expect every clinician to be aware of every scientific discovery the moment it is published, it is unreasonable to assume
clinicians will be aware of every relevant commercial offering. This is particularly true of specialties, such as emergency medicine, that incorporate medical technologies from a variety of domains. Therefore, the Task Technology Fit framework will guide clinician focus group discussions about which challenges in patient diagnosis, treatment, and management could be addressed through radical changes in technology.

Outcomes from clinician interviews and focus groups will be combined to guide a thorough search of the health technology market. The goal of the market review will be to identify radical health technologies that reflect clinicians’ perceptions of usefulness, ease of use, and fit with clinical workflow.

2. **Prioritizing Potential Radical Innovations**

Research Question 2: Can clinician opinions provide insight into prioritization and implementation of radical technologies? Resource constraints are a reality of healthcare innovation. Research Question 1 will provide a list of radical health technologies that reflect clinician preferences in general. It is unlikely that the organization will have sufficient resources to invest in all of the radical health technologies simultaneously. It is also unreasonable for the organization to construct a business case for each candidate technology. While methods may vary between organizations, prioritization is a standard business practice. In health care settings, it is not standard practice to incorporate clinician decisions directly into the prioritization process. This is partially due to the fact that most methodologies designed to understand or explore opinions are not sensitive to the needs of the business community. Qualitative study outputs are often narrative or abstract in nature; purely qualitative methods
are not amenable to ranking. Quantitative methods also generally avoid forced choice; frequently in survey research, subjects have the opportunity to (and often will) select the same response throughout the entire instrument (i.e., indicate "5" for each item). This creates a significant risk that the survey will not yield any new or useful information.

In contrast, Q-methodology, is designed to explore similarities in opinion sets through a ranking exercise (the Q sort). In this study, the list of radical technology candidates (derived from research question 1) inspired generic statements that clinicians ranked as “most likely” or “most unlikely” to improve care. Participants’ sorts were correlated and subjected to factor analysis. Each factor represented a shared opinion of which technologies were perceived as “most likely” and “most unlikely” to improve care. Positive consensus across factors reveals specific technologies that should, from the clinicians’ perspective, be implemented first. Preference patterns within each factor were used to construct “innovation profiles” that could inform change management strategy, should hospital leaders choose to implement a technology that one group perceived unfavorably.

This study proposes a methodology to facilitate gathering clinician opinions regarding health care technology that will be implemented in the emergency department (ED) of a large, suburban teaching hospital in the Chicagoland area. The specific site was selected due to convenience, as well as its history of research participation, complexity of patient mix, and number of qualified clinicians.
II. LITERATURE REVIEW

A. Overview

The following sections highlight how innovation is described across multiple disciplines in order to compare and contrast how innovation has developed as a theoretical construct. Associated terms, such as implementation and adoption, are also described to differentiate between the related concepts and set standard definitions used throughout this work. Following the discussion of innovation, characteristics of innovative organizations are described and applied to the hospital setting. Finally, theories of individual adoption and the application of these theories to clinical practice are presented.

B. Conceptual Framework of Innovation

As described in the introduction, innovation is considered a key factor in the long-term success or viability of an organization. As such, it has been extensively studied from many perspectives, which has resulted in a broad range of definitions being developed for the term. Despite these different approaches and philosophies, there is a good deal of agreement on what constitutes an innovation; however, there are also many divergent opinions that must be addressed in order to establish an underlying philosophy for this study.
C. **Anatomy of an Innovation**

1. **Newness**

   The concept of newness is unanimously considered a required component of innovation across disciplines (27). Almost all definitions specifically use the word “new” or some close synonym, such as “novel” (7, 8, 27-32). One interesting exception to this trend is Amabile’s definition of innovation as a successful implementation of creative ideas within an organization (33); however, she goes on to define these ideas as new products, services, or processes. There is a general consensus that products, processes, services, and policies can all be areas for innovation (7, 8, 27, 30, 33, 34), but Edwin Mansfield (35) refines the concept further. He states that innovation must reflect the “first use ever” by an organization; all subsequent uses by other social systems should be described as imitation. This view is also held by Daft (28), who defines innovation in terms of being the first in a given industry, market, or general environment to effect some kind of change. This is in contradiction to Thompson (8) and Zaltman et al. (31), who argue the notion that the innovation need only be perceived as new by the relevant adopting unit (the organization). Further distinctions have been made between invention and innovation; the former is described as the creative act and the latter its application (36, 37).

2. **Multiple Stage Process**

   There is wide agreement that innovation represents a multi-stage process. This is consistent with general theories of organizational decision processes (38). There remain, however, many interpretations of what these phases are, precisely. Among the most
parsimonious descriptions are two-step processes; Becker and Whisler (36) broadly describe innovation events as a range of inputs and outputs, and Knight (39) suggests that innovation is comprised of the creation and development of an idea and its introduction and adoption. More commonly, researchers propose three or more stages to describe the innovation process. Thompson (8) proposed generation, acceptance and implementation as the stages of innovation. Damanpour et al. (7, 27) and Zmud (40) define the stages as initiation, adoption decision and implementation. Wilson (41) suggests conception, proposing, and adoption and implementation of the change. Shepard (42) identified idea generation, adoption, and implementation. Similarly, Kanter (34) defined the stages of innovation as generation, acceptance, and implementation. Zaltman et al. (31) reviewed a number of innovation models (at both the individual and organizational levels) to explore common themes; each model had a cognitive component followed by an ideation and decision phase, and a terminal activity such as adoption or implementation.

One of the difficulties in refining the theoretical models of innovation is that, even though the academic community recognizes a multi-stage process, empirical studies often operationalize innovation as a single stage event, i.e., did an organization invest in a technology or not (27, 32)? In much of the organizational innovation literature, data are collected through surveys that are generally poorly suited to explore issues of process, but are well suited to measure historic actions, such as whether a hospital purchased a given medical device. Thus, the differentiations between definitions proposed by the researchers above may be more a matter of semantics than an indication of intellectual discord. Another difficulty in attempting
to describe innovation is that in practice, it is a fairly rare event and can be drawn out over years (43) in rapidly changing organizational environments (44). This makes applying qualitative methods, which are better suited to studying multi-stage processes, challenging. While it is possible to conduct interviews after the fact, the results are more prone to recall bias than in an observational study. Finally, since innovation is so closely connected with competitive advantage, it is likely that many organizations would prefer to keep their (successful) processes confidential, resulting in sample bias. Despite the challenges facing empirical confirmation, the fact that so many members of different disciplines collectively recognize the presence of multiple stages that are conceptually similar lends credence to the face validity of the theory that innovation is a multi-stage process.

3. **Innovation and Change**

Another necessary component of innovation is that some change must occur; the frequency with which implementation and adoption were included as stages of innovation demonstrates the theoretical importance placed on change. There remains, however, some controversy surrounding what makes innovation a unique phenomenon from other types of organizational change (29). As mentioned earlier, some hold that being the absolute first in a social system separates innovation from routine change (28, 35). This may be an important distinction. In practice, change management often utilizes “lessons learned” and refers to previous experience to help manage change; however, the academic definition of change management does not reference comparisons to other organizations, and specifies that all changes should be managed in the same manner (45). This supports the idea that the
uniqueness of innovation lies solely in timing (i.e., being first) rather than the type of change that occurs. This also implies that a majority of the experimental data on organizational innovation in the health care sector actually describes organizational change.

If one accepts the premise that newness to the organization is sufficient, in the tradition of Thompson and others, then on what criteria can innovation be distinguished from other change? Damanpour (27) specified that innovation is initiated by choice. Drucker (46) suggested that innovation is a “purposeful and organized search for changes.” King and Anderson (29) support the notion of intent and add that the motivation behind an innovation should be some type of benefit (to the organization or wider society) as well as having a public effect (meaning more than one person must change). Amabile (33) stressed the importance of creativity: “...[innovation] implicitly or explicitly includes the notion of creative (novel and useful) ideas being successfully implemented by a larger group.” Thompson (8) points out that changes resulting from innovation represent a strategic effort for that organization. Taken together, these concepts provide additional criteria to differentiate innovation from routine change beyond the strict “first ever” interpretation. It is possible that primacy is more important to the definition of innovation in some contexts more than others; for example, if the greatest value of an innovation lies in an intellectual property claim or the ability to create a market (as it might in industry), then being the first ever is critical. Alternately, in the service sector (such as health care), the value of an innovation may lie in the ability to improve service to its local customers. If a hospital is the only one that offers a new treatment option in a 200-
mile radius, it is likely irrelevant to the local patient population that another hospital 2000 miles away offered the same treatment first.

D. **Operational Definition of Innovation**

So far, several definitions and criteria to discern innovation have been presented. There is agreement that an innovation can be a product, service, idea, or process. There is also agreement that the innovation must be new to the organization, though some argue that an organizational innovation only occurs when the organization is the absolute first to effect a given change. Most agree that innovation represents a process, though the exact components of this process remain under debate. For a change to be classified as an innovation, it must be intentional, creative, in some way beneficial, and influence more than one person. For the purpose of this study, innovation will be defined as the initiation, acceptance, and implementation of a new product for the first time within an organizational setting (8, 27). These particular concepts were intentionally selected from two sources to be most relevant to this study, which focuses on healthcare innovation in a hospital setting. First, the definition is narrow—to only include products—as this research focuses on strategic investments in medical devices. Thus, “initiation” (27) more closely reflects the acquisition process that would be necessary to begin an innovation process. This term was selected instead of “generation” (8), which implies a design or development component that is not usually applicable to hospitals. “Acceptance” (8) was selected in favor of “adoption” (27) to differentiate between the required organizational action as part of an innovation process and the voluntary individual behavior to interact with a medical device, which will be discussed later.
E. Organizational Innovation

Innovation is a multi-level process affected by organizational and individual variables. This section will address theories surrounding organizational innovation and how these theories are applicable to hospitals. The next section will address individual adoption theories and applicability to clinician behavior. The various constructs that have been identified and empirically linked to organizational innovation can be grouped into two categories: climate and structural. Climate variables embody concepts such as trust and commitment. While climate variables may be more difficult for an organization to measure and manipulate, the effects on innovation can be dramatic. Structural variables refer to more concrete aspects of the organization such as reward systems and resource allocation; these variables are easier to recognize and change, but may not influence innovativeness long term.

1. Climate Variables

Following the work of Moran and Volkwein (47), climate is defined as:

...a relatively enduring characteristic of an organization which distinguishes it from other organizations: and (a) embodies members collective perceptions about their organization with respect to such dimensions as autonomy, trust, cohesiveness, support, recognition, innovation, and fairness; (b) is produced by member interaction; (c) serves as a basis for interpreting the situation; (d) reflects the prevalent norms values and attitudes of the organization’s culture; and (e) acts as a source of influence for shaping behavior.

It is important to touch on the conceptual differences between climate and culture, though an in-depth discussion of the distinction falls beyond the scope of this study. While the terms “culture” and “climate” are often used interchangeably in innovation and other
organizational theory literature (48), they are two separate (though perhaps poorly defined) phenomena that originate from two different academic disciplines (47). Two distinctions between culture and climate are especially relevant to this work. First, in practice, climate is more shallow than culture and thus forms and changes more rapidly (47). This is consistent with the goal of this study, which is to broaden the understanding among hospital leaders of clinician perceptions. These perceptions may change rapidly based on a number of stimuli, including the implementation of new medical technologies, without changing the organization’s ideological or philosophical stance. Second, organizational culture reflects the assumptions and behaviors that are “taken for granted” within a group (47). This conflicts with the operational definition of innovation in this work, which specifies a conscious search for change. Following these distinctions, any changes made by leaders to improve the ability of a hospital to innovate are, in fact, influencing organizational climate. If these changes become permanent and are taken for granted over time, then a cultural change has been affected. Climate, therefore, is a more appropriate descriptor for the group of variables discussed in this section.

Empirical research has demonstrated that climate can strongly influence organizational performance (47, 49). In healthcare settings, climate has been associated with job satisfaction, emotional exhaustion and expression of empathy (50). Additionally, work-group norms have been found to influence nurses’ conflict management style (51). Three components of organizational climate routinely described as influencing innovation are: attitudes toward innovation, trust, and diversity. The actions of leaders and managers can, in turn, shape these variables.
a. **Attitudes toward Innovation**

Organizations that value innovation successfully innovate more frequently. Strategic decision-makers and managers with a positive outlook on change are associated with higher rates of organizational innovation (7, 27, 32). One way to express this value is to incorporate innovation as part of an organization’s strategy, as there is some correlation between a lack of strategic connection and innovation failure (43). Another way to demonstrate value for innovation is to maintain a “strategic attention span” long enough to allow time for an innovation to be developed or deployed (43). Clear strategic vision, strong leadership, and good managerial relations can create a receptive context that is conducive to innovation. Greenhalgh et al. (19) and Dougherty (52) suggest that people organize their thinking and actions pertaining to innovation as “interpretive schemes” that can inhibit innovation, and this inhibition can be further exacerbated by organizational routines that constrain joint learning. Amabile (33) cited low regard for innovation in general, the lack of organizational faith or interest in a project, and perceived apathy toward the outcomes and accomplishments of a project as barriers to innovation.

In the health care sector, medical technologies are often assessed and selected in relative isolation; sometimes they are not linked in a meaningful way with a long-term mission or strategy (1). Some business practices utilized in hospitals can detract from the perceived importance of innovation. In an example from literature, when financial incentives rather than clearly defined clinical benefits drove the implementation of a health information system (HIS), there was very strong resistance to the change (53). In an ED quality
improvement study, Muntlin, Carlsson and Gunninberg (54) recognized that discord in the perceptions of nurses and physicians regarding performance shortcomings presented a barrier to implementing new practices. Pardo de Val and Fuentes (55) suggested that political deadlocks and leadership inaction are frequent causes of inertia during the implementation of new technologies in the hospital setting; however, when hospital leadership holds a favorable attitude toward innovation and links it with strategy, great changes can be affected.

Carroll and Edmonson (56) recognized leadership and organizational commitment as drivers to overcome barriers to change in the hospital setting. A positive correlation exists between hospitals that innovate and whose Chief Information Officers and other top managers express favorable opinions about innovation (41, 57). A study of an HIS implementation showed that a strategic outlook on technology investment that anticipated high levels of integration resulted in greater benefit to the organization (58). Hospital board configurations can influence the likelihood and success of a radical diversification effort, such as offering a new specialty (59). Additionally, leaders outside of the C-suite can also positively influence innovation. In a Canadian hospital, surgeons drove the adoption of an endovascular stent partly because they openly valued innovation and actively sought to introduce new techniques to their organization (60). In a study of the influence of leadership on healthcare-acquired infections, staff-level clinicians (epidemiologists and nurses) drove the adoption of best-practices, which in turn promoted an organizational culture of excellence (61). Organizational cues regarding the importance of training have been shown to influence clinicians’ adoption behavior following an educational experience (62).
b. **Trust**

When members of an organization feel comfortable expressing opinions and ideas, the organization is more likely to be innovative. Environments that foster criticism and external validation are less likely to generate new ideas (33). An atmosphere of trust creates a climate in which people are able to experiment with new thoughts and take risks (63). Employees who trust the organization they work for are more likely to innovate on behalf of the organization, regardless of the reward structure (64). Likewise, Corwin (18) found that organizations where members are protected from status risk are more likely to be innovative. Forcing operations-level personnel to constantly negotiate support from a subordinate position curbs innovation (43).

In hospitals, issues of trust are often associated with facilitation or disruption of innovation. First, medical communities tend to be local in their orientation and do not trust those perceived as outsiders, even if they are members of the same organization (65). Physicians are typically hesitant to adopt new protocols if they feel there is insufficient evidence to support a change (66). Bartone and Alder (67) found that in military field hospitals, confidence in leaders and a perceived high level of leaders’ concern for soldiers was positively associated with group cohesion. Nurses who feel that they work for “good” managers are more likely to use research in their practice (68). Second, a degree of professional distrust exists within many hospitals, which can inhibit innovation. Graber (69) recognized that poor working relationships contribute to failures in achieving hospital goals, including innovations that improve patient care. Physician-nurse relationships are often strained, making collaboration
and joint-learning difficult (51, 70). Physicians propagate anecdotes about paramedics incorrectly pronouncing patients dead and foster distrust of paramedic skills, which plays a role in slowing the implementation Advanced Life Support protocols (66). Nurse reluctance to approach physicians to endorse studies and patient protocols is identified as a major barrier to conducting research and, therefore, innovation (70). Muntlin et al. (54) suggested that bridging the divide between physicians and nurses will improve “team spirit” and enhance hospitals’ ability to enact change.

c. **Diversity**

Innovation is likely to arise in situations where diverse viewpoints are available. Thompson (8) argues that diversity of inputs is necessary to generate the creative ideas that ultimately lead to innovation. There is evidence that heterogeneity in occupational types within an organization is a positive moderator of innovation (7, 32). The absence of a single professional ideology can aid innovation (32). Multiple group membership (also referred to as cosmopolitanism) is theorized to aid innovation by increasing the diversity of inputs and allowing shared responsibility for new ideas (8, 18). Likewise, purposeful efforts to provide collaborative structures within organizations can aid creative thinking, although these groups are less effective if power imbalances or lack of commitment prevent true collaboration (43, 52). If a climate of conflict emerges, the positive effects are mitigated.

Innovation can exacerbate conflicts (49). Thompson (8) advocates for “benevolent intellectual competition rather than malevolent status and power competition.”
Amabile (33) cautioned that climates that foster a self-defensive attitude will inhibit creativity and, therefore, innovation. Pierce et al. (32) suggested that a lack of singleness of vision can inhibit acceptance and implementation of innovations. During the implementation of an HIS across multiple sites, administrative pressure to move a project forward created a hostile environment for clinicians and the vendor, thus inhibiting the innovation necessary to make the system work for the organization (53). In the later phases of the stent implementation described earlier, conflicts emerged between radiologists and vascular surgeons, which prevented establishing, long term, the surgical innovation (60).

Recently in the hospital setting, a great deal of emphasis has been placed on multidisciplinary participation in selecting and implementing innovations. As the healthcare market is shifting internationally, hospital organizational designs are converging on an integrated specialty and multidisciplinary team model (71). Kimberly (72) found that hospitals with administrators who also participated in clinical practice and chiefs of medicine who also participated in administrative functions tended to adopt more innovations. Berwick (65) suggested altering the physical configuration of clinical space to promote casual interactions among individuals from different departments and backgrounds as a method to promote organizational innovation. Keenan et al. (51) argued that high quality solutions to patient needs should include input from physician and nurse perspectives. Munlin et al. (54) stressed the importance of multidisciplinary participation in the implementation process. Multidisciplinary teams improve patient outcomes in austere intensive care units, partially due to an enhanced ability to innovate in a challenging environment (73).
2. **Structural Variables**

In addition to the climate variables described above, an organization’s design and management structures can also influence innovation. Four structural variables are routinely associated with organizational innovation in the literature: availability of slack resources, professionalism and reward systems, communication pathways, and decentralization (i.e., the locus of decision-making authority) (7). These variables may not be orthogonal to those describing climate, but they are easier to measure and manipulate in order to aid innovation in the short-term. Organizational changes in these areas might also be a first step to creating a more innovation-friendly climate or culture.

a. **Slack Resources**

As stated earlier, organizational intent is a key component in the definition of innovation; one of the clearest ways to express intent is to commit resources. “Innovation does not happen on its own; it requires special knowledge and funding” (27). Financial assets of an organization, including cash position, can influence its strategic position and its ability to innovate (9). Insufficient equipment, materials, facilities, funds, or manpower can lead to innovation failure (33). The focus of the manpower is also important; individuals who are in reality occupied with task overload or “fire-fighting” will not think creatively and will not aid organizational innovation (33). In a study of grade schools, Corwin (18) found that access to outside funds could create the organizational slack needed to encourage innovation. The size of an organization is often considered a function of its health; therefore, size is sometimes used as a surrogate for a direct measure of organizational slack (27, 32). This
appears to be consistent in healthcare; hospital size is consistently a significant organizational predictor of innovation (7, 68, 72).

There are many techniques hospitals use to determine the resources they have available to fund innovation. These techniques may favor or discourage innovation. As an example, hospitals require formal analysis of the financial impact of technology adoption and turn to classic financial techniques, such as Return on Investment (ROI), Cost Benefit Analysis (CBA), and Net Present Value (NPV) calculations. These techniques do not, however, fully capture the benefit of innovation (58, 74). Comparisons are made assuming that maintenance of the status quo will result in the same performance over time, “...when new technologies or capabilities are required for future competitiveness, margining on the past will send you down the wrong path”(74). Further, in order to achieve accurate results, these techniques require an exponentially increasing number of variables, which can ultimately lead to model failure due to sheer complexity (58). Calculating ROI for potentially disruptive technologies provides an even greater challenge (1).

Despite the challenges organizations face in determining what resources it can afford to commit to innovations, academic leaders recognize the positive influence that planned investment has. Neumann et al. (6) recommended pooling the financial savings realized through technology investment for reinvestment in innovations. Dougherty and Hardy (43) advocated deliberately distributing resources to support innovation. Organizations that
provide dedicated and ongoing funding for implementation tend to have more success with innovation (19).

Healthcare innovation is simultaneously viewed as an upward driver of healthcare cost and a possible solution for cost-cutting (4, 75). It is generally accepted, however, that some slack in hospital budgets must be set aside to promote innovation (65). Hospitals can approach the assignment of resources to innovation in several ways. First, hospital leaders generally consider the reimbursement structure from CMS and private insurers a major source of external slack; insurers’ willingness to pay is a major component of a hospital’s decision to innovate (1, 4). A second means of generating slack is assessing the healthcare innovation in terms of potential cost reduction and cost-effectiveness. Focusing on cost reduction allows hospitals to enact a reinvestment strategy (6). Several management and clinical evaluation scholars argue that technology assessment should specifically consider reduction of operating costs (4) and contribution to cost containment (76, 77). Other academic circles favor discussion in terms of cost-effectiveness, in order to emphasize that cost alone should not dictate the decision to introduce a new intervention. As a health care economics term, cost-effectiveness, by any number of measures, refers to the ratio of resources consumed by providing an intervention to the resulting health improvement outcome (78, 79). This is an important distinction because cost-effective interventions may not be less expensive than current practice, but a hospital could assign value to providing new treatment options to the patient population. In a survey of hospital executives, 58% cited increased cost-effectiveness of
a technology as one of the top five reasons to favor adoption, and 57% rated decreased cost-effectiveness as one of the top five reasons to avoid implementing a technology (80).

b. **Communication Pathways**

Two forms of communication are important to innovation: intra- and inter-organizational. Within an organization, strong communication channels provide a pathway to spread information and to receive ideas for innovation. When communication within an organization is easy, open, and legitimate in all directions, there is the greatest opportunity for successful innovation (8). Facilitating communication within interdisciplinary groups is especially challenging; each profession brings a “thought world” with unique funds of knowledge that does not allow easy sharing (52). Access to external knowledge sources positively influences an organization’s adaptive capacity and innovation (19, 81). Empirical studies have found external communication to be a positive moderator of innovation (7, 32); however, too strong a reliance on networking will result in innovation “in spite of the system, not because of it,” (52). Thus, if the goal of an organization is to become more innovative in general, it will have to do more than simply promote champions or superusers (52).

Communication is widely recognized as an important component of innovation in hospitals and other healthcare settings. The interdisciplinary nature of the hospital setting provides a great opportunity to take advantage of different communication networks to find innovative solutions. As an example, hospital leaders can influence innovation by tapping into the more externally-oriented open networks of nurses to gain access to new
ideas and leverage the internally-oriented cohesive networks of physicians to aid in implementation (82). One-on-one conversations are often necessary before physicians engage in innovation (65). Greenhalgh et al. (19) point out that: “...an important use of knowledge in healthcare organizations is the application of research evidence for the efficacy of health technologies.” Nurse-to-nurse communication positively influences the use of research findings in practice (68), but nurses are less likely to use research findings if there is not a knowledgeable colleague available with whom to discuss the research (70). Satisfaction with communication flow was found to positively influence group cohesion and performance in a medical unit (67). Ineffective communication between EMS medical directors and online medical control physicians can lead to failure to adopt the most current emergency response protocols (66).

c. **Professionalism and Reward Structures**

Innovation can also be motivated either intrinsically or extrinsically. Creativity and innovation are most effectively driven by intrinsic motivation; satisfaction stems from the search, professional growth, or esteem of respected colleagues (8, 33). Thus, professionalism (defined as the amount of pre-employment training expected or required) is found to have a positive association with innovation (27, 32). Managers are encouraged to provide extrinsic rewards to encourage innovation (27).

Hospitals largely employ a highly professional staff. Physicians and many nurses obtain post-graduate degrees and are required to maintain current knowledge through
continuing education. In hospitals, there is evidence of both intrinsic and extrinsic motivation to innovate among clinical and support staff. Vascular surgeons expressed professional pride in their ability to bring innovations to their patients (60). One nurse stated that it felt good to enact best practices for an underserved patient population who appreciated healthcare providers that do the right thing (61). Estabrooks et al. (68) recognized “praise for a job well done” as a significant predictor of nurse use of research in practice. Recognition from colleagues can also hinder innovation; physicians describe positive reinforcement from senior leaders when they avoided admitting patients during an emergency room (ER) rotation (54). Some studies also recommend extrinsic motivators for innovation; nurses have suggested merit pay or paid time away from clinical duties to conduct research as incentives to increase participation in innovative activities (70).

d. **Decentralization**

The degree to which organizations include its members in decision-making also influences innovation. Structurally complex and decentralized organizations are more easily changed (18). Decentralization can also aid leaders in identifying high pay-off changes to implement (9). It is proposed that broad participation influences the initiation phase of innovation (32). In describing an ideal-type innovative organization, Thompson (8) proposed that workers would be more autonomous, power would be more widely dispersed, and resource assignment decisions would be decentralized. In practice, Dougherty and Hardy (43) found that project teams given authority and responsibility were more innovative. They went on to recommend that “senior managers should set the strategic direction, but involve
people well down in the organizational hierarchy to solve problems and to create assessment criteria.”

Traditionally, hospitals in the United States have a somewhat decentralized organizational design due to the existence of two distinct hierarchical lines: one for physicians and one for other resources (71). Encouraging hospital leaders to obtain input from end-users (i.e., clinical staff) during technology selection is a mainstay of technology evaluation and health information systems literature. Substantial evidence exists to support this recommendation. Kimberly and Evanisko (72) found that centralization was a significant negative moderator of innovation in hospitals. Part of the success in implementing infection control improvements came from the ability of nurses and hospital epidemiologists to address Foley catheter procedures at the staff level (61). Estabrooks et al. (68) found that the ability for nurses to implement policy change independently increased the use of research. Conversely, Chan (70) found that nurses’ perceptions that they were not authorized to change patient care procedures was a barrier to using research in practice.

F. Summary of Organizational Innovation

Climate and structural variables influence organizational innovation. Climate variables are difficult to measure and influence, but can have a profound effect on innovation. Structural variables may reflect organizational climate and culture, but they are easier to measure and alter. Changes to organizational structure may not dramatically influence innovation and may damage organizational health if enacted thoughtlessly. Empirical studies support that general
theories of organizational innovation apply to the hospital setting. The ability of a hospital to innovate successfully is only the first step; the reaction of clinicians to the innovation will influence the sustainability and effective value of a new technology.

G. **Organizational Innovation and the Individual**

As described above, from the perspective of those interested solely in organizational behavior, an innovative act concludes with the firm’s implementation of something new (a process, service, product, etc.). In the health care sector, the importance of innovation is realized in how care is shaped, both in terms of cost and patient outcomes. Both of these issues are heavily influenced by the interaction between healthcare providers and the innovation, which for the purposes of this work is defined as a product (a medical device). The leadership decisions that result in a hospital acquiring a given medical device tell only half the story; the decisions and behaviors of individual clinicians to use or resist a technology will determine its ultimate utility. Healthcare providers build the bridge between the hospital’s intentions and the patients’ reality; therefore, studying healthcare innovation at the organizational level alone will not account for the outcomes at the individual level, where individual providers navigate change as a personal experience.

1. **Individual Adoption**

As discussed earlier, “acceptance” was explicitly selected to describe one phase of organizational innovation. For the purposes of this research, “adoption” will refer to the individual behavior of using an innovation. This follows the tradition of Rogers’s (83) definition
of adoption: “A decision to make full use of an innovation as the best course of action available.” In the study described herein, adoption will refer to the decision of a clinician to make full use of a medical device as the best course of action available, given the possibility of using a variety of interventions and barring contraindications.

2. **Theoretical Perspectives**

   A literature review revealed that a wide variety of acceptance and adoption theories have been applied to the technology use behavior of healthcare providers, largely representing two perspectives: adoption related to individual attitude and adoption related to task or workflow. This division is logical because when an innovation is introduced into a clinical setting, it requires action on the part of the individual to use the innovation to accomplish a task. Assuming that the ultimate goal is innovation adoption, theories of usage behavior should focus on the facets of adoption that are most readily adjusted in practice. If the user refuses to integrate a technology into his or her practice, revisions to the technology will most readily come in the form of modifications to the interface (where the user interacts with the technology) or the way the technology accomplishes the task. The following sections will explore these two perspectives in depth.

3. **Adoption and Individual Attitudes**

   In studying clinician usage behavior, two theories that relate individual attitudes to acceptance and adoption predominate: the Technology Acceptance Model (TAM) (25) and the Innovation Diffusion Theory (IDT) (83). Both TAM and IDT propose a causal relationship
between characteristics of a product (a form of innovation) and the intended audience’s decision to embrace it. Under both theories, modifying these characteristics has the potential to aid or hinder the adoption process.

a. **The Technology Acceptance Model**

The Technology Acceptance Model (TAM) is probably the most pervasive theory of usage behavior (84), particularly in the field of information technology (IT). The TAM was created originally as a fast and simple way to assess initial reactions toward new IT products. The TAM is an adaptation of the broader Theory of Reasoned Action and included two variables as determinants of computer usage: perceived ease of use (PEoU) and perceived usefulness (PU) (85). PEoU is conceptually defined as the user’s belief that the technology in question is easy to use (25). PU is conceptually defined as the user’s belief that the technology would aid in job performance (25). The theory was initially supported empirically through surveys exploring the opinions of MBA graduate students and business professionals about email programs and word processors (25, 85). The TAM was extended by Venkatesh and Davis (86) to include Subjective Norm (SN), conceptually defined as the perception that peers and others held in esteem or value the system, as a predictor of behavioral intent, and is known as TAM2.

b. **Innovation Diffusion Theory**

IDT is another widely recognized model and has been applied to technology use behavior; it has been particularly favored by U.S. government agencies
interested in the adoption of health information systems (HIS) (87). In the IDT framework, the
decision to adopt an innovation occurs in five stages: 1) knowledge - the awareness that the
innovation exists; 2) persuasion - when an attitude is formed toward the innovation; 3) decision
- an individual engages in activities that lead to a choice to adopt or reject an innovation; 4)
implementation - when the innovation is put to use; and 5) confirmation - when an individual
seeks reinforcement of an innovation decision (83). The rate of adoption, defined as the
relative speed with which members of a social system adopt an innovation, is determined by
the end user’s perception of several attributes. These advantages include the relative
advantage, which is the degree to which the innovation is perceived as better than the idea
before it. Compatibility is the degree to which an innovation is perceived as consistent with
existing values and needs as well as past experience. Complexity is the degree to which an
innovation is considered difficult to understand or use. Trialability is the degree to which
experimentation may occur. Observability is the degree to which the results of innovation use
are visible to others (83).

Conceptually, there are some similarities between the two frameworks
when applied to healthcare innovation; for example, “relative advantage” is conceptually
similar to PU. Both relative advantage and PU are reflected in common arguments supporting
the wider use of healthcare innovation, such as increased efficiency, patient safety, and quality
of care or decreased operational costs. Likewise, PEOU and “complexity” are conceptually
similar. Researchers in medical technology usage behavior have routinely blended these two
concepts, thus blending the two frameworks to describe adoption. This logic supported Wu,
Wang, and Lin (88) in their theory that PEOU, PU, “compatibility”, and two other constructs
(mobile health system self-efficacy and technical training and support) influence physicians’, nurses’ and medical technicians’ behavioral intent to use HIS. Likewise, Tung, Chang and Chou (89) proposed that PEOU, PU, “compatibility”, trust, and perceived financial cost affect nurses’ behavioral intent to use an electronic logistics system.

c. **Application of Individual-Oriented Theory in Healthcare**

Given the strong theoretical background and empirical testing associated with TAM and IDT, the usage behaviors associated with a wide range of healthcare innovations have been studied from the individual adoption perspective (90). TAM was used to explore usage behaviors in a variety of clinical settings. TAM served as the theoretical model for studying telemedicine technology use behaviors among physicians in tertiary care hospitals in Hong Kong (91). TAM was also applied to the study of electronic documentation applications, such as whether physicians would prefer a Spoken Dialog System while performing an endoscopic exam (92), nurses’ intent to use an electronic adverse event reporting system (88), clinicians’ acceptance of electronic medical record systems (93-96), and pharmacists’ perceptions of a new integrated electronic prescribing system (97). Finally, TAM has been used to explore specialized technology functions, such as differences in perception and acceptance levels of Female-focused Healthcare Applications (98) and perceptions of a triage-based decision support tool for Emergency Medical Service providers (99).

TAM was developed to specifically study IT adoption; IDT emerged as a broader model to explain adoption behaviors, which is reflected in the diverse applications of
IDT in healthcare innovation literature. Many clinicians have presented summaries of IDT and its potential applications to clinical practice (65, 100-102). IDT was applied to the adoption of a new cancer drug (103), as a framework to monitor the diffusion and adoption of a cardiovascular health counseling program (104), and to guide the publicity of a smoking cessation intervention (105). Spaulding et al. (106) operationalized Rogers’ constructs in a survey administered to physicians and physician’s assistants in rural Kansas to assess adoption and acceptance of telemedicine. This instrument addressed separately the relative advantage and compatibility for the patient and practitioner. IDT was also used as part of a framework to assess hospital innovativeness as a predecessor to HIS (107) and PACS (108) adoption and to study the diffusion of a point-of-care, online, evidence system (109).

Overall, the most frequently utilized constructs in theories of technology adoption in behavior among healthcare professionals are PEoU, PU, and compatibility; Figure 1 illustrates their causal linkages. These theories are useful to the study of usage behavior in healthcare innovation because they provide a clear focal point for understanding why a particular innovation is failing. One of the weaknesses of this perspective, however, is that it essentially forces an adversarial relationship between people and technology. Creating a causal link between perceptions and technology characteristics makes changing a person’s mind a reasonable intervention for positively influencing adoption, rather than redesigning undesirable features (110, 111). One other difficulty in applying the individual adoption theories to innovation adoption in the healthcare sector is the concept of choice or voluntariness; often
times in large organizations such as hospitals, an innovation once implemented is mandatory, and the alternative technology is no longer available.

![Individual Perspective Framework](image)

Figure 1. Individual Perspective Framework. This framework illustrates how perceived ease of use, perceived usefulness, and compatibility influence intent, which in turn influences adoption behavior.

4. **Adoption from the Task Perspective**

Unlike the theories that focus on the relationship between individuals and technology to explain usage behavior and healthcare innovation, task-oriented theories focus on the relationship between the technology and its function. Proponents of this perspective would argue that healthcare innovation adoption cannot occur if the technology does not consider a clinician’s workflow; this is supported by the “unintended consequences” literature (112). Tasks are defined as the wholeness of working processes that have to be completed by the user and is supported by technology, and technology is any tool required to complete a task
Frameworks and typologies that demonstrate this perspective are Task-Technology Fit (TTF) (26), Fit between Individuals Task and Technology (FITT) (113), and the Interactive Sociotechnical Analysis (ISTA) (114).

a. **Task-Technology Fit**

The Technology Performance Chain model contains Task-Technology Fit (TTF), which is a measurable theory of technology use and its effect on performance. TTF is defined as the degree to which a technology assists an individual in performing his or her portfolio of tasks (26). The empirically tested model includes task characteristics and technology characteristics as predictors of TTF, and TTF as a predictor of utilization and performance impacts. It is important to note that under this model, utilization is defined as the proportion of tasks performed using the system. Overall, this framework suggests that the skill of the individual, the technology function, and the task to be supported by a healthcare technology interact to result in a successful outcome (i.e., improved performance of the task). FITT is a modification of TTF developed to describe HIS adoption in clinical settings. FITT proposes that the interaction between the task and the user is also important to HIS adoption.

b. **ISTA**

ISTA was developed in response to the need to document unintended consequences, defined as undesirable and unintended outcomes associated with HIS, that limit acceptance (114). This typology draws from many areas of research, including sociotechnical systems, ergonomics, social construction, technology-in-practice, and social informatics. ISTA
proposes that unintended consequences arise from the interaction between new HIT, the social system, HIT-in-use, and the technical and physical infrastructure. This framework recognizes the complexity of healthcare environments, and the authors suggest it should be used as a guide for medical professionals and system designers to differentiate between technological and psychological barriers to HIS adoption.

c. **Application of Task-Oriented Theory in Healthcare**

The models described are more recent contributions to innovation adoption theory, and as such, these frameworks have not been used as extensively as the theories from the individual perspective. Several examples of the application of the task-oriented theories are available in the literature. The TTF model was suggested as a premise for measuring the effect of access to eHealth services (e.g., WebMD, Medline, etc.) on the performance of medical professionals in long term care facilities. Breen and Zhang (115) argued that eHealth is an appropriate technology for the task of seeking additional information that would positively influence decisions regarding patient care and, therefore, improve task performance. TTF was used to conduct a study of the relationship between nurses’ perceptions of technology and quality of care (116). TTF has also been combined with individual theories of adoption to conduct a mixed-methods study of nurses’ use of mobile information communication technologies (117) and to explore nurses’ perceptions of an electronic documentation system (118). The FITT framework was used to retrospectively analyze IT adoption following various HIS implementation efforts of a Regional Health Information Network in Crete (119). Usage patterns recorded on the IT systems implemented in Crete
revealed differing adoption rates across organizations and departments in the health system. Using the FITT framework, the authors identified instances where weak fit between the technologies, task, and users resulted in slow adoption or rejection of technology and where strong fit resulted in faster adoption and wide user acceptance (119).

The main constructs in the task-oriented frameworks are tasks, technology, and individuals and are represented in Figure 2. Since these frameworks focus on tasks rather than perceptions, they are better suited to guide the development of new technologies; however, the constructs are much more difficult to operationalize and study empirically. Another difficulty in applying these theories to healthcare innovation adoption is the lack of representation of organizational influence. The FITT model suggests that “organization” is captured (due to the cooperation and communication inherent in clinical work) between tasks and individuals (113). While this might be true for smaller organizations such as private practices, it does not capture the dynamics in large organizations where, by and large, those who are not practicing medical professionals make decisions that are vital to the adoption process. ISTA separates the “social system” from the technical and physical infrastructure, but does not explicitly define who composes the social system.
Figure 2. Task Perspective Framework. This figure illustrates the interactions between the task, the technology in question, and an individual’s preference on adoption behavior.

H. **Literature Review Summary**

The literature largely supports that innovation is a multi-level phenomenon; variables at the organizational and individual level influence acceptance and adoption. Though many definitions of innovation exist, the concepts of newness, multiple stages, and change are ubiquitous. At the organizational level, both climate and structural variables affect innovation. Climate variables include attitudes toward innovation, trust, and diversity. Structural variables include the availability of slack resources, communication pathways, professionalism and reward structures, and decentralization.
At the individual level, there are two predominant perspectives from which adoption is considered: from the individual perspective and from the task perspective. TAM and IDT are the two theories most commonly applied to healthcare professionals’ adoption behavior. These frameworks largely attribute innovation adoption behavior to variations in PU, PEoU, and Compatibility. TTF, FITT, and ISTA--each consider the interaction between a technology and the task that it is intended to support as an indicator of innovation adoption behavior. These theories hold that the Task, the Technology, and Individual perceptions mediate innovation adoption.

The literature also provides numerous examples of the same organizational and individual variables that influence innovation in other industries influencing healthcare innovation. This supports the validity of applying general innovation theories to hospitals and healthcare providers; thus, leaders involved in creating a technology investment strategy (i.e., facilitating healthcare innovation) should consider both organizational needs and individual reactions in order to realize a technology’s full potential to benefit the hospital mission.

This study will incorporate the Perceived Ease of Use and Perceived Usefulness variables from TAM and the Task Technology Fit framework in the analysis of health technology perceptions at the individual level. The act of systematically gathering opinions about radical innovations will reflect the organization’s favorable attitude toward innovation, open new communication pathways, and improve trust between administrators and clinicians, thereby providing a more hospitable climate for innovation.
I. **Q-Methodology**

1. **Background**

Q-methodology refers to the philosophical, psychometric, and statistical ideas oriented to the systematic study of the individual (120, 121). Q-methodology was first presented by William Stevenson (122) as a method to explore individuals’ subjectivity (i.e., their opinions). A series of qualitative and quantitative procedures are performed to operationalize this methodology. The first step, development of a **Q-concourse**, is a qualitatively oriented step that seeks to gather information from multiple perspectives on the topic of interest. To quote Brown (120), a Q-conourse is defined as the “flow of communicability surrounding any topic.” Interviews usually generate a Q-concourse, but the concourse can also include ideas presented in newspaper articles, essays, or communications. A **Q-sort** is the rank ordering of a sample of statements derived from the Q-concourse by individuals whose opinion on the research topic is of interest. To facilitate statistical analyses, the ranking is forced into a quasi-normal distribution, as illustrated in Figure 3. Once a group of Q-sorts is completed, quantitative analysis begins. The Q-sorts are used to create an NxN matrix that allows the calculation of correlation coefficients for each pair of respondents. These coefficients indicate clusters of people who rank statements similarly and, therefore, are likely to share a similar perspective on the topic of interest. These clusters of people form **Factors** that are then interpreted by assessing the strongly held statements that characterize the factors. In contrast with R-methodology that typically seeks to correlate variables with population trends, Q-methodology requires individuals to construct a measure from a population of ideas to reveal patterns among those measures (123). Previous studies using R-methodology in healthcare settings
have generated lists of technologies or administrative processes (usually generated in
collaboration with a panel of experts) to measure innovation based on the reported number of
implementations (72, 124, 125).

In this study, Q-methodology will allow clinicians to express their perceptions of
technologies and capabilities as a whole experience, whereas R-methodology would collect a
series of isolated impressions. These isolated impressions do not take into consideration the
context of the technology, nor does it bring focus on the human “systemness” surrounding the
use of technology. Q-methodology has been shown to bring unique insight in the study of
human subjectivity in clinician attitudes (126-128), needs (129), and health care computing
(130-132). It is the method selected for this study to bring an understanding in the human
behavior side of the selection and use of health care technology.

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Figure 3. Example of Q-sort Response Grid. This grid would guide the sort for a 17 item Q-Set.
2. **Validation**

The individual Q sorts do not carry any sort of validity measure because there is no external frame of reference to judge a person’s point of view or the consistency of his or her attitudes and beliefs. As the Q concourse and Q sample are developed, validity is established by use of triangulation, respondent validation, reflexivity, and fair dealing (133). Interpretation of the Factors should include consideration of individuals who did not align significantly to any Factor. In terms of quantitative analysis, the application of statistical procedures to Q sort data has raised some concern because the forced distribution essentially violates the assumption of independence between the items; however, forced distribution also prohibits the research subject from avoiding the statement entirely, which in a Likert study, can bias results. Applying more conservative criteria to the assignment of statistical significance, such as by increasing the level of significance to 0.01, addresses the limitations of the forced sort. Once the technical merits of the instrument are established, discriminant validity is tested by conducting Q sorts with different relevant audiences and determining if it maintains the ability to differentiate participants in accordance with its underlying theory. Comparing outcomes of Q sorts with other established measures of the phenomenon of interest tests convergence validity.
III. METHODOLOGY

A. **Introduction**

Most health care technology assessment frameworks recommend that decision makers include providers’ opinions when developing a health care technology innovation strategy; however, these frameworks neither provide practical guidance for soliciting opinions in a systematic manner nor explicitly consider individual adoption theories as part of priority setting. This research will develop and demonstrate a systematic process, using Q-method, for hospital leaders to obtain provider opinions about radical innovations to consider as they set innovation priorities at the departmental level. The study site is an ED housed within a large, suburban teaching hospital located in Chicagoland. The following section describes how qualitative methods can be combined with a market review to construct an instrument that captures clinicians’ opinions and facilitates analysis at the individual and group level. Individual factors provide insight that can assist change management efforts during technology implementation, whereas group level analysis provides insight into areas of consensus across distinct opinion groups that indicate overarching priority from the clinicians’ perspective.

B. **Study Setting**

The Emergency Department (ED) of a large teaching hospital located in a near-Chicago suburb was selected as the site for all aspects of this study. The study site has a Level I trauma designation and reported over 101,000 visits in 2012. The hospital serves a mix of urban and suburban residents; approximately 27% of patients are Medicaid or Medicare recipients. An ED with a Level I trauma designation and a teaching mission is a particularly interesting setting to
study innovation and adoption. The Level I trauma designation requires that more equipment be available than an average ED, which adds to the potential diversity of relevant medical devices that could be considered for implementation. As a teaching facility, the ED is expected to implement best practices and provide students with access to a range of technologies that they might encounter in other clinical settings. Theoretically, the staff has access to many cutting-edge technologies, making perceptions of inadequacies particularly salient. An existing research relationship with faculty of the University of Illinois at Chicago facilitated the selection of this specific study site in favor of the other Level I trauma centers and teaching hospitals in the Chicagoland area.

C. **Identifying Radical Health Care Technologies**

1. **Overview**

   The overarching goal of Research Question 1 is to generate a list of radical health technologies that could be implemented in the ED. Ultimately, this list will serve as the Q-concourse and the basis for the instrument necessary to address Research Question 2. One approach might be to conduct a market analysis alone and then use a comprehensive list of every technology commercially available as the Q-set for participant sorting to address Research Question 2. A more refined method, however, would utilize qualitative data to guide market research efforts in order to provide items that were most relevant to the clinician participants. This strategy is advantageous for several reasons. First, the final instrument will be shorter and easier for participants to complete. In time sensitive environments, such as the ED, it is important to be respectful of participants’ busy schedules. Second, the qualitative data
can be invaluable during factor interpretation, especially in circumstances when interesting (or confusing) results emerge between factors. In order to develop a concourse of radical technologies that would be most meaningful to the study site clinicians, two topics required exploration: 1) what features of medical technologies, in general, are considered favorable or unfavorable, and 2) which clinical situations would most benefit from the introduction of radical technology. Two qualitative techniques were implemented to gain deeper understanding of these topics. One-on-one interviews provided insight into favorable and unfavorable features through questions that were, themselves, derived from the Technology Adoption Model variables of Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). Focus groups provided insight into the clinical situations in which providers felt the introduction of radical technology would be most valuable; the focus group’s guiding questions were derived from the Task-Technology Fit model of innovation adoption.

2. **One-on-One Interview Procedure**

   Experienced clinicians, defined as physicians or nurses with more than 3 years’ experience in the ED, were asked to take approximately 10 minutes to review the equipment currently available to them to diagnose, treat, or manage patients. Each experienced clinician was brought into a treatment area and asked to look on the room’s walls and comment on any technology that he/she would like to change and how, if given the opportunity. Next, the researcher asked the expert clinician to comment in the same manner on stored items (including packaging), such as those in drawers or under tables. Then, the expert clinician was asked to comment in the same manner on portable items, such as items on carts. Finally, the
researcher asked the expert clinician to comment in the same manner on any other shared department resources that had not yet been considered, such as infusion pumps, defibrillators, or electrocardiograms. The researcher documented the devices and nature of the comments as the expert clinician shared his or her opinions. Participant recruitment ended when saturation was achieved. Saturation was defined as the point where no unique observations or opinions emerged. Notes from the interviews were transcribed and analyzed using ATLAS.ti 6.2 to highlight positive and negative opinions and to construct a general framework of favorable and unfavorable design qualities for health care technology.

3. **Focus Group Procedure**

Given the abstract nature of the question, soliciting clinician opinions for radical innovations is a distinct challenge. Rather than asking clinicians to give opinions on medical devices with which they interact routinely, decision makers must elicit opinions about medical devices not currently implemented or perhaps nonexistent. While some clinicians may maintain an awareness of emerging technologies out of personal interest, many will not; therefore, hospital administrators are likely to find more utility in soliciting opinions about the perceived ability of current technology to diagnose, treat, and manage patients based on clinical condition. This may be one method to implement the strategy endorsed for health technology assessment prioritization by IOM and AHRQ, introduced earlier, at the hospital level. As described in the introduction, AHRQ prioritizes technology evaluation based on clinical conditions rather than considering isolated innovations as they emerge. AHRQ determines which clinical conditions are of interest by soliciting opinions from the public (any stakeholder
in health care is able to nominate a topic for evaluation). At a hospital level, however, this strategy is impractical. Rather, focusing on clinician perceptions of their current ability to treat specific clinical conditions can help hospital leadership identify opportunities for radical innovation.

Another way of conceptualizing this situation is that some medical devices do not “fit” their intended tasks (i.e., to diagnose, treat, or manage a given clinical condition) and this poor Task-Technology Fit promotes technology rejection. For this study, two focus groups were conducted for the purpose of identifying clinical conditions that pose various forms of difficulty to providers. The focus groups were comprised of physicians and nurses who have participated in at least one formal medical device evaluation and acquisition decision. Several planned discussion topics were introduced to the group, and probing and clarifying questions were asked as the discussion progressed. All comments were written down and reviewed with the group between each question and, again, at the end of the discussion to ensure all opinions were captured. Notes from the two focus groups were transcribed and analyzed to reveal themes in the clinical conditions and workflows that providers felt could be improved through implementing new technologies. The themes that emerged were used to focus the market analysis on solutions to the most challenging situations clinicians faced while providing care.

4. **Market Review Procedure**

The themes identified in the interviews and focus groups correlated with five health technology markets: 1) health communications, 2) *in vitro* diagnostics, 3) non-invasive
monitoring, 4) new treatment options, and 5) imaging. The investigator identified potential radical innovations in each of these markets through a variety of resources including trade journals, peer reviewed medical and nursing literature, and social media tailored to emergency medicine nurses and physicians. Once an innovation was identified, its features were assessed for “positive” and “negative” traits, as described in the One-on-One Interview Outcomes section in the next chapter. Innovations with more negative traits than positive were excluded from the concourse.

D. Prioritizing Potential Radical Innovations

1. Instrument Development and Validation for the Radical Innovation Q Study

a. Q Concourse

The 53 technologies identified in the market review conducted in Research Question 1 served as the concourse in the Q-methodology study that addressed Research Question 2.

b. Q-Set Development

A Q-set was developed by creating generic descriptions that reflect the distinctive features of the products described in the market review (see Tables III-VII). The market analysis revealed an additional technology, the Aethon TUG (http://www.aethon.com/solutions/deliver/), that did not fall within the major market themes, but did address a recurring sentiment that equipment is often hard to find and retrieve in the ED. The Aethon TUG uses a Radio Frequency Identification system to track, locate, and retrieve
equipment, supplies, and other items. Two statements explicitly rejecting POC diagnostics and new imaging technologies were drafted to allow participants to express that improvements in care will come from improved workflows in other departments. The following 43 statements served as the draft Q-set for the pilot study.

1) A mobile application that allows clinicians to assign a task (e.g., a consult or blood draw), track acknowledgement, and receive a call or text when it is complete.

2) A mobile application that supports video conferences between providers (e.g., ED to EMS or ED to Neuro).

3) A paper-based hand-off checklist completed by physicians and nurses together in a designated quiet place.

4) A mobile application that records video of an EMS encounter, including vital signs and ECG, which is sent to the ED during transport.

5) A mobile application that receives real-time ECGs from EMS and integrates automatically with hospital records.

6) A mobile application that facilitates sharing charts with clinicians outside the hospital (such as a PCP).

7) A networking website that provides verified contact information for physicians including: phone, fax, back office numbers and a secure text or messaging system.

8) A patient-controlled mobile application that maintains a single health record of previous care that can be automatically uploaded, with permission, into the hospital EHR.

9) A government-controlled database that allows clinicians to search for full medical history of any patient and also allows insurers, researchers, and others access to data.

10) POC test that quantifies a patient’s sepsis risk with results in 20 minutes.
11) Lab-based test that provides a definitive sepsis dx and resistance profile with results in 7 hours.

12) POC test that provides ectopic pregnancy risk with results in 20 minutes.

13) Lab-based test that provides definitive ectopic pregnancy dx in 7 hours.

14) POC metabolic panel (including K+ and CRE) with results in 20 minutes.

15) POC electrolyte panel that provides results in 20 minutes.

16) POC cardiac marker panel that provides 4 markers with results in 20 minutes (Troponin I, CK-MB, Myoglobin, NT-proBNP).

17) POC cardiac marker test that provides 1 marker with results in 10 minutes (BNP or cTnI).

18) POC lactate monitor (similar to a glucose monitor) that provides results in 10 seconds.

19) POC test for H&H levels that provides results in 25 seconds.

20) POC test that provides results in 20 minutes for stroke risk and odds that tPA will be effective.

21) Lab-based test that provides results in 1 hour to confirm stroke and whether tPA will be effective.

22) We don’t need POC tests; the lab techs just need to be more efficient and better organized.

23) A non-invasive sensor that differentiates between stroke, TBI, dementia, and other neurological disorders during an examination.

24) A non-invasive sensor that continuously measures H&H.

25) A fully wireless 12-lead ECG with disposable probes that can be worn under clothing.

26) A vest that transmits wirelessly and collects vital signs and 5-lead ECG without affixed electrodes.

27) A vital signs sensor worn on the arm, designed to alert the triage nurse if a patient in the waiting room deteriorates.
28) A non-invasive, handheld screening tool for cranial bleeding that helps prioritize or rule out the need for a CT.

29) Robots that locate and retrieve shared equipment, such as IV pumps or respirators, and deliver it to the proper location.

30) An extracorporeal blood purification system that removes cytokines from the bloodstream in order to prevent organ failure in septic, trauma, and other patients.

31) An extracorporeal blood purification system that removes endotoxin from the bloodstream of septic patients.

32) An extracorporeal blood purification system that prevents sepsis in at-risk patients, but has no side effects if the patient is not septic.

33) A cream that delivers drugs through the skin, just by rubbing it on.

34) A handheld device to condition the skin to allow drugs to be delivered through a patch.

35) A needleless injection system that delivers liquid or powder drug formulations, in any volume, to any specified depth, without hurting the patient.

36) A self-contained device that induces therapeutic hypothermia following resuscitation from cardiac arrest through the esophagus instead of a central line.

37) A portable x-ray machine dedicated to the ED that a radiology tech brings to the patient to collect any x-rays ordered.

38) A handheld x-ray machine dedicated to the ED that clinicians can use to obtain quick digital x-rays of extremities, such as arms or legs.

39) A portable head and neck CT scanner dedicated to the ED that performs scans in a standard room while the patient remains in a regular gurney.

40) A portable full body CT scanner that moves to patients to perform scans in a standard room, but requires patient transfer to another bed.

41) Pocket ultrasounds carried by all ED physicians, which support black and white and color-coded blood flow imaging for initial screening.

42) Ultrasound probes carried by physicians, which plug into Smartphones via mini- or micro-USB for initial screening.
The ED doesn’t need new imaging technologies; the people in radiology just need to be more efficient and better organized.

c. **Condition of Instruction**

The Condition of Instruction was developed based on the Q-set described above. The Condition of Instruction guides participants in ranking the items presented in the Q-set using a response grid provided by the researcher. The perceived ability of a technology to improve care is positively associated with technology adoption. The Condition of Instruction and the ranking structure, therefore, were crafted to emphasize improvement in care and to make grammatical sense with the statements in the Q-set. The draft Condition of Instruction was "When thinking about technology and techniques to support improving care in the ED, which of the following do you feel would be most likely / most unlikely to improve the care you provide?" In order to maintain the concise statements in the Q-set, participants were also explicitly asked to consider four assumptions when ranking the statements: 1) the technologies are FDA approved; 2) the technologies are HIPAA compliant; 3) full integration (i.e., any results automatically enter the patient record); and 4) each technology works as well as you can imagine. Finally, the acronym “POC” was defined to avoid confusion.

d. **Demographic Questions**

A series of demographic questions were developed to aid factor interpretation. Studies of health care innovation often seek to correlate variables such as professional background, age or years of experience, and other personal traits with adoption behavior. In this study, demographic information was used to establish whether these traits
were consistent among participants who significantly align with a given factor or whether some other latent variable was more likely to explain the emergence of distinct opinion sets. As an example, one might expect physicians and nurses to align to different factors or that more experienced clinicians would align differently from their junior colleagues. After completing the sort, participants were asked to provide a brief explanation of why they ranked items as +3 and -3 (to confirm that the Condition of Instruction was applied correctly), as well as their licensure, years of experience, and self-described innovation style (83).

e. **Pilot Q Study- Instrument Validation**

Establishing the content validity of a newly developed instrument is an important aspect of survey design; therefore, the Condition of Instruction, Q-set statements, and demographic questions were administered to a small group of potential participants prior to recruiting for the full study. Pilot study participants provided feedback on the instrument and suggestions for improvement prior to full implementation.

2. **Implementation of the Radical Innovation Instrument**

a. **Recruitment and Sampling**

A convenience sample was recruited to complete the final Q study. The researcher recruited participants, in person, at the study site. A mass email was sent to all physicians and nurses on duty during the shifts when the researcher was present. The clinical staff was invited to participate in a 15-minute survey of their opinions about the medical
devices and equipment they use. Refreshments (coffee and donuts) were provided as compensation for participant time and effort.

b. **Inclusion Criteria**

    All physicians and nurses on staff in the department were eligible to participate in the study. Nurses and physicians of all experience levels were encouraged to participate. There were opportunities for participation by all shifts, to allow the fullest possible representation of the clinical staff. Clinicians who spent less than 51% time assigned to the ED were excluded. As part of the consent form, participants were asked to confirm their job title and the time spent working for the ED prior to participating in the study.

c. **Consent Procedures**

    When a potential research subject expressed an interest in participating in the study, a written information sheet was provided for review. The information sheet described the purpose of the study, benefits and risks associated with the study, and asked for confirmation of their clinical role and their assignment to the ED of more than 51% time. The sheet stated that completing and submitting a Q-sort indicated consent to participate. Appendix A contains the full text of information sheet. Since the Q-sorts were completed anonymously, signed consent forms were not collected since this would be the identifying information to link a participant with the study.
d. **Q-sort Procedures**

Once the research subjects completed the consent process, they were asked to select how they wished to complete the sort: on a computer or using the paper instrument. Participants who selected a computer-administered Q-sort were directed to the Q-Assessor™ website where the study was posted. The participant could either use the researcher’s computer on which a browser was directed to the appropriate webpage or use any other personal computer through a dedicated study link (Appendix B contains screen shots from the computer-administered Q-sorts). After submitting the Q-sort, participants were asked to complete a short supplemental survey online. Those who chose paper administration were provided with a hard copy of the study instrument (consisting of the Q-set, sorting instructions, Condition of Instruction, and answer grid) and a supplemental survey. See Appendix C for the survey instrument and supplemental survey.

e. **Data Analysis**

i. **Quantitative Analysis**

Generating a factor solution based on the Q-sorts gathered in a study is a critical step in data analysis. In this phase, the researcher must decide which extraction technique should be used (Centroid or Principal Components Analysis) and how many factors to extract. The desire to explain as much variance as possible might lead an investigator to extract many factors, but the larger the factor solution, the greater the risk that some of the significant loadings on factors are actually artifacts. In some circumstances, the value of an interesting or important viewpoint might outweigh the mathematical weakness of a
factor. This is acceptable, since the philosophy that underlies Q-methodology gives statistical and theoretical considerations even weight; at its heart, Q is an exploratory technique. It is important, therefore, to maintain this sense of balance between statistics, theory, and practicality throughout the entire study, but particularly during data analysis. There remains the need for some statistical justification for the overall interpretation, or there is no reason to collect Q-sorts at all.

Data from all Q-sorts were entered manually into PQMethod v2.32 for analysis. The Q-sorts were subjected to factor analysis techniques, including centroid factor extraction and principal components analysis (PCA). These results were subjected to rotation procedures, including theoretical rotation (also known as hand rotation) and Varimax rotation, which mathematically establishes the most orthogonal factor solution. Next, the investigator systematically varied the number of factors and other parameters to reach a point where Eigenvalues for all factors were above one, the cumulative explained variance was as high as possible (ideally >50%), and the correlation scores between factors were as small as possible. Once the preferred factor solution was selected, individual significantly aligned Q-sorts were flagged to generate the factor arrays used for qualitative analysis.

The quantitative phase consisted of three steps: 1) establish which factors to extract and interpret; 2) identify the Q-sorts that best represent each factor based on factor rotation and theoretical considerations; and 3) generate factor arrays, which guide factor interpretation. One of the greatest challenges that Q-methodologists face during
this phase of a study is that there is not an absolute, authoritative method for accomplishing steps one or two. Instead, the researcher must balance mathematical evidence with theoretical and practical considerations that also inform the overall study. There are several general guidelines accepted by the factor analytic community, however, that can provide a solid foundation for the quantitative analysis.

ii. **Qualitative Analysis**

Once factors were mathematically defined, they were qualitatively examined. The qualitative analysis sought out the similarities and differences between opinion groups based on the statements that received strong responses (either positive or negative) as well as the characteristics (clinical background and innovation style) of the individuals who shared opinion sets. Interpretations of the opinion sets were developed to identify groups of individual clinicians with distinct technology preferences. That outcome guided a secondary analysis of department-wide preferences and supported recommendations on 1) the types of technologies more likely to be adopted; and 2) those technologies more likely to encounter resistance.
IV. RESULTS AND DISCUSSION

A. Identifying Radical Health Care Technologies

1. One-on-One Interview Outcomes

One-on-one interviews were conducted on May 22 and May 25, 2012, at the study site. Participants were recruited from physicians and nurses on duty, not actively engaged in patient care during the day shift, following approved protocols (UIC protocol #2011-1129 and Advocate Protocol #5323). All interviews were conducted in one of three unoccupied rooms in the Pediatric section of the ER. While the Pediatric section is reserved primarily for pediatric patients, it functions as a mixed-use area when the main treatment areas are overcrowded and there are insufficient numbers of pediatric patients presenting to fill all of the rooms. As a result, this area contains equipment designed for both adult and pediatric patients. The pediatric rooms were selected because they experience lower traffic than the main treatment area and were most likely to have unoccupied rooms and fewer distractions. The pediatric section contains the same general equipment and has a layout similar to the main floor, so as participants looked around the room and commented on medical devices, there were the same visual triggers as on the main floor. Participants were also specifically instructed to comment on anything not in the pediatric area that was on the main floor. Physicians rotate between pediatrics and the main floor, so they would be familiar with the similarities and differences between the two sections. Nurses are permanently assigned to either pediatrics or the main floor. As this policy was instituted about five years ago, however, nurses who worked in the study site ER for more than five years are familiar with equipment and supplies in both
areas. In addition, there are some shared resources between the pediatric section and the main floor, so nurses from both areas do interact and are familiar with room layouts and inventory in both areas.

a. **Participant Profiles**

Ten interviews were conducted in total, five participants were nurses and five were physicians. Licensure was confirmed by checking each participant’s ID badge. All participants had at least 3 years’ experience in the study site ER; nursing experience in the ER ranged from 3-12 years (mean 6.8) and physician experience ranged from 3-32 years (mean 15.2). Specific profiles are summarized in Table I below.

<table>
<thead>
<tr>
<th>Occupation</th>
<th>ER Experience (Years)</th>
<th>Total Experience (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurse</td>
<td>3</td>
<td>6.5</td>
</tr>
<tr>
<td>Physician</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Nurse</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Nurse</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Physician</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Nurse</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Physician</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Nurse</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Physician</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>Physician</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>
After the interviews were completed, the responses were transcribed (see Appendix D) and entered into ATLAS.ti 6.2 for coding. The first round of analysis was free coded to establish how frequently a given technology or concept was mentioned. The second round of coding focused on highlighting whether a statement expressed a positive or negative impression about a device (change statements that were not explicitly negative, as in “I would change X about this device” were coded as negative). Next, devices were organized into Positive, Mixed, and Need Improvement groups based on the general opinions expressed by participants. Devices were considered “positive” when all participants responded favorably to a device or would not change it at all, “needs improvement” when all participants expressed frustration with a device or would change it in some way, and “mixed” when both positive and negative impressions were expressed. This activity resulted in nine devices categorized as “positive”, seven categorized as “mixed”, and eighteen categorized as “negative”. Table II summarizes which devices fell into each category.
<table>
<thead>
<tr>
<th>Positive</th>
<th>Mixed</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airway management tools</td>
<td>Computers</td>
<td>Bair Huggers</td>
</tr>
<tr>
<td>Call Buttons</td>
<td>Electronic Records</td>
<td>Papoose boards</td>
</tr>
<tr>
<td>Carts/Boxes (crash, foreign body, airway)</td>
<td>Labels</td>
<td>Bicillin shots</td>
</tr>
<tr>
<td>Emesis Basins</td>
<td>Lights</td>
<td>Deaf Talk</td>
</tr>
<tr>
<td>Lab Trays</td>
<td>O₂ and Suction</td>
<td>EKG</td>
</tr>
<tr>
<td>Monitors</td>
<td>Rapid Infuser</td>
<td>Garbage/soiled linen cans</td>
</tr>
<tr>
<td>Patient Distracters</td>
<td>Vein Finder</td>
<td>Hand hygiene</td>
</tr>
<tr>
<td>Point-of-Care Diagnostics</td>
<td></td>
<td>Infant Warmer</td>
</tr>
<tr>
<td>Rolling Vital Signs Cart</td>
<td></td>
<td>IV tracks</td>
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<tr>
<td></td>
<td></td>
<td>Otoscope/Ophthalmoscope</td>
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<tr>
<td></td>
<td></td>
<td>Packaging</td>
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<tr>
<td></td>
<td></td>
<td>Rape kits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rectal thermometers</td>
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<tr>
<td></td>
<td></td>
<td>Scales</td>
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<tr>
<td></td>
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<td>Slit lamps</td>
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<tr>
<td></td>
<td></td>
<td>Storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ultrasound</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urinals</td>
</tr>
</tbody>
</table>
The compiled list was compared against the Food and Drug Administration definition of a “medical device” (134):

"an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article, including a component part, or accessory which is:

- recognized in the official National Formulary, or the United States Pharmacopoeia, or any supplement to them,
- intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals, or
- intended to affect the structure or any function of the body of man or other animals, and which does not achieve any of its primary intended purposes through chemical action within or on the body of man or other animals and which is not dependent upon being metabolized for the achievement of any of its primary intended purposes."

Based on this definition, call buttons, patient distracters, labels, garbage/soiled linen cans, bicillin shots, packaging, and storage were excluded from further analysis because they are not medical devices. The remaining items were analyzed within each category to establish themes that generally are associated with positive or negative opinions about a given technology.

b. **Positive Impressions**

Among the positive impressions, three themes were expressed clearly across a wide variety of medical devices: 1) Medical devices should be “ready to go”; 2) Devices should move easily; and 3) Devices should have simple instructions.
i. “Ready to Go”

Participants seemed to speak most favorably about medical devices and device configurations that result in all necessary components being together and “ready to go” as soon as needed. One physician summarized this theme: “The biggest thing I’d like to change is for equipment to be where it should be. Everything stocked, labeled, no broken or dirty stuff.” The specific medical devices that seemed to embody this concept most consistently across both nurse and physician participants were the monitors, the specialized carts and tackle boxes (e.g., code/crash carts, trauma carts, foreign body kits, airway boxes, vital signs cart), and automated dispensing systems.

1. Monitors

The monitor shows all the vital signs, including tidal CO2, which is very awesome.

The monitors are new and they’re nice ones. They’re modular with a full range of functions. They’re also networked with other monitors.

2. Specialized Carts and Tackleboxes

I love the rolling vital signs cart. Everything is contained in one little area. The best thing they ever came out with, in my opinion.

The crash cart works well and we also have a difficult airway cart. There’s a fiberoptic thing that is hard, it’s always missing a part, so we tend to use the glide scope.

The code cart is much better now. Before we had two types of code carts, now we have a combined medical and equipment cart... a Broselow.
The crash carts are well designed; the colors correspond with the different sizes. Adults are standardized throughout the hospital; however, these carts overall are not designed for our needs. So, we put together tackle boxes with other equipment, like the airway equipment in the cart has a disposable laryngoscope. The physicians here prefer metal; they’re more durable...so we keep that on the side.

The code carts are nicely condensed, we used to have two carts, but now we have just one.

I like that the airway management stuff is in a tackle box, it’s much easier than going through drawers.

Portables? I like the trauma cart.

I like the foreign body kit.

3. Automated Dispensing Systems

Automated dispensing systems are secure devices that contain medications and sharps that require additional security based on OSHA standards. The Advocate system utilizes the Omnicell system, but comparable technologies include the Pyxis Medstation, the Baxter ATC-212, and the McKesson AcuDose.

I’d like to see something like the PICU [the Omnicell system], where there is a med car that needed a code to get into, but it had needles, Tylenol, etc. all easily available.

As far as improvements...we can’t have needles in the room or meds. I’d like to find a way that we could keep those closer. [Miniaturized automated dispensing systems accommodate this need]
4. **Additional Examples**

In addition to these consistent responses, several other statements reflect positive opinions toward properly grouped and easily accessible medical devices.

_We keep the hemocult developer in the room, so you don’t need to walk around with stool samples, so that’s nice._

_I really like the lab trays; we have them pre-set so everything is all at your fingertips._

_With pelvic exams, you used to have this plug-in light that you’d have to find, make sure it worked, make sure it was clean... now we have these disposable speculums that has a light built in. That’s really nice._

_Okay...so the emesis basins on the wall, I like those. They’re easy to find and get to when a patient is actively vomiting._

ii. **Portability**

The second theme that emerged from the positive statements regarding medical devices currently in use revolved around the ability to move devices and equipment around, either bringing items to a patient or moving items with a patient. Specific devices that embodied this trait included the monitors, the specialized carts, the computer on wheels (COW), and portable examination lights.

1. **Monitors**

_The monitors are good, they detach for moving, so you can keep monitoring constantly during a transfer._
The monitors are new and they’re nice ones. They’re modular with a full range of functions. They’re also networked with other monitors.

2. Specialized Carts

We’ve made good progress with the carts and things. They have foot controls and are more standard across the hospital. It’s good to have standards.

The rolling trauma carts are a nice feature.

3. COW

I really like the portable COW [computer on wheels]. This lets you have one nurse charting at bedside during trauma cases.

4. Examination Lights

There are exam lights that wheel in and seem pretty useful.

iii. Simple Instructions

The third theme derived from the positive statements relates to simplicity of instructions. Physicians and nurses both clearly prefer medical devices that have clear instructions indicated on the device itself. Physicians favored the clear instructions on the pacer/defibrillator on the crash cart; nurses indicated a desire for step-by-step instructions, as illustrated in the next section.

The crash carts are more ER-friendly than other technologies here. They start with pre-hospital simplicity and make sure it’s easy to use. There are general instruction modules for all devices that help clinicians switch between brands and show order of operation in 1, 2, 3 steps. [Participant illustrates point on the defibrillator, which has large numbered labels next to buttons to
indicate the order needed to turn the device on, use the pacer, administer shock, etc.]

As far as the pacer box, we’re all comfortable with that, remembering indications, pads, how to connect chargers, knowing synchronized vs. asynchronous pacing.

c. **Negative Impressions**

Review of the negative statements about medical devices and equipment currently in use revealed eight themes: 1) Equipment that is sometimes or never “ready to go”; 2) Devices that do not accommodate easy movement; 3) Devices with poor or no instructions; 4) Configurations that promote wasting time; 5) Configurations that promote wasting resources; 6) Reliability; 7) Size; and 8) Inability to adjust settings. The first three themes are in direct contrast to those discussed in the “Positive Impressions” section above, which illustrates a degree of internal validation; given that the devices favored across all participants incorporated these themed features, one would expect that the same participants would have negative opinions regarding devices that exhibit the opposite of these characteristics. The remaining themes relate to waste (whether time or physical resources) and function (conflict with workflow).

i. **Not “Ready to Go”**

In contrast to the highly positive opinions about devices perceived as always ready or equipment grouped in a manner that was favorable for efficient treatment, several devices were singled out as causing problems because pieces were missing, dirty, or disparately located. Examples included the suction equipment, the Level 1, the ultrasound, urinals, and pediatric patient immobilizers.
1. **Level 1**

   For the infusion equipment [referring to the Level 1], it’d be nice if there were tubing taped to the back so things are ready to go.

2. **Suction Equipment**

   As far as suction, it’s important to have them all set up. Things get busy, it doesn’t get done. In the main room it’s not set up all the time.

   The suction is often missing or dirty.

3. **Otoscope and Ophthalmoscope**

   The otoscope and ophthalmoscope in the main room are often not ready for use. The heads are off, they’re not plugged in.

4. **Ultrasound**

   Multiple participants cited instances in which the ultrasound could not be found easily, was not returned to the central storage location, or was not ready for use.

   The ultrasound, it’d be nice to have those everywhere. Usually I can’t find it, there’s no central place for it. If the trauma team was using it before you, it’s usually all bloody and disgusting.

5. **Urinals**

   I hate it when I walk into the room and there’s a urinal full of urine just sitting there because housekeeping won’t touch it and they also won’t tell the nurses to deal with it. So I had this poor like 78 year old woman sitting in a room with a urinal full of urine that she clearly didn’t put there. It’s gross.
6. **Pediatric Patient Immobilizer**

   *With the Bair Huggers, *it’d be nice* to have blankets on them* so they’re ready to go.*

   ii. **Poor Portability**

   The adult scale used in the ED provided a very emphatic example of a device that perceived negatively because it is hard to move. Only nurses held these perceptions as they are the ones responsible for recording patient weight. The baby scale was perceived more favorably because it was on wheels and had an effective foot break. In contrast, the adult scale must be either lifted or dragged across the floor to bring it closer to a patient. This is particularly challenging to the nurses in the pediatric wing because pediatric medication dosages are generally calculated based on patient on weight.

   *The adult scale is really hard to move. If they come through triage, they just get weighed up front but if they come in by ambulance, we need to weigh them back here. It’s really important in pediatrics because doses are so often based on weight. The scale is hard to move and it’s not user friendly. There is one on a cart, but it’s not accurate. The baby scale is great, it has wheels, moves easily, has a brake...*

   *The big person scale that we use if the person is brought in on ambulance, that scale is heavy and hard to move.*

   iii. **Poor Instructions**

   Two devices frequently used or encountered by nurses provided examples of medical devices with poor instructions, or no instructions on the device itself. It is interesting to note the level of anxiety expressed by these participants when interacting with technologies that are unfamiliar and do not provide an easy way to ensure proper use. This
anxiety seems to stem from a combination of fear about providing inferior care and appearing incompetent or unprofessional.

The infusor [referring to Level 1]... it doesn’t get used often, it’s scary to use. It makes me cringe. It’s not as easy as it could be, you have to set up all of this tubing. I’ve never used it with an actual patient. The guidebook is useless [picks up and leafs through a 4-page booklet with laminated pages and small print]. Can you imagine me picking this up during a trauma? That won’t inspire patient confidence. It takes a lot of focus to set up, and that’s not possible during a trauma.

I also get nervous around med ports. It’s a very detailed sterile process. Maybe if you’re used to them it’s not a big deal, but we don’t see them that often. It’d be nice if the med port company included a quick-steps guide. I mean, you need to keep it sterile and I’d hate to cause an infection in some immune-compromised kid.

iv. Wasting Time

Many complaints regarding wasting time reflected how the current configuration, whether a storage issue or user interface, fostered inefficiency or redundancy. Participants provided several examples where supplies for the same procedure were not co-located, which resulted in “running around” to obtain all of the necessary components to perform a procedure. The second example of wasted time stemmed from the computer interface on the Electronic Health Record used in the ED. The third scenario that prompted perceptions of wasted time came from specific devices. DeafTalk, a video link to a sign language interpreter, was perceived as taking too long to set up and not providing sufficient patient benefit. The rectal thermometer was perceived as taking too long to complete its measurement, resulting in patient discomfort and stress.
1. **Task Inefficiencies**

In general, it’s just detrimental to go find something if it’s not in a central location or if it wasn’t put back correctly. There should be RFID or something so I can call up on the computer where it is.

For pelvic exams and STD testing, I have to go fishing for pieces. If you want to be cost effective, you need to be efficient. When you go looking for things you lose efficiency. So, like the ultrasound, the slit lamp.

It seems little things that are related are all over the place; for example, with sutures: needles, syringes, and anesthesia are in three different places.

The eraser boards are okay [used to show the name of the doctor and nurse for the area, other info. It’s covered in a plastic case that locks so that the writing isn’t accidentally erased or altered on purpose.] It would be nice if they were electronic so the nurses could centrally update them, rather than walking from room to room. So right now it’s Dr. Dean, but next shift it’s someone else and someone has to walk around and update each by hand.

2. **Computer Interface**

There are never enough computers, they’re never in the right locations. They need to be everywhere and portable. Everyone is documenting on computers, so usability of software platforms is pretty bad. Like logging in and logging out cuts productivity. If it takes a minute every time and you have to do that 50 times during a shift, you’re losing almost an hour. That’s like 10% of your time.

The RapidStrep test you have to hand document the QA, it could be 1 click. It’s redundant.

I don’t like the IT systems, it’s a waste of my training for me to sit and be a typist.
3. Technology Performance

I really don’t like this DeafTalk system. Basically, there’s a hook-up to video feed interpreters to deaf patients. The patients dislike it; I think actual interpreters increase patient satisfaction. There’s just a lack of personal connection, it’s not as fast as the other interpreters where you call on the phone. It takes me a bunch of time to set it up and then the patient doesn’t even like it.

I don’t like the rectal thermometers. They take too long, patients get anxious and I can’t blame them. They can take up to 60 seconds for a reading.

v. Wasting Resources

Participants also cited wasting resources as a source of frustration during their daily routines. Three examples of wasted resources provided were unit dose medicine, prepackaged urine sample kits, and suture kits. Each of these contained some component that was not useful to the task it was meant to perform. In the case of unit dose medications, unused portions of the drug must be discarded (a frequent occurrence in the pediatric wing). In the case of the urine sample kit, the cup used to collect specimens came pre-packaged with the wrong type of sample tube. In the case of the suture kits, there is a tray that does not hold a sufficient quantity of saline to complete the procedure.

The new medicine cups are wasteful, they are 200mL, so you have to throw out the rest of the unit/dose if you don’t need it all.

These urine cups drive me nuts. They are prepackaged by the manufacturer or something, but we don’t use these yellow-topped tubes. It’s a waste of money because we have to use the yellow/red instead because they keep longer. It just seems wasteful to me, we have a whole overflowing bin of unused yellow top tubes.
When I think of packaging, suture kits come to mind. I guess there’s a weird compromise between options vs. cost. So suture kits come with a plastic tray for saline. The current kit has a tray that’s divided into three compartments. Why? Now I can’t put as much saline in there.

vi. Reliability

The next theme among negative statements related to the reliability of certain types of equipment. Both nurses and physicians expressed concerns about pieces of equipment that regularly did not work or gave false positive results. The three specific devices that were cited include devices for eye and ear examinations (i.e., otoscopes, ophthalmoscopes, slit lamps), lighting, and ultrasound-based vein finders.

1. Eye and Ear Exams

   When you have to do an eye exam, the slit lamps are a disaster here. You have to worry, is it working? In other hospitals I’ve seen hand-held slit lamps that are really nice.

   I often see where the otoscope isn’t working.

   Equipment wise, I guess the one thing I would change is that the ear and eye devices tend to burn out.

2. Lights

   The overhead lights bother me a little. Sometimes they work, sometimes they don’t. If they don’t get moved often, they get dusty so when you do move them, it rains dirt all over the patient.

   The lights on the wall sometimes don’t work.

3. Vein Finder

   I’m not a big fan of the vein finder. There’s no depth, you get false readings.
vii. **Equipment Size**

Space is at a premium in the ED. It is a common refrain that EDs remain financially solvent based on patient throughput; therefore, fitting as many patients as possible in the space allotted to the ED is a high priority. One nurse expressed her distaste for the number of large items that end up in treatment areas: “I dislike the size of things, space is limited. There are lots of sick people and nowhere to put them.” The problem with many modern EDs is that the space requirements for each patient were estimated in the 1970s and 80s, before many technologies were available in a portable format. One physician explained: “You have to understand that ultrasounds, computers on wheels...these things were not in the thought process 20 years ago.” The ultrasound machine was cited most frequently as the most difficult device to fit in the patient room; physicians and nurses both commented that they would like to have access to more ultrasounds, especially if the ultrasound had a smaller footprint.

1. **Ultrasound**

*The ultrasound is tough, you have to find a good parking spot that’s out of the way, but still accessible.* You pick a spot based on today’s experience and you’ll be wrong tomorrow.

*The ultrasound is a bit big so it’s hard to work around.*

*Regarding the ultrasound, again I’m interested in smaller size and more durability. A smaller footprint. There are some cord problems, there are a few ER-focused companies, but theft is a concern. Maybe you could put in some type of GPS computer chip that will tell you where the thing is and will disable the device if removed or damaged.*
When you bring in an ultrasound machine, it’s a big machine and takes lots of room.

2. Other Devices

EKGs are fairly portable, but the techs do them so I don’t use them. But like everything else, it’d be nice if they were more flexible/durable, simpler, smaller; however, smaller is easily stolen.

The infant warmer is big, it’s challenging to put in the room. It’s heavy and bulky, but it rolls.

viii. Inability to Adjust Settings

There were two examples of devices perceived negatively due to an inability to adjust settings: lighting and computer components. The lighting in the Advocate ED is likely the least standardized technology that the physicians and nurses encounter. There are three different lighting configurations in the pediatric ED alone. Some rooms have overhead lights that can be repositioned for optimal illumination of procedures, some have only standard fluorescent lights that cannot be adjusted, and some have a combination of lighting options that allow dimming. The complaint about computer components referred to the inability to adjust the physical position of computer equipment for different users, which resulted in discomfort to the providers.

1. Lighting

But going back to this, we don’t have dimming lights in half of the pediatric rooms. They’re either on or off. You can’t dim the rooms to create a different ambiance.

Lighting is never set up correctly. If I had to suture in this room (Room 15, non trauma-bay, no movable overhead light), it would be too dim, no way to add light. In this room, the track for the IV makes the light even worse. You need to be able to illuminate better.
I don’t like the lighting in here, you can’t adjust it. In some of the rooms on the other side [of the pediatric unit] you can dim the lights. Here it’s either on or off. It’s more soothing to have the lights dimmed, but total dark can be too much.

2. Computer

The computers aren’t laid out very ergonomically. I use bifocals, so I need the monitor a bit lower and I can’t adjust these well. Other people need the screen higher. It seems no one thought of it actually being used. And that matters when I spend 60% of my time in a chair on the computer.

d. One-on-One Interview Summary

The one-on-one interviews with physicians and nurses revealed a number of themes associated with positive and negative opinions about the medical devices they use in the course of completing their work. Devices that were generally considered always “ready to go” were perceived positively; devices that were frequently not “ready to go” for a variety of reasons were perceived negatively. Likewise, devices that moved easily were perceived positively and devices that were difficult to move were not well liked. Devices with simple instructions, clearly communicated on the device itself, were considered easier to use than devices that did not have instructions or only provided complicated directions. Devices or configurations that were perceived to cause waste, either in terms of time or physical resources, were perceived negatively. Users considered important physical attributes such as size and customizability. Finally, several examples of devices with poor reliability were perceived negatively. The themes identified in the one-on-one interviews were applied to the market analysis, discussed below, to exclude potential ED technologies that did not align with the clinicians’ own definition of what is easy to use or useful.
2. **Focus Group Outcomes**

   a. **Setting**

   Two focus groups were conducted to explore themes to guide concourse development for the radical innovation Q-sort. The first focus group, consisting of four physicians who met the inclusion criteria defined in the research protocol, was conducted over two hours on May 1, 2012. The participants sat at an octagonal table; the researcher arbitrarily assigned seat numbers, starting to her immediate left, to identify participant comments but maintain anonymity during transcription. The second focus group, consisting of six nurses who met the inclusion criteria defined in the research protocol, was conducted over one hour and fifteen minutes on June 8, 2012. The participants sat at a rectangular table; the researcher again arbitrarily assigned seat numbers, starting to her immediate left. All participants were provided a written information sheet that was reviewed prior to the start of the discussion. All 10 participants reviewed the information sheet and indicated informed consent by continuing their participation until the end of the focus group, consistent with the instructions on the information sheet and the approved protocol. See Appendix E for the full transcript from these sessions.

   Participants considered four main questions:

   1. Can you describe clinical conditions/presentations that you feel are challenging to diagnose, treat, or manage?

   2. Can you name evaluations or assessments that seem to be more time consuming than they should be?
3. Can you share an experience you have had treating a patient where you felt the outcome would have been better if different technology was available to you?

4. What type(s) of information do you feel clinicians should receive more rapidly?

b. **Physician Focus Group**

Among the physicians, four major themes emerged to describe areas where technology could improve quality of care in the ED: Information Movement, Treatment Options, and Diagnosis for Ambiguous Symptoms. Information Movement describes current pathways deemed important for patient information, but at least occasionally dysfunctional. These pathways are further categorized into two general scenarios: internal information movement describes failure to effectively transmit information within the institution, and external information movement describes the failure to efficiently receive clinically significant patient data from external sources. Treatment Options refer to various clinical actions taken during a patient’s time in the ED, including diagnostics, interventions, and pharmaceuticals. Diagnosis for Ambiguous Symptoms refers to scenarios in which differential diagnoses are particularly difficult to establish.

i. **Information Availability**

Inadequacy of information availability was the most common and recurring theme among the information-oriented observations. This result is not surprising, given the nature of emergency medicine; treatment must often be rendered relatively quickly,
whether the patient can provide a reliable medical history or not. This fast pace is only partially
driven by clinical necessity, more often it is in response to administrative pressures to free beds
and maximize efficiency within the department. In addition, patients are generally not
enthusiastic about a prolonged ER stay, especially if they are unlikely to be admitted into the
hospital. Delays in obtaining clinically relevant information, therefore, may result in a patient
being discharged (or just leaving) before ascertaining a full understanding of their health status.
This group identified two main scenarios where critical information gaps exist: within the ED
(Internal) and between the ED and other health providers (External).

1. **Internal**

   The group expressed their greatest frustration with

   information flow between nurses and physicians. The transition from paper charts to electronic

   has, in their opinion, negatively affected overall communication within the ED.

   “*There is a huge IT disconnect between docs and nurses. When I look at an electronic health record, I have no idea
   what meds, fluids, etc. were given... Docs don’t even read the nursing notes. The important information is buried.
   Cerner sucks.*”

   Overall, I think we need better system-wide communication.

   These internal communication deficiencies have led to the

   performance of unnecessary procedures, patient identification errors, treatment delays, and

   misdiagnosis.
So, in our ED, the back hallway is our gynecological area: GC 18, GC 19, and GC 20. Patient in GC 18 has vaginal bleeding; patient in GC 20 was motor vehicle accident. GC 20 gets confused with GC 18. GC 20 is supposed to get X-ray of c-spine, ends up getting a pelvic ultrasound. She took off all of her clothes, got into the stirrups, had the full exam. The patient doesn't say anything.

I had a patient once, who came in as a psych patient. The triage nurse sees her, the girl is not in good shape, saying all sorts of bad stuff to the nurse and the nursing note mentions suicidal stuff. The doc sees the girl, she denies suicidal thoughts, no depression, says she's just drunk. The psych consult didn't see the nursing note, patient continues to deny suicidal stuff. She was discharged, and let's just say there was a bad outcome. We need to be able to autofeed nurse notes into doc's and psych's notes.

Lab tests, blood tests, radiology. The problem with blood draws is that they are a black hole. Then the doc has to search for the break down; for example, if phlebotomy misses the patient for some reason...they're getting an x-ray, they're in the bathroom, whatever... they say they'll come back, but they don't. Also, if the blood draw has a problem, like the blood is drawn, but it clots in the tube so the test can't be run, they won't tell you until you ask.

The group also cited situations where health IT introduced minor errors into workflow. While these were not negative outcomes for patients, there was still some resentment for being made to look unprofessional.

Yeah, like our CPOE, it has drop down menus that I have screwed up multiple times by clicking on the wrong thing. So, like on the request for CT, you then have to pick from a drop down list what type of contrast you need. And for some reason "NONE" is right next to "rectal administration". So I end up ordering a CT scan of the head and rectally administered contrast. It's not a big deal, radiology catches it and calls me, but you just look stupid.
There is something like that on the discharge lists, where “nursing home” is below “home” so I’ve accidentally discharged pediatric patients to nursing homes. It just looks unprofessional.

A second internal information gap is related to supply and equipment inventory. Often these physicians were not aware that a room or patient area was not correctly or sufficiently stocked until they needed something that was not present.

We need lots of help tracking inventory in the ED. Where are things? Where can they be found? The people who stock the rooms aren’t docs, they don’t know what stuff is, so they often don’t catch when things are missing or if it’s not quite the same thing.

There is also variation from room to room in terms of what is supposed to be present, which creates variations in treating the same condition in different rooms.

So anyone in a hallway bed is going to take longer to work up because the required equipment is not at hand.

All of the participants agreed that they would like to see a technology that facilitates the movement of “important” data or a “push” function from the source to the intended recipient (i.e., from the lab to the physician). They unanimously agreed that placing the burden on physicians to retrieve important information was detrimental to the workflow in the ED.

We need like a data “push” function. Right now we can only pull, and only pull certain things.

Yeah. I really need to see important things. I don’t want everything, just important things pushed to my notes.
It should be like a hotel, they know what rooms are open, clean, etc. We need that data “pushed” to us.

Along a similar vein, more distinct communication regarding drug interactions is desired among the participants.

I’d also like alerts for drug-drug interactions. So they have okay alerts for allergies, but there is no priority on drug-drug interactions. They give the same alert for “there’s a 1% chance that the person will get dizzy” as “if they have both drugs, they’re going to have a heart attack”. The alerts don’t give enough information to allow me to assess risk, so I just don’t listen to them.

Not even color codes work [for alerts]. We need like a black box with smoke to indicate trouble.

There was also unanimous desire for better communication regarding bed availability in other departments to facilitate patient transfer.

I’d like to know when beds are clean. Why aren’t beds cleaned? They should start some sort of reimbursement by # of beds clean to incentivize getting it done faster.

I’d like to know when beds are available so we can get people out of the ED faster.

I’d like something that lets me know when an appropriate bed is open to let me transfer a patient.

2. **External**

The participants also repeatedly requested technology that could facilitate communication between the ED and external entities. Treating patients admitted from nursing homes and treating patients transported to the ED by emergency
medical services were the two most common scenarios in which poor information transfer between external entities and the ED were most detrimental to patient care.

When you get patients from nursing homes, it’s really hard to diagnose and treat them. You have no ideas about their background. Sometimes you don’t even know why they were sent to the ER. You call the home, the person who called EMS is off shift, didn’t leave notes. The next person has no idea who the patient even is.

Patients from nursing homes are challenging. Especially if the nursing home is not affiliated with [the study site], so there are no records and no notes from the [unaffiliated] institution.

I had a guy once... it was early morning on a slow day. The patient was in the hallway, had an epigastric pain complaint. Medical student goes in and does the first interview, resident goes in and sees the patient, guy tells the doc he had epigastric pain but now he’s feeling better. Looks like a minor problem, nothing else is in the chart, no history. A few hours later the guy is back, he got hit by a car, so now he’s a trauma patient. His wife is complaining about the diagnosis. Turns out EMS was called to his house because he was suicidal; it’s on the EMS note. He attempted suicide at home, but the triage nurse didn’t get the EMS note.

Yeah. The paramedics write notes after the patient is admitted, sometimes not until the end of their shift. The hospital gets a piece of carbon paper. So you can’t move information easily from EMS to ED.

EMS is so bad with notes. I prefer to talk directly to the EMT, when you don’t know, you just ask for everything. Nurses don’t know what to ask.

The group also expressed frustration with obtaining information from other healthcare providers in general.

I’d like to have past medical records and be able to transfer records between facilities.
Yes. Sometimes you end up calling County [Stroger Cook County Hospital] to get records from a dungeon.


I’d like better ways to communicate with other doctors and get feedback.

I’d like to have a better link with primary care docs...

The second external information theme related to general patient knowledge, particularly for special needs populations, such as geriatric, pediatric, and psychiatric patients. There was consensus among the groups that one of the things that makes diagnosis and treatment so challenging in the ED is an inability to establish a patient’s baseline function.

Psychiatric patients- they may have an underlying medical problem as well as psych condition, then you try to hand off the patient, you have a lack of previous information, patients use fake names and you don’t know the patient’s history. Then there is difficulty handing this information off and the patient can get stuck in limbo.

Geriatric baselines are really hard to establish.

Having no baseline on a [stroke] patient is really hard. You don’t know their “normal”.

In general, I’d like to know how they normally function at home so I can tell how far from that they are.

A&Ox3 [alert and oriented to person, place and time] doesn’t tell me shit. We need a better measure.

Finally, the group discussed the use of the Illinois Prescription Monitoring Program in the ED as an example of a moderately functional means to obtain outside information while providing care. The Illinois Prescription Monitoring Program is
an electronic tool that collects data on controlled substance prescriptions from retail pharmacies so that dispensers and providers can review an individual’s prescription history. Some of the group found this tool useful in treating chronic pain patients because they can verify treatment history; however, there were complaints about the security requirements (frequent password changes), inability to search outside of Illinois (as Chicago is geographically located very near two state lines), and lag time in system updates (sometimes as long as 60 days).

It’s [the opiate registry] helpful, but it would be nice to decrease the lag in prescription history updates. Currently, I think it’s like 60 days behind. You also have to change your log-in and password a lot.

And chronic pain is a waste of time and resources [in the ED]. IDPH has a login for opiate profiles for patients. You can look up opiate prescription history, but this access gives you more confidence to call out prescription pain medication abuse.

But I think it [the opiate registry] clears the air more often than implicates for me. I can check on a person who says “I saw this doc, at this time, and he gave me this...” and I can look it up and it’s true, so I feel better about prescribing.

ii. Treatment Options

The second area where technology could influence the ED was in the area of treatment options for specific conditions. The most challenging conditions identified included stroke, sepsis, acute heart attack, and ectopic pregnancy. As each group member suggested an issue, the rest of the group confirmed the difficulty with these specific conditions.
1. **Stroke**

_Stroke_ makes me nervous. You have to decide when to give TPA and make sure you have a proper diagnosis.

Having no baseline on a [stroke] patient is really hard. You don’t know their “normal”.

And giving TPA is a life changing decision for the doc.

Participant 1: Strokes are really hard for me to deal with.

Participant 3: Yes. And there are guidelines, many of them conflict, there is just lots of information.

Stroke. Neuro consult takes forever, CT scan, MRI takes forever.

2. **Sepsis**

_Sepsis_ or overwhelming infection is really hard to diagnose and treat. The standard protocols are great, but they presume you know sepsis when you see it [since sepsis often mimics many other conditions].

3. **Obstetrics**

Diagnosing issues with vaginal bleeding is particularly challenging, especially if you try to figure out an ectopic pregnancy.

4. **Acute Heart Attack**

The concept of acute heart attack has potential to take a lot of time. So you have the EKG and if it’s a STEMI it’s easy, there are guidelines and national standards, but how long it takes to get through that protocol probably varies a lot across the community [If a STEMI is ruled out, diagnosis is ambiguous and the workup is longer still]. If you look at the time it takes to go from symptoms to the cath lab, I bet there is often a lot of wasted time.

The availability of appropriate medications was also discussed in some detail. There was great concern that certain drugs that are vital to providing
treatment are slowly becoming unavailable due to either dwindling supply or regulatory changes.

I’ve had trouble with the drug shortage. There are certain meds we just keep running out of.

Apparently now that some of the drugs are older and have run out the patent, drug companies are slowing down production because these meds aren’t profitable. I’d love to see a research study across the country to see who is missing what drugs.

Paralytics in particular.

Also, I’d like to know why the FDA keeps taking drugs away. There were things that worked really well that just keep disappearing.

Finally, participants expressed some frustration with performing what are typically routine procedures on patients who are morbidly obese.

I have trouble with really obese patients. I can’t get access to start an IV or a central line [the needle is too short]. Usually an EZ IO will work even if the patient is fat, but they need a whole line of medical devices to deal with morbidly obese people.

iii. Ambiguous Symptoms

The third theme that emerged related to the treatment and diagnosis based on ambiguous symptoms. The group identified several clinical presentations that it felt were especially difficult to address, many times because the risk of misdiagnosis was very high. As an example, most instances of pediatric fever indicate routine illness but, in some instances, may indicate a more severe condition; missing that diagnosis could mean severe
morbidity or mortality of the child. General symptoms that pose difficulty in diagnosis include weakness, pain (e.g., chest, lower back, and abdominal), and several pediatric conditions.

1. **Weakness**

   *Patients presenting with weakness are hard to diagnose.*

   *An unstable patient of any kind is hard to deal with.*

2. **Pain**

   *Chest pain is hard to diagnose.*

   *It [chest pain] can be hard, but you have to accept that there is a baseline non-diagnosis for chest pain.*

   *Lower back pain. I hate when they present with lower back pain.*

   *Abdominal pain is hard to diagnose.*

3. **Pediatric**

   *Nose bleeds and pediatric fever are challenging to diagnose and treat sometimes.*

   *Pediatric fever takes a long time to assess. Most of the time it’s nothing, but you want to be sure.*

   *Same with pediatric hip pain.*

c. **Nurse Focus Group**

   The nursing focus group also revealed three overarching themes for the challenges that might be addressed by new technology. These included Information Movement, Patient Management, and New Technologies. As with the physician results, Information Movement describes current pathways for patient information deemed important but at least occasionally dysfunctional. Patient Management refers to the challenges
associated with providing patient care from a nursing perspective; management issues arise from patients admitted with specific clinical presentations, time management challenges, and ER misuse. Finally, New Technologies includes the “wish list” of what the group would like to see incorporated into an ER that would solve many problems for nurses.

i. Information Movement
   1. Internal

   Like the physicians, the nurses expressed frustration with the ways health IT mediates communication in the ED. Nurses felt that their current electronic charting interface was not user friendly. Two factors seemed to contribute to this impression: 1) data entry is difficult; and 2) data redundancy is perceived when data generated by independent medical devices is not automatically consolidated (for example, infusion pumps do not automatically populate the patient’s chart with IV stop times). Nurses also identified circumstances in which miscommunication occurs because of the way electronic orders are presented to the nursing staff.

   Participant 6: There would be a user friendly charting system.
   Participant 2: A charting system that doesn’t require stop times for IVs, that they get charted automatically.
   Participant 3: Verbal charting. Dictate notes where we’re standing.
   Participant 1: Uh. I don’t know...we might end up with words in there that maybe we don’t want. Maybe it needs like “profanity check” or something [group laughs].
A doctor gives a series of orders and finishes with a discharge order. All you see is the last thing, the discharge order, so you don’t realize there were other orders first.

The nurses also expressed some frustration with general communication failures that delay treatment or general management and comfort of patients.

Also better communication with other physicians; for example, the ER calls a physician, they don’t talk to the nurse or the ER attending. They just waltz in and don’t even say “hello”. We go check with the family and they say “Oh, they were here.” But they never talk to the ER staff and we’re like “Well, can they eat? Can we give them pain meds?” Then they [the consulting physician] get pissed off that the ER calls them to ask what’s going on.

The EMR does not currently have a feature, of which the staff is aware, that would allow an external physician to leave a “note” or some sort of alert to the staff following a consult.

2. **External**

The nurse participants also expressed a desire for additional means to access **relevant** patient history from outside the hospital, particularly in circumstances where direct communication with patients is not possible due to language barrier or cognitive state.

*Participant 4:* Communicating EKG off the radio from EMS is very valuable. It’s not in Chicago, but the surrounding suburbs have it.

*Participant 1:* EMS is pretty good about calling in an MI or stroke. EMS is well trained and well versed around here, they call ahead and let us prepare.
Participant 4: The more info we have before they come in, the better. So the ones from the surrounding suburbs can transmit actual EKG readings on the way in.

Participant 1: Non-English speaking. You can’t talk to them right away... if they’re crashing, there’s no time to find an interpreter and you have no real patient history.

Participant 4: Non-verbal or non-English speaking.

Patients come in unresponsive, with no history. It’d be very helpful to be able to access past medical history. Like dogs with those chips...scan their bellies and you know everything about them.

It’d be nice if you put in a name, date of birth and get the history with an icon you can click that gives you faster access to relevant records, not every single visit.

Mental illness is the top of my list. You can’t talk to them, you usually don’t get patient history. Then if you have to restrain them you have to fill out restraint packets and I don’t want to fill those out [all participants agree].

ii. Patient Management

Challenges in patient management fell into three sub-themes: 1) Clinical conditions that are inherently challenging to manage; 2) Time management; and 3) ER Misuse. The nursing focus group identified several clinical conditions that were difficult to manage, including sepsis, traumatic injury, diabetic complications, chronic heart failure, and chemotherapy (already immune suppressed) patients experiencing acute health concerns. During the focus group, each participant’s statement received verbal and/or nonverbal agreement from the rest of the participants, often emphatically. Time management related to the tasks that nurses felt took too long to complete and might be aided with better technology.
Examples included faster turnaround on labs, better access to imaging resources (e.g., ultrasound), and shorter, yet still accurate, standardized assessments.

### Clinical Conditions

It’s hard to find the source [sepsis] and to keep them from getting hypertensive. It takes constant care.

Doing septic workups for kids [is difficult to manage].

Trauma. There are so many different mechanisms and you have to check a lot of things.

Sickle cell is really hard to deal with.

Diabetics, especially when they’re DKA [diabetic ketoacidosis]

Participant 6: Managing diabetic patients, a lot of them develop comorbidities. They come in with a DKA situation and they are very critical patients. So there are many labs and lots of assessments to do. Also, if they miss a dialysis treatment, they end up short of breath, they’re critical.

Participant 4: Yeah. When a patient comes in and needs dialysis, the machine is now occupied for 4 hours.

Chemo heart failure patients are really hard to manage.

Chemo patients are hard to manage, thinking about your last question. It’s really big when we have someone from oncology and you have to get them adequately and safely cared for in a filthy ER. And they’re all filthy ERs.

### Time Management

In addition to identifying specific clinical conditions that were difficult to manage, nurses also expressed some workflow-related challenges that mostly arose from the time it took to complete a given task. These time challenges fell into four categories:
1) time until lab results are received; 2) delays in imaging; 3) time it takes to conduct standardized assessments; and 4) time spent managing patients who “misuse” the ER.

1. **Laboratory Results**

   It would be nice to have labs expedited. You can request this when a sample is drawn, so like with critical patients you can code to call for expedited labs.

   Participant 2: Cardiac labs take a lot of time.
   
   Participant 1: There is a machine that does cardiac markers.
   
   Participant 4: We really care about troponin and H&H [hemoglobin and hematocrit]
   
   Participant 6: I’d like a point-of-care electrolyte panel.
   
   Participant 4: They have point-of-care tests that read cardiac enzymes in 20 minutes, which is better than an hour.
   
   It’d be good to get a UA [urinalysis] faster. It takes about 40 minutes right now.
   
   Microscopic analysis takes a long time.
   
   I’d like to get urine cultures faster.
   
   H&H, pregnancy, creatinine, troponins, electrolytes are what I want up front.

2. **Imaging**

   Participant 4: Radiology, x-ray, ultrasound…you’re always waiting to get in.
   
   Participant 6: It’s back to the space issue.
   
   Participant 4: The major barrier is that we’re competing with inpatient and outpatient for imaging.
Participant 2: It’d be good to have our own.

Participant 1: I mean, if you need a stat test for testicular torsion, it takes forever to get an ultrasound. Then, after hours, the EEG closes at 3am. They need to keep going. They need to just schedule people later, why can’t we have people come at 8pm after work for a CAT scan?

Participant 2: It all comes down to money.

Participant 3: I agree. Ultrasound and stress tests would be nice to get results from faster. Maybe we should just close at a certain point [laughter from all].

3. Standard Assessments

The NIH stroke scale, it’d be nice to have something faster with the same accuracy.

The CIWA for alcholoics. [Clinical Institute Withdrawal Assessment used in hospitals to assess and treat withdrawal syndrome and alcohol detoxification].

Psych evaluations. There is a lot involved, security, safety, resources, sitters.

Waiting for social workers, if they’re busy, they take a long time. 2 hours at least per patient, so if we’re third on the list, that’s 4-6 hours of waiting right there.

Neuro and trauma assessments take a long time. Neuro in particular…you have to go through a bunch of steps to complete it.

4. ER Misuse

Participant 6: I think a big challenge is the general barriers to care. Some people don’t seek out primary care, or they have no insurance, so we [the ED] are the follow up. People wait until they’re too sick to seek treatment.

Participant 1: We are the follow up [Participant 2 nods head emphatically].
Participant 1: Meanwhile, someone came to the ER for an earache. They didn’t need to be here. Their doc told them to come.

Participant 6: But when you can’t get in to see your primary care doc for 10 days, what do you expect?

Participant 4: Well, there’s no copay when you’re in the ER, the primary care folks won’t see the patient until they pay the copay.

Participant 2: Yeah. They don’t have money for health care, but they do for other things that are less important. They have better phones than me.

I’d like simple stuff at the doctor’s office to be done better, like taking correct temperature and appropriate treatment for fever.

I’d like someone, an NP [Nurse Practitioner] maybe, who says “You’re not ER material, go to our clinic down the block”.

iv. Future Technologies

A final question was posed to the group: “If you could have any sort of technology in the ER, don’t worry about how it would work or what it would cost or where it would come from... but if you could have anything, what would it be? In other words, what would you want the ER of the future to look like?” Throughout the conversation to this point, the nurses stayed very concrete in their responses and solutions. This question presented the opportunity to be creative and emphasize what really mattered to them. The technologies they described fell into four categories: 1) improved mechanisms to conduct imaging; 2) improved mechanisms for patient movement; 3) improved drug administration; and 4) technologies that protect patient dignity.
1. **Imaging**

   Participant 4: *I’d like a cart that can go into the CT scanner so I don’t have to transfer the patient.*

   Participant 6: *Or a bedside CT.*

   Participant 5: *Same with the MRI, being able to do an MRI without moving all the pumps, tubing change overs…*

   Participant 1: *Maybe a memory foam bed like cement, they sink in and stay still [for imaging].*

   Participant 6: *Well, maybe it should be that imaging should not be as sensitive to patient movement.*

2. **Patient Movement**

   There would be easier ways to move patients.

   Participant 4: *I’d like on my cart a ventilator that doesn’t trail behind…is attached somehow.*

   Participant 3: *It would have a gurney with everything on it. Vital signs, etc.*

   Participant 6: *We just saw an amazing talk from a physician here who just got back from a military hospital in Germany that had something like that. I think it was called a SMEED? [Special Medical Emergency Evacuation Device]*

   Participant 4: *I’d like to levitate patients. Like an anti-gravity bed. [group laughs] What? She said anything we want. I want them to float around and just stick a litter box under them and call it a day.*

   Participant 1: *Like the scooping litter so we can clean it more easily?*

   Participant 4: *Yeah! I want to float them down the hall to X-ray or CAT scan.*
3. **Treatment Options**

I’d like something that secures an IV for diaphoretics, keeps it in place and sticks until you take it off.

Participant 1: I’d like ways to sedate a child more easily, not Versed [midazolam], so that they don’t go nuts when there is a procedure that if they move it screws it up.

Participant 4: I’d like to see more drugs where you don’t have to start an IV.

Participant 1: Like they sniff it and get what they need.

Participant 2: I wish the COOLGUARD protocol was around before.

Facilitator: What’s that?

Participant 2: It’s a protocol to induce hypothermia in neuro patients

Participant 4: I’ve noticed more people being revived from new CPR; for example, someone comes in who should be dead and we get them back. We revive them and then we need to cool them. We’re getting people back when we wouldn’t before.

4. **Patient Dignity**

I’d like an EKG where you don’t have to be naked from the chest up...in triage.

Participant 6: Yes, maybe a different gown configuration.

Participant 1: Well, that [the floating bed] makes me think I’d like a way for females to pee without standing up. Like a urinal for women. The bed pan sucks to their butt, sprays everywhere. It’s awful.

d. **Focus Groups Summary**

Both focus groups provided interesting insights into potential areas where the introduction of radical health technology innovations might improve patient care in
the ED. The clearest overlap in technological need revolved around Health IT. Both physicians and nurses expressed concern at their inability to communicate effectively with each other through electronic notes. Physicians cited instances where they did not receive critical patient information from nurses; nurses cited instances where they missed physician orders due to a confusing user interface on the EMR. Further, both physicians and nurses identified inaccessible patient history as a major concern during treatment of a wide variety of patients, but especially in vulnerable populations such as the elderly and mentally ill.

Physicians and nurses also identified a series of clinical presentations that are inherently difficult to treat or to manage. Both groups specifically identified sepsis as hard to treat and to manage; however, most other conditions were either challenging to diagnose or challenging to manage. Stroke was considered hard to diagnose and treat, but nurses explicitly stated that stroke patients were not hard to manage. Physicians focused on acute heart conditions as difficult to treat; nurses focused on chronic heart failure as hard to manage. A trauma diagnosis is generally easy to make, but managing a trauma patient is challenging. These contrasts provide an interesting avenue for Q concourse development. Including both diagnosis and management challenges will allow study of the ED culture and the importance participants place on colleagues’ struggles. As an example, might physicians perceive a technology that will help nurses manage a frequent challenging condition more favorably than a technology that helps physicians confirm a challenging diagnosis that occurs rarely? Alternatively, will each clinical specialty emphasize only the technologies that will solve its own
problems? The concourse, therefore, must include both themes under the overarching category of “challenging patients.”

Both groups identified lag times in obtaining laboratory and imaging results as a barrier to providing care. Though some of the delay might be addressed through logistical or managerial means (there have been anecdotal assertions that imaging and lab technicians are not as efficient as they could be), these procedures and protocols do take a certain amount of time that might be decreased by introducing emerging technologies, such as point-of-care diagnostics or more rapid image acquisition. Statements reflecting advances in imaging (including configurations that accommodate standard-size ER beds) and point-of-care diagnostics (particularly those that address differential diagnosis among the ambiguous symptoms described by physicians) should be included as part of the concourse.

Finally, both groups identified the need for additional treatment options. Treatment areas for exploration included drug administration (alternatives to IV) and hypothermia induction methods.

Based on the focus groups described above, the Q-concourse on radical innovation must reflect five major themes: 1) Innovations in Health IT; 2) Innovations to Address Challenging Patient Care; 3) Innovations that Reduce Laboratory Time Burden; 4) Innovations that Reduce Imaging Time Burden; and 5) Innovations that Provide New Treatment Options.
3. **Market Review Outcomes**

There is a great deal of variation in the number and types of innovation across the medical marketplace; for example, dialysis appears to be in what Christensen (135) describes as a sustaining phase in which a few large companies dominate the market and only offer incremental technical improvements. On the other hand, emerging markets, such as point-of-care diagnostics and health IT, offer many different solutions to the same problem. The market analysis identified multiple technologies in each target area, which were used to populate the final Q-concourse. The specific technologies are summarized below and a full description of each technology is provided in Appendix F.

a. **Health Communication**

Based on the focus groups outcomes, health communication technologies should operate in one of three contexts: facilitating internal communication, facilitating external communication, and retrieving relevant patient history. There are currently a wide array of independent solutions marketed to hospitals and individual clinicians to address each of these areas. Smartphones are the most popular platform for communication solutions; trade journals, literature, and social media--all report increased use of Smartphones by nurses and physicians. Commercial solutions clearly reflect this trend. Many of the communication solutions described below are marketed as enterprise-wide applications, but a few are targeted specifically for ER use. Table III summarizes the health communication technologies included in the Q-concourse.
### TABLE III. HEALTH COMMUNICATION TECHNOLOGY SUMMARY

<table>
<thead>
<tr>
<th>Product</th>
<th>Context</th>
<th>Distinguishing Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nervecentre</td>
<td>Internal</td>
<td>Task assignment, ranking, and completion monitoring</td>
</tr>
<tr>
<td>PerfectServe</td>
<td>Internal</td>
<td>Message routing, team communication</td>
</tr>
<tr>
<td>Avaya Flare</td>
<td>Internal</td>
<td>Video collaboration</td>
</tr>
<tr>
<td>CodeHeart</td>
<td>External</td>
<td>Live video and camera feed from EMS to ED</td>
</tr>
<tr>
<td>AirStrip</td>
<td>External</td>
<td>Mobile transmission of ECG, touch screen capabilities, access to historic data</td>
</tr>
<tr>
<td>Surgichart</td>
<td>External</td>
<td>Facilitates chart sharing among physicians, automatic health data deidentification</td>
</tr>
<tr>
<td>Doximity</td>
<td>External</td>
<td>Social network with physician contact information</td>
</tr>
<tr>
<td>Sermo</td>
<td>External</td>
<td>Supports secure lab, imaging, and photo sharing</td>
</tr>
<tr>
<td>Mobile MD</td>
<td>Patient Hx</td>
<td>Facilitates patient record exchange across vendors</td>
</tr>
<tr>
<td>MedXCom</td>
<td>Patient Hx</td>
<td>Smartphone app that maintains a personal health record that can be shared or uploaded</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with patient consent</td>
</tr>
<tr>
<td>VueMe</td>
<td>Patient Hx</td>
<td>Allows patients to store and share digital copies of imaging results</td>
</tr>
<tr>
<td>Health Information Exchange</td>
<td>Patient Hx</td>
<td>Comprehensive patient medical record</td>
</tr>
</tbody>
</table>

b. **In Vitro Diagnostics**

In vitro diagnostics (IVD) is a rapidly expanding field. Improved methods for biomarker discovery in combination with improved biomedical engineering techniques have fostered the development of many new diagnostics for a wide range of disease states. On average, lab-based methods provide more sensitive and specific results, but take more time to complete. In contrast, point-of-care methods usually provide results in under an hour, but are often less accurate. In many cases, a lab-based test provides data that support definitive diagnosis in several hours while a point-of-care test provides sufficient data for a physician to estimate relative risk in a few minutes. The time-sensitivity of the medical condition in
question and a physician’s confidence in a given diagnostic will be important influences on technology preference. Table IV provides a summary of the IVD technologies that aligned with challenging clinical conditions identified in the focus groups.

**TABLE IV. SUMMARY OF IVD TECHNOLOGIES**

<table>
<thead>
<tr>
<th>Product</th>
<th>Context</th>
<th>Condition</th>
<th>Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>VYOO</td>
<td>Lab</td>
<td>Sepsis</td>
<td>Identifies pathogen and resistance profile</td>
</tr>
<tr>
<td>Magicplex</td>
<td>Lab</td>
<td>Sepsis</td>
<td>Identifies pathogen and resistance profile</td>
</tr>
<tr>
<td>IschemiaCare</td>
<td>Lab</td>
<td>Stroke</td>
<td>Measures gene expression profiles to identify a stroke’s point of origin</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(heart vs. large vessel)</td>
</tr>
<tr>
<td>Randox</td>
<td>Lab</td>
<td>Stroke</td>
<td>One assay confirms stroke, second assay predicts risk of future strokes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>or cardiovascular mortality</td>
</tr>
<tr>
<td>BRAHAMS PCT</td>
<td>POC</td>
<td>Sepsis</td>
<td>Measures procalcitonin to stratify sepsis risk</td>
</tr>
<tr>
<td>Troponin I Ultra</td>
<td>POC</td>
<td>Chest pain</td>
<td>Measures four biomarkers that help complete differential diagnosis of chest pain patients in 20 minutes</td>
</tr>
<tr>
<td>i-STAT</td>
<td>POC</td>
<td>Chest pain</td>
<td>Measures acute coronary syndrome and congestive heart failure biomarkers</td>
</tr>
<tr>
<td>Alere Triage</td>
<td>POC</td>
<td>Chest pain</td>
<td>Measures cardiac and pulmonary embolism biomarkers in 15 minutes</td>
</tr>
<tr>
<td>System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hCG assay</td>
<td>POC</td>
<td>OB</td>
<td>Rules out ectopic pregnancy</td>
</tr>
<tr>
<td>Pronota NV</td>
<td>POC</td>
<td>OB</td>
<td>Stratifies risk of preeclampsia</td>
</tr>
<tr>
<td>Piccolo Xpress</td>
<td>POC</td>
<td>General</td>
<td>Comprehensive metabolic panel in 20 minutes</td>
</tr>
<tr>
<td>Lactate Scout</td>
<td>POC</td>
<td>General</td>
<td>Measures lactate on a sensor strip (similar to blood glucose monitor) in 10 seconds</td>
</tr>
<tr>
<td>HemoControl</td>
<td>POC</td>
<td>General</td>
<td>Measures H&amp;H from a finger stick in 25 seconds</td>
</tr>
</tbody>
</table>

**c. Non-Invasive Monitoring**

Advances in remote sensing and wireless networking have recently translated into several medical technologies that support patient monitoring and diagnosis. In some instances, these technologies provide new ways to monitor a patient (such as receiving a reading
wirelessly rather than through patient contact) and in some instances provide an opportunity to replace an IVD (in the case of the Hemoglobin and Hemaocrit sensors). Table V summarizes the non-invasive monitoring technologies.

<table>
<thead>
<tr>
<th>Product</th>
<th>Context</th>
<th>Target</th>
<th>Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile Careguide 3100</td>
<td>Monitoring</td>
<td>Hematocrit</td>
<td>Sensor is affixed to patient’s calf, shoulder, or thigh and provides readings once per minute</td>
</tr>
<tr>
<td>HEMOGLOBIN</td>
<td>Monitoring</td>
<td>Hemoglobin</td>
<td>Sensor provides continuous or intermittent monitoring of blood hemoglobin levels</td>
</tr>
<tr>
<td>Visi Mobile</td>
<td>Monitoring</td>
<td>ECG + vitals</td>
<td>Wirelessly transmits 5-lead ECG, blood pressure, respiration rate, ( \text{SpO}_2 ), and skin temperature</td>
</tr>
<tr>
<td>Mini-MEDIC</td>
<td>Monitoring</td>
<td>Vitals</td>
<td>Wirelessly transmits ( \text{SpO}_2 ), pulse, skin temperature, and a criticality metric</td>
</tr>
<tr>
<td>E-Bra</td>
<td>Diagnosis/</td>
<td>ECG + vitals</td>
<td>Wirelessly transmits ECG, EEG, body temperature, heart rate and blood pressure</td>
</tr>
<tr>
<td>LifeSync</td>
<td>Diagnosis</td>
<td>ECG</td>
<td>Wireless 12-lead ECG with disposable electrodes that stay with the patient</td>
</tr>
<tr>
<td>InfraScanner</td>
<td>Screening</td>
<td>Trauma</td>
<td>Detects possible brain hematomas</td>
</tr>
<tr>
<td>DynaDx</td>
<td>Diagnosis</td>
<td>Stroke</td>
<td>Measures blood pressure and blood flow velocity to detect disruptions in cerebral autoregulation</td>
</tr>
</tbody>
</table>

d. **New Treatment Options**

The final market analysis explores new treatment options relevant to EDs. Pharmaceuticals fall beyond the scope of this study, which disqualifies the majority of innovative treatments. There are several innovations in drug delivery, blood purification, and
therapeutic hypothermia, however, which did meet inclusion criteria. Table VI summarizes new treatment technologies.

### TABLE VI. SUMMARY OF NEW TREATMENT TECHNOLOGIES

<table>
<thead>
<tr>
<th>Product</th>
<th>Context</th>
<th>Condition</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cytosorb</td>
<td>Blood purification</td>
<td>Sepsis</td>
<td>Selectively filters cytokines when they are elevated due to injury or infection</td>
</tr>
<tr>
<td>Toramyxin</td>
<td>Blood purification</td>
<td>Sepsis</td>
<td>Therapeutic hemoperfusion device removes endotoxin from the bloodstream</td>
</tr>
<tr>
<td>PLEASE Professional</td>
<td>Drug Delivery</td>
<td>N/A</td>
<td>Uses lasers to condition skin for drug delivery</td>
</tr>
<tr>
<td>“Solid-in-oil” nanodispersion</td>
<td>Drug Delivery</td>
<td>N/A</td>
<td>Demonstrated transdermal delivery of insulin using a cream</td>
</tr>
<tr>
<td>Prelude SkinPrep</td>
<td>Drug Delivery</td>
<td>N/A</td>
<td>Uses ultrasound to facilitate drug delivery</td>
</tr>
<tr>
<td>DosePro</td>
<td>Drug Delivery</td>
<td>N/A</td>
<td>Needleless subcutaneous injection system</td>
</tr>
<tr>
<td>BioJector 2000</td>
<td>Drug Delivery</td>
<td>N/A</td>
<td>Needleless subcutaneous and intramuscular injection system</td>
</tr>
<tr>
<td>MIT Jet Injector</td>
<td>Drug Delivery</td>
<td>N/A</td>
<td>Needleless injection system for liquid and powder formulations to any depth</td>
</tr>
<tr>
<td>OnQ</td>
<td>Drug Delivery</td>
<td>N/A</td>
<td>Uses ultrasonic vibrations to improve aerosolization of inhalational drugs</td>
</tr>
<tr>
<td>OptiNose</td>
<td>Drug Delivery</td>
<td>N/A</td>
<td>Breath-powered device delivers power or liquid formulations to the nasal cavity</td>
</tr>
<tr>
<td>Esophageal Cooling Device</td>
<td>Hypothermia</td>
<td>Cardiac arrest</td>
<td>A closed system circulates chilled saline in the esophagus to induce mild hypothermia</td>
</tr>
</tbody>
</table>
e. **Imaging**

There are several imaging modalities routinely used to diagnose conditions and guide procedures. Imaging equipment is generally expensive and usually a centralized resource, either within the department (e.g., ultrasound) or within the institution (e.g., X-ray, MRI, CT, and PET scanners). As a result, patients often experience delays in treatment because these resources are in high demand; however, many more affordable and portable x-ray, ultrasound, and CT scan products are emerging. Table VII summarizes the imaging innovations identified in the market analysis.

<table>
<thead>
<tr>
<th>Product</th>
<th>Context</th>
<th>Modality</th>
<th>Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACUSON</td>
<td>Handheld Ultrasound</td>
<td>Pocket-sized, black and white display</td>
<td></td>
</tr>
<tr>
<td>Vscan</td>
<td>Handheld Ultrasound</td>
<td>Pocket-sized black and white display with color-coded blood flow imaging.</td>
<td></td>
</tr>
<tr>
<td>Mobius</td>
<td>Handheld Ultrasound</td>
<td>A single-crystal ultrasound probe interfaces with Smartphones through the micro-USB port.</td>
<td></td>
</tr>
<tr>
<td>Nomad Pro</td>
<td>Handheld X-ray</td>
<td>Intended only for extremities (i.e., hand, wrist, arm, foot, ankle)</td>
<td></td>
</tr>
<tr>
<td>CMDR-2S</td>
<td>Portable X-ray</td>
<td>Ruggedized digital x-ray unit with one minute set up and less than 10 second image capture</td>
<td></td>
</tr>
<tr>
<td>Mobilette Mira</td>
<td>Portable X-ray</td>
<td>High resolution digital x-ray, flexible positioning, motorized movement, wireless detectors, and wireless communication</td>
<td></td>
</tr>
<tr>
<td>Optima</td>
<td>Portable X-ray</td>
<td>High resolution digital x-ray, flexible positioning, wireless detectors, and wireless communication</td>
<td></td>
</tr>
<tr>
<td>CereTOM</td>
<td>Portable CT</td>
<td>Eight slice head and neck CT does not require patient transfer</td>
<td></td>
</tr>
<tr>
<td>BodyTOM</td>
<td>Portable CT</td>
<td>32-slice full body imaging, safe for use in patient room, powered by standard outlet</td>
<td></td>
</tr>
</tbody>
</table>
f. **Unaddressed Themes**

Several themes uncovered during the focus groups cannot be addressed directly by medical devices. ED misuse, obesity, dialysis, and treatments for congestive heart failure are not included in any of the representative statements. ED misuse is a challenging issue for many reasons. First, many important concepts surrounding ED misuse remain undefined. Terms such as “inappropriate use,” “non-urgent care,” and “overcrowding” are often used interchangeably across the literature to describe very different phenomena. Second, the majority of literature describing ER misuse comes from social, economic, and policy perspectives and do not clearly define the specific conditions or patient presentations that are categorized as non-urgent or inappropriate during analyses. Failure to define specific conditions that are considered particularly challenging to handle prevents performing a market analysis to match medical devices with these conditions. Given these restrictions, some of the technologies presented as potential solutions to other challenges, such as patient remote monitoring and or simple point-of-care diagnostics, may have applicability to ED misuse.

Despite well-documented need, it does not appear that many medical devices have emerged to address treating bariatric patients. The specific issues highlighted in the focus groups were starting central lines and moving patients. Study of nursing blogs and bulletin boards revealed a wide array of other problems, including injuries sustained during CPR administration and cleaning patients, as well as ethical challenges in caring for obese patients (e.g., if I know that performing chest compressions is going to injure my wrist, what are the ethics of asking another nurse to step in?). Following discussions with a paramedic and medical
device representative, it appears there is some pressure for companies to expand product lines to include the longer needles and catheters necessary to treat large patients, but none seem to be pushing to lead in the market. There are some publications and blogs that provide suggestions for off-label uses of current devices, such as using a spinal catheter to start a central line. As it stands, there is no evidence that any existing company is preparing to address this need with a new product line or that any academic centers are embarking on studies to engineer specialized devices for obese patients, so no representative statements could be developed.

Based on market research and literature reviews, dialysis technology appears stagnant. There are a few limited efforts to introduce home-based dialysis, but these systems do not work any faster than current technologies and do not address the concerns with treatment duration raised during the focus groups. The investigator’s attempts to identify faster or more efficient dialysis systems were unsuccessful. There is some progress in wearable dialysis systems, but these devices are surgically implanted outside the ER. Thus, while broader use of these permanent systems might decrease the number of distressed patients that present at the ER, wearable dialysis systems would not be a technology the ER could implement.

Similarly, there are several innovative medical devices designed to treat or manage congestive heart failure; however, these are either surgically implanted (such as an implantable cardioverter defibrillator) or utilize mobile health to aid with patient monitoring. Again, both strategies may result in fewer distressed patients presenting at the ED or
presenting with lower acuity if there is an emergency, but these are not innovations that would be implemented by the ED.

B. **Prioritizing Potential Radical Innovation**

1. **Pilot Q-sort- Instrument Validation Outcomes**

   The pilot study was conducted on September 11 and 13, 2012. Six clinicians (4 nurses and 2 physicians) agreed to complete Q-sorts and provide feedback on the experience. Each participant was provided with instructions, an answer grid, and a stack of cards with each individual statement in the Q-set printed on them. The researcher remained nearby to answer any questions as the participants completed the Q-sorts. All volunteers were able to complete the Q-sorts successfully without the need for clarifying guidance. The questions participants asked were related to whether these technologies actually existed, rather than procedural issues (e.g., “Is this for real? A robot that fetches equipment?”) None of the participants identified statements that they felt were irrelevant, unclear, or needed revision.

   Participants who completed the Q-sort in a single sitting were able to finalize results and respond to the follow-up questions in approximately 15 minutes. Participants who were interrupted during a Q-sort completed the survey in 1-4 hours. The participants who left the survey and came back to it felt that they did not have trouble picking up where they left off.
a. **Participant Recommendations**

Participants did make a few recommendations, which were incorporated into the final design. First, they requested a computer-based administration. The ER is very crowded and it is difficult to find sufficient surface area to spread out all of the cards while completing the sort. One participant dropped a few cards on the floor when, inadvertently, the cards slipped through a crack between two desks. Participants also felt that since the survey was about innovation and technology, it was incongruent to provide a paper-based instrument. Second, some of the participants felt that they would prefer a less “neutral” grid so that they could express stronger opinions (meaning, there were more boxes to the far left and right of the grid). Third, the pediatric section nurses felt very strongly that there would be significant differences between their responses and those of nurses assigned to the main ED. They suggested providing a means for pediatric nurses to identify themselves to allow data analysis that is more meaningful. Based on these inputs, the final study included a computer-based administration option using Q-Assessor.com, a modified answer grid (expanded from 3-5-8-11-8-5-3 to 4-6-7-9-7-6-4), and a demographic question asking whether the participant is primarily assigned to the pediatric section.

b. **Quantitative Assessment**

In order to establish that the Q-set was capable of revealing different opinion groups, a preliminary quantitative assessment was performed. Q-sorts from the pilot study were entered into PQMethod v 2.32 (136) and subjected to centroid factor analysis following procedures outlined in Brown (123). The extracted factors were subjected to Varimax
rotation and assessed to determine the demographics of the sorts that defined each factor. Of the six sorts, five aligned significantly with one of three factors. The two participants who aligned on the same factor shared similar characteristics (both were pediatric specialty nurses with similar experience levels). The participant who did not significantly align with any factor was a nurse who had not been involved with patient care for several years. Based on the preliminary quantitative outcomes and initial user feedback, the instrument was capable of revealing differences in opinion.

2. Implementation of the Radical Innovation Instrument

   a. Participant Profiles

   The investigator recruited research subjects in person and via email between November 3 and November 16, 2012; in person recruitment occurred during all three shifts (7am-3pm, 3pm-11pm, and 11pm-7am) to encourage participation and representation across all possible schedules. All sorts were completed using the web-based administration; no participants elected to complete the study using the paper-based instrument. In total, 12 physicians, 25 nurses, and 3 participants of undisclosed licensure completed 40 Q sorts. The average reported experience level was 10.3 years of ER experience; the range of reported experience was 6 months to 37 years. There were 36 participants who self-identified as possessing one of four innovation styles; the majority (31/36) considered themselves either Early Adopters or Early Majority, as defined by Rogers (83). Figure 4 illustrates the distribution of reported experience levels and Figure 5 illustrates the distribution of reported innovation styles.
Figure 4. Distribution of Study Participants by Years of Experience.

Figure 5. Distribution of Participants by Self-reported Innovation Style.
b. **Quantitative Analysis**

i. **Defining the Factor Solution**

Throughout the data analysis in this study, it was important to bear in mind the ultimate intended application and audience for the outcomes. The goal is to provide a reasonable mechanism by which health care administrators can incorporate clinician opinions into technology acquisition strategy, which is ultimately a business decision and driven heavily by financial analysis. As such, the statistical justification for the factor solution should be rigorous to encourage integration with other mathematically-oriented solutions. The solution, however, should also demonstrate a high level of inclusiveness such that the viewpoints (and potential strategic directions) presented are representative of the department as a whole. The solution should favor senior members of the staff, as this is culturally expected and aligns with the change management practice in which a respected leader serves as the “champion” for any innovation. The investigator used these guiding principles in the factor extraction process.

ii. **Determining the Number of Factors for Rotation**

1. **Seven Factor Centroid Solution**

Factor analysis provides the first opportunity to explore the data collected during field work. In this spirit, the search for a factor solution began with Brown’s recommendation (137) to first extract seven centroids from the data using PQMethod and rotate using the Varimax protocol. Significant factor loading at the 0.01 level was calculated to be 0.40 (i.e., $2.58 \times \left[1 \div \sqrt{43}\right] = 0.3934$). The rotated factor matrix explained
49% of the cumulative variance and contained significantly weighted sorts on five of the seven factors. Each of these factors had eigenvalues (EVs) above 1.00 (the Kaiser-Guttman criterion (138, 139)). Inspection of the unrotated matrix (Table VIII) revealed Factor 6 contained a single, weakly significant, sort. Factor 5 contained three significant sorts, all of which were confounded with Factor 1 and one of which (Sort ID 5181) was very weakly significant. Based on Humphrey’s rule (137), Factor 5 was also considered questionable. While there are more than two sorts defining the factor, the cross product of the two highest loadings was 0.23 (i.e., 0.4924 x 0.4589 = 0.2259), which did not exceed twice the standard error (SE = 0.32).

2. Four Factor Centroid Solution

The seven factor outcome supported the exploration of a four factor solution and the procedure was repeated as above, extracting four centroids instead of seven. The rotated four factor solution explained 42% of the study variance, but contained significant loadings on only three factors. Varimax rotation revealed 30 significantly loaded sorts and a preliminary review of the matrix revealed several confounded loadings that might be resolved by hand rotation. Based on the unrotated matrix (Table IX), all three factors were defined by at least six significantly loaded sorts and all met Humphrey’s rule.
## TABLE VIII. UNROTATED FACTOR MATRIX FOR SEVEN CENTROIDS

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Shaded cells indicate significant loading on a factor.
3. **Three Factor Centroid Solution**

The statistical results presented in the previous section supported a three factor solution. Before proceeding with an interpretation, additional statistical tests were performed to establish whether the three factor centroid solution provided the best basis for this study. Watts and Stenner (140) highlight several additional decision making criteria for factor extraction that might be applied to a Q study at a researcher’s discretion; for example, the scree test provides a more rigorous application of EVs to the decision process than the Kaiser-Guttman criterion to support a given factor solution. In the scree test, one plots the EVs derived from a principal component analysis (PCA) against the number of factors and looks for a change in slope. This slope change represents the point where extracting additional factors demonstrates a diminishing return, even when the factors maintain an EV above 1.00. Figure 6 illustrates the scree plot for this study. Though EVs remain above 1.00 until the eleventh component, the majority of the variance is accounted for in the first four iterations. Thus, based on the scree plot, it is reasonable to extract three or four factors from this data set.
### TABLE IX. UNROTATED FACTOR MATRIX FOR FOUR CENTROIDS

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<table>
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<table>
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<tr>
<td>24</td>
<td>10</td>
<td>7</td>
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</tr>
</tbody>
</table>

Shaded cells indicate significant loading on a factor.
4. Four Component Solution

Though PCA maintains a controversial method for interpreting data in Q studies, there are certain features of the technique that support the exploration of PCA solutions for this particular application. Keeping in mind that the ultimate goal of this study is to provide hospital administrators with a reasonable way to integrate clinician opinions into business decisions, the fact that PCA provides a mathematically “best” solution might be of benefit. Factor analysis already holds a tenuous position in the statistical community because the flexibility that permits the unfettered exploration that
psychometricians treasure leaves the outcomes open to critics’ concerns of unbridled subjectivity. Varimax rotation revealed 30 significantly loaded sorts and a preliminary review of the matrix revealed several confounded loadings that might be resolved by hand rotation. Based on the unrotated matrix (Table X), all three factors were defined by at least six significantly loaded sorts and all met Humphrey’s rule.

Q-methodology was originally developed for and is primarily utilized by psychologists who seek to gain understanding of a subjective experience and use that understanding to develop and inform theory. In such a pursuit, there is a strong rationale for favoring centroid factor analysis, which permits some level of theoretical testing by way of rotating factors to meet scenarios of interest to the researcher; however, this study is designed from a public health perspective with the goal of informing policy decisions. As such, some of the philosophical considerations necessarily diverge from those posed by Stephenson (141), Brown (137), among others and, therefore, may support the use of PCA in favor of the centroid method. The reality is that policy makers in the United States’ health care system are (or at least vociferously claim to be) primarily driven by structured mathematical solutions. This is especially true when considering acquisition decisions and the diffusion of health care technology. This reality warrants the exploration of structured mathematical solutions to this data set, as provided by PCA.
### TABLE X. UNROTATED MATRIX FOR FOUR COMPONENTS

<table>
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<th>Sort ID</th>
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<th>3</th>
<th>4</th>
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<td>-0.1006</td>
<td>0.2984</td>
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</table>

% Expl. Var. 17 11 12 13

Shaded cells indicate significant loading on a factor.
Based on the scree test shown above, a four component solution was extracted from the data set using PQMethod. A total of 33 sorts aligned significantly to the four component solution, which explained 53% of the study variance. Inspection of the unrotated matrix (Table XV) confirmed that all four factors contained at least 6 significantly loaded sorts; however, the cross-products of the two highest loadings on the fourth factor were calculated as 0.26 and, therefore, did not meet Humphrey’s rule. As stated previously, there is no requirement to discount a factor if it does not meet a given decision criteria, and given the relative strength of the solution overall, it remains a possible model for interpretation.

5. Three Component Solution

Finally, a three component solution was extracted using PQMethod as described previously. A total of 29 Q-sorts significantly loaded across the three components, which explained 46% of the total study variance. The relatively significant drop in explained variance (7% total, representing a 13% decline of the overall variance) makes this model less attractive than the four component model, though it is mathematically the most rigorously defined.

The three component centroid solution met the a priori criteria that the model remains inclusive, as 30 of the 40 sorts aligned significantly, and, potentially, the additional confounded sorts could be resolved through hand rotation. The Q-methodology community philosophically favors a centroid solution, but this solution provided
the lowest relative explanation of study variation and was at the highest risk of rejection by the intended audience (hospital administrators). The four component solution explained the greatest variance (53%) and also included the largest number of statistically significant sorts (33), but the fourth factor was weakly supported mathematically. The three component solution was mathematically the most rigorously defined and demonstrated the second highest explanation of variance (46%), but was also the least inclusive (29 sorts significantly aligned).

To support a final decision on which solution to interpret, the investigator reviewed each model in terms of the third a priori condition described at the beginning of this section, that of favoring the opinions of clinicians with seniority. For the purpose of this study, years of experience (collected in the supplemental survey) served as a proxy for seniority. First, a purely theoretical rotation was performed on a data set with three extracted centroids. The clinicians of interest were highlighted using the PQROT utility in PQMethod and manually manipulated in a step-wise fashion around pairs of axes until a balance of significantly aligned senior clinicians and overall participants was achieved. Table XI summarizes the characteristics of each model. The four component PCA model best aligned with the a priori criteria proposed for a factor solution. This model explained the most variance, incorporated the highest possible number of significant sorts, included the opinions of the most senior clinicians, and explained the most variance of any of the tested models. This model, therefore, was selected for final interpretation.
TABLE XI. FACTOR SOLUTION COMPARISONS

<table>
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<tr>
<th>Model</th>
<th>Significant Sorts</th>
<th>Senior Clinicians</th>
<th>Senior MDs</th>
<th>Variance Explained</th>
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<tr>
<td>4 Component PCA</td>
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<td>5</td>
<td>53</td>
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<td>3 Centroid Theoretical Rotation</td>
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<td>10</td>
<td>4</td>
<td>42</td>
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<tr>
<td>3 Centroid Varimax Rotation</td>
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<td>4</td>
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<td>3 Component PCA</td>
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<td>3</td>
<td>46</td>
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</table>

The resulting factor array, displayed in Table XII, serves as the basis for the interpretations to follow.

c. Qualitative Analysis

Upon selecting the four component PCA model for interpretation, a full analysis of the participants significantly aligning to a factor was conducted to determine if any patterns in background were recognizable among the factors. Based on participants’ demographic responses, each of the factors was composed of both physicians and nurses, contained a wide range of experience levels, and displayed a mix of innovation styles. Factor 1 is composed of 3 MDs and 10 RNs with an average of 11 years’ experience. Factor 2 is composed of 3 MDs and 1 RN with an average of 4 years’ experience. Factor 3 is composed of 1 MD, 6 RNs, 1 LPN, and 1 undisclosed professional with an average of 8.5 years’ experience. Factor 4 consists of 4 MDs and 6 RNs with an average of 13 years’ experience. Likewise, innovation styles are spread across each factor. This initial review, showing clinicians and experience levels dispersed across the factors, suggests that some underlying subjective
## TABLE XII. FACTOR ARRAY

<table>
<thead>
<tr>
<th>Category</th>
<th>Statement</th>
<th>Speed</th>
<th>Holism</th>
<th>Acuity</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Communication</td>
<td>A mobile application that allows clinicians to assign a task (e.g., a consult or blood draw), track acknowledgement, and receive a call or text when it is complete.</td>
<td>1</td>
<td>3</td>
<td>-1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>A mobile application that supports video conferences between providers (e.g., ED to EMS or ED to Neuro).</td>
<td>-1</td>
<td>1</td>
<td>-2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>A paper-based hand-off checklist completed by physicians and nurses together in a designated quiet place.</td>
<td>0</td>
<td>-2</td>
<td>-2</td>
<td>-3</td>
</tr>
<tr>
<td>4</td>
<td>A mobile application that records video of an EMS encounter, including vital signs and ECG, which is sent to the ED during transport.</td>
<td>-1</td>
<td>-2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>A mobile application that receives real-time ECGs from EMS and integrates automatically with hospital records.</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>A mobile application that facilitates sharing charts with clinicians outside the hospital (such as a PCP).</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>A networking website that provides verified contact information for physicians including: phone, fax, back office numbers and a secure text or messaging system.</td>
<td>1</td>
<td>0</td>
<td>-2</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>A patient-controlled mobile application that maintains a single health record of previous care that can be automatically uploaded, with permission, into the hospital EHR.</td>
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<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>A government-controlled database that allows clinicians to search for full medical history of any patient and also allows insurers, researchers, and others access to data.</td>
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<td>2</td>
<td>-3</td>
<td>-1</td>
</tr>
<tr>
<td>Category</td>
<td>#</td>
<td>Statement</td>
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<td></td>
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<tr>
<td>----------</td>
<td>---</td>
<td>-----------</td>
<td>--------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In vitro Diagnostics</td>
<td>10</td>
<td>POC test that quantifies a patient’s sepsis risk with results in 20 minutes.</td>
<td>2 -3 1 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Lab-based test that provides a definitive sepsis dx and resistance profile with results in 7 hours.</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>POC test that provides ectopic pregnancy risk with results in 20 minutes.</td>
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<tr>
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<tr>
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<td>POC metabolic panel (including K+ and CRE) with results in 20 minutes.</td>
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<tr>
<td></td>
<td>15</td>
<td>POC electrolyte panel that provides results in 20 minutes.</td>
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<tr>
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<td>16</td>
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</tr>
<tr>
<td></td>
<td>17</td>
<td>POC cardiac marker test that provides 1 marker with results in 10 minutes (BNP or cTnI).</td>
<td>1 -2 1 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>POC lactate monitor (similar to a glucose monitor) that provides results in 10 seconds.</td>
<td>2 -1 2 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>POC test for H&amp;H levels that provides results in 25 seconds.</td>
<td>2 0 1 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>POC test that provides results in 20 minutes for stroke risk and odds that tPA will be effective.</td>
<td>3 -1 2 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>Lab-based test that provides results in 1 hour to confirm stroke and whether tPA will be effective.</td>
<td>2 -1 3 -1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>We don’t need POC tests; the lab techs just need to be more efficient and better organized.</td>
<td>-3 0 -3 -3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Statement</td>
<td>Speed</td>
<td>Holism</td>
<td>Acuity</td>
<td>Info</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>-------</td>
<td>--------</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>Non-invasive Monitoring</td>
<td>A non-invasive sensor that differentiates between stroke, TBI, dementia, and other neurological disorders during an examination.</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>A non-invasive sensor that continuously measures H&amp;H.</td>
<td>-1</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>A fully wireless 12-lead ECG with disposable probes that can be worn under clothing.</td>
<td>-3</td>
<td>1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>A vest that transmits wirelessly and collects vital signs and 5-lead ECG without affixed electrodes.</td>
<td>-2</td>
<td>-1</td>
<td>-2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>A vital signs sensor worn on the arm, designed to alert the triage nurse if a patient in the waiting room deteriorates.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>A non-invasive, handheld screening tool for cranial bleeding that helps prioritize or rule out the need for a CT.</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Robots that locate and retrieve shared equipment, such as IV pumps or respirators, and deliver it to the proper location.</td>
<td>-2</td>
<td>-2</td>
<td>-3</td>
<td>-1</td>
</tr>
<tr>
<td>Tx Options</td>
<td>An extracorporeal blood purification system that removes cytokines from the bloodstream in order to prevent organ failure in septic, trauma, and other patients.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td></td>
<td>An extracorporeal blood purification system that removes endotoxin from the bloodstream of septic patients.</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>-2</td>
</tr>
<tr>
<td></td>
<td>An extracorporeal blood purification system that prevents sepsis in at-risk patients, but has no side effects if the patient is not septic.</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>A cream that delivers drugs through the skin, just by rubbing it on.</td>
<td>-3</td>
<td>1</td>
<td>-2</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>A handheld device to condition the skin to allow drugs to be delivered through a patch.</td>
<td>-2</td>
<td>-1</td>
<td>-2</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>A needleless injection system that delivers liquid or powder drug formulations, in any volume, to any specified depth, without hurting the patient.</td>
<td>-2</td>
<td>2</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>Category</td>
<td>#</td>
<td>Statement</td>
<td>Factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>---</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging</td>
<td>36</td>
<td>A self-contained device that induces therapeutic hypothermia following resuscitation from cardiac arrest through the esophagus instead of a central line.</td>
<td>0 1 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging</td>
<td>37</td>
<td>A portable x-ray machine dedicated to the ED that a radiology tech brings to the patient to collect any x-rays ordered.</td>
<td>-1 2 0 -2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging</td>
<td>38</td>
<td>A handheld x-ray machine dedicated to the ED that clinicians can use to obtain quick digital x-rays of extremities, such as arms or legs.</td>
<td>-1 0 1 -2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging</td>
<td>39</td>
<td>A portable head and neck CT scanner dedicated to the ED that performs scans in a standard room while the patient remains in a regular gurney.</td>
<td>0 3 3 -3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging</td>
<td>40</td>
<td>A portable full body CT scanner that moves to patients to perform scans in a standard room, but requires patient transfer to another bed.</td>
<td>-2 3 2 -2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging</td>
<td>41</td>
<td>Pocket ultrasounds carried by all ED physicians, which support black and white and color-coded blood flow imaging for initial screening.</td>
<td>-2 2 0 -2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging</td>
<td>42</td>
<td>Ultrasound probes carried by physicians, which plug into Smartphones via mini- or micro-USB for initial screening.</td>
<td>-1 2 3 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imaging</td>
<td>43</td>
<td>The ED doesn’t need new imaging technologies; the people in radiology just need to be more efficient and better organized.</td>
<td>-3 -3 -3 -3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lightly shaded cells with bold text highlight items considered “likely to improve care” by the factor. Dark shading with italic text highlights items considered “unlikely to improve care” by the factor.
perception beyond professional background or experience level influences health care innovation preferences.

i. **Factor 1: Speed Oriented Providers**

The most distinctive pattern held by members of Factor 1 is the clear and consistent preference for accessing quantitative information as quickly as possible ("Speed Oriented"). Of the top eleven innovations they ranked as “Most Likely to Improve Care”, nine detected some marker of health status in blood that could be obtained in an hour or less. Of these, eight were point-of-care tests that provide results in less than 20 minutes (and several provide results in seconds). In addition to rapid turnaround, the emphasis on blood levels implies a preference for rapid interpretation. Unlike imaging diagnostics, for example, blood levels typically have an accepted range or cut-off that guides diagnosis and treatment regimens. This reinforces the interpretation of a Speed Oriented perspective. A second important component of improving patient care from a Speed Oriented perspective is access to patient history. Speed Oriented providers are happy to receive this information from the patients themselves (in the form of an electronic record maintained privately) or from a government entity (like a Health Information Exchange). Speed Oriented clinicians do not demonstrate much interest in innovations related to patient experience; for example, several drug delivery devices that are described as less painful were considered among the items “Most Unlikely” to improve care. Likewise, accommodating patient dignity by adopting a wireless ECG that allows patients to remain clothed was not considered important to improving patient care. Overall, the Speed Oriented clinicians are interested in receiving information quickly and in a
form easy to interpret. Their personal definition of “care” appears to be tied primarily to patient physiology rather than patient experience.

ii. **Factor 2: Holism Oriented Providers**

In contrast to the Speed Oriented clinicians, Factor 2 places greater emphasis on the care continuum and the whole patient. The Holism Oriented clinicians expressed interest in a range of technologies including those that would facilitate communication among clinicians, access to patient history, improved access to imaging, and improved patient experience. Like the Speed Oriented clinicians, the Holism Oriented clinicians want access to a structured patient history, regardless of its source; however, the similarity ends there. In addition to patient history, the Holism Oriented clinicians place importance on communication, internal and external. These clinicians placed “a mobile application that allows clinicians to assign a task...” and “a mobile application that facilitates sharing charts with clinicians outside the hospital...” as even more important (+3) than having access to patient history (+2). The extreme emphasis on imaging is unique to this group. Five of the top eleven technologies ranked “most likely to improve care” were related to imaging. The only non-imaging technology of interest is a needleless injection system that allows greater flexibility in drug administration while not hurting the patient. These technology choices could be interpreted two ways, either emphasizing patient experience or emphasizing a more qualitative approach to care. “Imaging” was included as a theme in this study in response to several complaints about the amount of time patients had to wait for imaging to be available; therefore, heavy selection of imaging options exclusive to the ED might be in response to the
desire to minimize that “wasted” time. Also, imaging techniques have been featured more prominently in medical curricula (142) in the last 5-10 years, which may be why this relatively younger group is more attuned to these technologies. The general perception that point-of-care technologies are unlikely to improve care (not one point-of-care solution was considered likely to improve care) may suggest a more fundamental reason for this preference, however. It may be relevant that Factor 2 consists solely of young clinicians. These clinicians might reflect a shift in education and health care culture, favoring patient-centered care over the physiology-driven practice of the Speed Oriented clinicians. It is also possible that these providers perceive negative consequences associated with augmenting their workflow (i.e., being required to spend more time per patient performing point-of-care tests themselves rather than ordering a test and being available to complete other functions).

iii. **Factor 3: Acuity Oriented Providers**

The clinicians in Factor 3 favor adopting a series of innovations that would be most relevant to high acuity patients. Among the “most likely to improve care,” Acuity Oriented clinicians selected a POC cardiac marker panel, a lab-based stroke and tPA efficacy diagnostic, a portable head and neck CT, and Smartphone enabled ultrasound probes. The Acuity Oriented providers also consider the handful of point-of-care devices developed to identify high acuity situations (metabolic panel, lactate, and stroke risk with tPA efficacy) likely to improve care. Unlike the Speed and Holism Oriented groups, the Acuity Oriented providers specify interest in two technologies that facilitate the transmission of data from EMS to the ED (a video record of an entire EMS encounter and real-time ECGs from the field into a patient
record). Interestingly, however, an application that would allow interaction between EMS and the ED (a mobile videoconferencing application) was considered unlikely to improve care (-2 in factor array). Clinicians in this group considered external communication and increased access to patient records least likely to improve care among all of the factors. In addition to the negatively ranked mobile videoconferencing application, a mobile application that facilitates sharing charts outside of the hospital was ranked -1; and a website with physician contact information was ranked -2. The extreme distaste for a government-controlled Health Information Exchange is particularly unique to the Acuity Oriented clinicians in this study. While this group remained neutral on a patient-controlled health record (0), they were clearly opposed to a government-controlled health record (-3). Given that the study introduction explicitly requested that participants envision each innovation working as well as they can imagine, a -3 rank implies that a large segment of clinicians in the ED cannot even imagine a Health Information Exchange working well enough to improve the provision of care.

iv. **Factor 4: Information Oriented Providers**

The fourth factor revealed during this study places a clear value on increasing the amount of information available in the ED. More than any other factor, Information Oriented clinicians selected more communication-oriented functions as “most likely to improve care”. They preferred a mobile app that allows clinicians to assign and track tasks (+3); a mobile application that facilitates sharing charts outside the hospital (+3); a mobile application that supports videoconferencing (+2); a mobile application that records video of an EMS encounter (+2); and a mobile application that receives real-time ECGs from EMS and
integrates with hospital records (+2). In fact, this group, among all factors, ranked “a mobile application that supports video conferences between providers” as more likely to improve the quality of care. Taken together, these technologies would provide the ability to obtain and share information across the continuum of care that this group of clinicians feels will improve the care they provide. The Information Oriented clinicians strongly preferred a patient-controlled record to a government-controlled record (+3 and -1, respectively). In addition to information-generating technologies, members of this factor favored technologies that would be useful for high acuity patients, similar to those selected by the Acuity Oriented clinicians (Ultrasound probe for Smartphone was ranked +3, POC test for sepsis risk, POC metabolic panel including K+ and CRE, and POC 4 marker cardiac panel—all were ranked +2).

d. Departmental Opinion Trends

Despite differences in opinion regarding the overall technology portfolio that would most improve care, multiple factors suggested several similar individual technologies as likely to improve care. Such consensus provides hospital leadership some insight into the array of technologies that would be generally well received, or tepidly regarded, or highly controversial. Table XIII serves to help visualize where trends in consensus and controversy exist; for example, all of the non-invasive monitoring technologies received either an ambivalent or a negative rank. The following sections will summarize the major trends revealed by the Q-sorts that could inform technology selection for the ED.
i. **Consensus Technologies**

For the purpose of this analysis, any technology that is ranked by two or more factors at either pole (i.e., ±2 or ±3) and has an ambivalent rank among the other factors is considered a consensus technology. Positively ranked consensus technologies are attractive candidates for innovation because there is a sizable population of clinicians who believe implementation will improve care and may serve as champions during the early stages of adoption. This strategy may be particularly effective in an organization populated heavily by early adopters and early majority innovators who explicitly state that they value the opinions and actions of respected colleagues when deciding to use a new technology. Table X contains the positively ranked consensus technologies that should be considered for testing and implementation in performance site ED.

<table>
<thead>
<tr>
<th>Category</th>
<th>Item #</th>
<th>Product Inspiration</th>
<th>Vendor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Communication</td>
<td>1</td>
<td>PerfectServe</td>
<td>PerfectServe, Inc.</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>AirStrip CARDIOLOGY</td>
<td>AirStrip Technologies</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>SurgiChart</td>
<td>SurgiChart, LLC</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>MedXCom</td>
<td>Giffen Solutions, Inc.</td>
</tr>
<tr>
<td>In vitro Diagnostics</td>
<td>14</td>
<td>Piccolo Xpress</td>
<td>Abaxis</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Lactate Scout +</td>
<td>EKF Diagnostics</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Cerebral Array I and II</td>
<td>Randox Laboratories Ltd.</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>IschemiaCare</td>
<td>Ischemia Care, LLC</td>
</tr>
<tr>
<td>Imaging</td>
<td>42</td>
<td>MobiUS SP1</td>
<td>MobiSante, Inc.</td>
</tr>
</tbody>
</table>
Negatively ranked consensus technologies should either be avoided, or hospital leadership should anticipate higher than average resistance to adoption if these innovations are introduced in this ED. It is important to note that a negative rank does not preclude the ultimate successful implementation of a technology; it simply provides an indication that a more rigorous change management strategy might be required to achieve that success. As an example, Item #3 (“A paper-based hand-off checklist completed by physicians and nurses together in a designated quiet place”) has demonstrated efficacy in improving patient safety in a variety of health care settings and, therefore, might be worth implementing even without widespread clinician support. Recognizing that clinicians do not consider a checklist as “likely to improve care” as other options, however, can help administrators prepare for resistance. Table XIV contains a list of the negative consensus technologies.

**TABLE XIV: NEGATIVE CONSENSUS TECHNOLOGIES, BASED ON FACTOR ARRAY**

<table>
<thead>
<tr>
<th>Category</th>
<th>Item #</th>
<th>Product Inspiration</th>
<th>Vendor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Communication</td>
<td>3</td>
<td>Literature</td>
<td>N/A</td>
</tr>
<tr>
<td>Non-invasive monitoring</td>
<td>26</td>
<td>“E-Bra” Prototype</td>
<td>University of Arkansas</td>
</tr>
<tr>
<td>Treatment Options</td>
<td>33</td>
<td>Solid-in-oil nanodispersion projects</td>
<td>Kyushu University</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>P.L.E.A.S.E. Professional</td>
<td>Pantec Biosolutions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prelude SkinPrep System</td>
<td>Echo Therapeutics</td>
</tr>
<tr>
<td>Other</td>
<td>29</td>
<td>Automated TUG system</td>
<td>Aethon, Inc.</td>
</tr>
</tbody>
</table>
Sentiments that there was no need for point-of-care tests and no need for new imaging technologies in the ED (Items 22 and 43, respectively) were both rejected across factors. This likely indicates that clinicians in the ED are willing to add point-of-care tasks to their workload if they perceive it is improving the care they can provide, even given the opportunity to push the task burden to another department. As the factor interpretation revealed, however, there are very divergent perceptions of how to improve care.

**ii. Controversial Technologies**

For the purpose of this analysis, technologies ranked as likely to improve care (+2 or +3) by two or more factors and ranked unlikely to improve care (-2 or -3) by at least one factor were considered controversial. Several technologies proved controversial across the health communications, in vitro diagnostics, and imaging categories. The results are summarized in Table XV below.

<table>
<thead>
<tr>
<th>Table XV: Controversial Technologies, Based on Factor Array</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category</strong></td>
</tr>
<tr>
<td>Health Communication</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>In vitro Diagnostics</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Imaging</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
The two in vitro diagnostic technologies (Items 10 and 16) were ranked unlikely to improve care only by the Holism Oriented providers (-3 and -2, respectively). As described above, the Holism Oriented providers universally preferred imaging technologies to in vitro diagnostics; however, it is important to recognize that the Holism orientation appears to be a minority viewpoint among the participants (only four sorts significantly aligned to this factor), held by less experienced clinicians. Given the more favorable opinions toward the POC cardiac marker and sepsis risk diagnostics held by the rest of the participants, it is likely worthwhile to explore these technologies. If implemented, hospital leadership should explicitly communicate the technologies’ ability to improve patient experience, which is likely to resonate more with Holism Oriented providers than focusing on faster turnaround times.

Among the controversial imaging technologies, the Vscan handheld ultrasound (Item 41) was considered likely to improve care only among the Holism Oriented providers. Given that the MobiUS ultrasound probe was a positive consensus item, it is likely that participants did not feel that two ultrasound options in the ED would improve care. Therefore, it appears that the distinguishing features of the MobiUS (such as Smartphone compatibility) were preferable to those of the Vscan (a self-contained unit). The two portable CT scanners (Items 39 and 40) were considered likely to improve care by the Holism and Acuity Oriented providers. The Speed Oriented providers ranked the head and neck CT scanner as more likely to improve care than the full body scanner (0 and -2, respectively). The Information Oriented providers ranked both as unlikely to improve care (-3 and -2). In this situation, it would be prudent for hospital leadership to formally study whether CT access is so challenging
that it might affect patient outcomes. If implemented, hospital leadership should explicitly communicate expected time-savings and how the information gained from CT scans obtained by portable devices can facilitate internal and external collaboration in order to engage Speed and Information Oriented clinicians.

CodeHeart (Item 4) was considered likely to improve care by the Acuity and Information Oriented clinicians (both ranked +2). Speed Oriented clinicians were relatively ambivalent about this technology (ranked -1) and Holism Oriented clinicians felt it was unlikely to improve care (ranked -2). Given the overall profile of the Holism Oriented providers, it is possible that they feel monitoring EMS activity is overly paternalistic. Distrust between EMS and physicians was previously documented and was reflected in some comments during the focus groups performed during this study. As younger providers, they may not have personally witnessed EMS incompetence that would support a desire to see exactly what happened during transport. If implemented, hospital leaders should communicate how CodeHeart could improve the level of care during transport and allow clinicians to essentially perform triage before the patient arrives and thus reduce their time spent in the ED.

Probably the most interesting controversy, especially in the context of national priorities, is related to the patient record. Moving all Americans toward interoperable electronic health records has been an explicit priority of the last two presidential administrations. The Federal government launched a series of efforts to develop and test regional and statewide health information exchanges to further this goal. Hospitals and private
practices have received extensive government subsidies to implement and improve electronic health record systems. Despite an emerging body of evidence supporting the positive influence that electronic health records actually have on care, patient safety, and health outcomes, many physicians still do not recognize these benefits. Based on the feedback across factors, it seems likely that this uncertainty is reflected in the technology preferences expressed by participants in this study. Given that only two items in the Q-set related to electronic health records, it is impossible to draw definitive conclusions about the motivations for these outcomes. There are, however, two issues at play in these items: 1) whether increased access to patient history is considered likely to improve care; and 2) whether governance of the record influences the perceived likelihood of improved care. Based on the Q-sort results, Speed and Holism Oriented clinicians seem to prefer to have access to patient history, no matter who controls the record (Items 8 and 9 were both ranked +3). The Information Oriented clinicians strongly prefer access to history controlled by the patient (+3), but were relatively ambivalent about a government-controlled record (-1). The Acuity Oriented clinicians did not seem to value additional access to patient history at all (Items 8 and 9 were ranked 0 and -3, respectively). Reflecting on the defining features of each Orientation type, this outcome makes sense. The Speed Oriented clinicians seem focused on identifying and addressing problems quickly, so getting fast access to patient history aligns with this value. It is reasonable to assume that either a government-controlled database or a patient-controlled record could be accessed quickly. This is in contrast to the chart-sharing application in Item 6 (ranked 1) or the website that provides verified contact information for physicians in Item 7 (ranked 1), both of which require establishing contact with an outside entity before information can be obtained. Given that the ED operates
24/7 and most private practices do not, there could be a significant time delay between when a patient presents and when necessary information is obtained. Likewise, the Holism Oriented clinicians value fast access to patient history (Items 8 and 9 ranked +2), but they value the ability to effectively consult other providers slightly more (Item 10 ranked +3). Information Oriented clinicians seem to consider an improved ability to collaborate real-time likely to improve care; this is illustrated by their interest in videoconferencing (Item 2, +2), real-time video streaming (Item 4, +2), real-time ECG feed (Item 5, +2), real-time chart sharing (Item 6, +3). A patient-controlled mobile application effectively facilitates real-time collaboration between the patient and the provider. There are certain aspects of a government-controlled record that do hinder collaboration and might explain the Information Oriented clinicians’ ambivalent rank (-1 on item 9). Numerous concerns regarding the quality of comprehensive health records raised during the qualitative component of this study support this notion; for example, it may be difficult to determine who entered information and how to contact that person for data verification. Taken together, the Speed, Holism, and Information Orientations seem to convey a utilitarian motivation for improving care. While their specific preferences differ, the overall technology profile does not clearly favor high or low acuity patients. This is in contrast to the Acuity Oriented clinicians, who exclusively identified technologies that are relevant to “true” emergency medicine as most likely to improve care. The focus group discussion related to “appropriate use” of the ER might relate to this ideological split in that Acuity Oriented clinicians selected technology based on those who “should” receive care in the ER, as opposed the other clinicians who accept the reality of who “does” receive care in the ER. Given these radically different definitions of “care,” it is not surprising that the Acuity Oriented
providers did not favor technologies that improve access to patient history. The “care” that matters most to them is based on clinical presentation in the moment. While a patient-controlled record may be a reasonable adjunct to the oral history provided during an examination (assuming the patient is conscious, alert, and oriented), a government-controlled record will most certainly contain an abundance of superfluous information that, in most cases, will not inform decision-making in an acute context.

This particular EHR controversy may be unique to emergency medicine practitioners. Given that ERs serve as a major point of entry into the health care system, however, it is significant. It is unclear what impact the opinion sets proposed in this study will have on EHR adoption in particular (keeping in mind that “adoption” is defined by the choice to use an innovation in preference to other options). It is reasonable that a large subset of emergency medicine providers would prefer to adopt innovations most useful in emergencies. This preference should not lead one to infer that a subset of providers offer substandard care in non-emergent cases. It does imply, however, that resistance to EHR adoption may stem from a deeper ideological or cultural understanding of the role patient history plays in the provision of care, rather than solely from objections to human-computer interface. This type of resistance is much more challenging to manage and may require a long-term effort to establish new cultural norms within the department. Such cultural shifts are not unheard of at the study site; a conscious effort to encourage interdisciplinary collaboration and respect that was initiated ten years ago is still clearly reflected today.
V. CONCLUSIONS

A. Significant Findings

The results obtained during this study support the notion that clinician opinions can guide radical technology identification and prioritization. Qualitative methods provided key themes surrounding technology features and functions that were most important to clinical end users. These themes provided sufficient detail to focus a market review of radical technologies intended for ED implementation. The market review served as the concourse for a Q-methodology study and inspired a Q-set that participants ranked to express their prioritization preferences. Four factors emerged during data analysis that represented four unique innovation profiles demonstrated by clinicians within the ED. Technology preferences within each factor provided a surprising insight into distinct personal definitions of what “care” is. Analysis across factors revealed positive and negative consensus technologies as well as several controversial technologies that summarized departmental radical innovation priorities based on clinician opinions.

1. Identifying Radical Health Care Technologies

One-on-one interviews conducted in an unoccupied treatment area revealed three major themes associated with technology that was considered easy to use and useful: 1) technologies perceived as always “ready to go”; 2) technologies that are portable or easy to move; and 3) technologies that have simple instructions. Eight major themes emerged to describe unfavorable characteristics, including technology perceived as: “not ready to go”, hard
to move, having complicated instructions, inherently wasting time and/or resources, unreliable, too large, or not customizable. Taken together, these characteristics were used to assess radical technologies that could be implemented in the ED.

Physician and nurse focus groups provided additional insights into the specific clinical conditions or situations that would, in their opinion, most benefit from the introduction of new technology. Based on the focus group results, five major themes for radical innovation were revealed: 1) Innovations in Health IT; 2) Innovations to Address Challenging Patient Care; 3) Innovations that Reduce Laboratory Time Burden; 4) Innovations that Reduce Imaging Time Burden; and 5) Innovations that Provide New Treatment Options. These themes were correlated with five health technology markets: 1) health communications, 2) in vitro diagnostics, 3) non-invasive monitoring, 4) new treatment options, and 5) imaging.

Fifty-three potential radical innovations that exhibited features and functions preferred by ED clinicians were identified through trade journals, trade shows, technology blogs, and peer-reviewed literature. Thus, the results from research question 1 demonstrate how clinician opinions could be used to identify radical innovations.

2. **Prioritizing Potential Radical Innovations**

Review of participants’ demographic information (collected following the Q-sort) did not reveal any clear patterns in professional background, experience level, or self-reported innovation style that drove technology preferences. Each factor included physicians
and nurses, a range of experience levels (measured as years of experience in the ED), and several innovation styles (for example, the four self-described innovators aligned to three different factors). This suggests that some underlying subjective perception beyond professional background or experience level influences health care innovation preferences.

Further analysis of each factor revealed distinct innovation profiles that seemed to reflect different perceptions of what “care” in the ED means. Speed Oriented clinicians gravitated toward technologies that provided easily interpretable results much more quickly than currently possible. Members of this factor strongly prioritized POC diagnostics and rapid access to a full patient history. Holism Oriented clinicians, in contrast, uniquely prioritized imaging technologies that provide qualitative results that are sometimes difficult to interpret. This group also felt that in vitro diagnostics were “most unlikely” to improve care in the ED, implying that their definition of “care” revolves around treating the patient as a whole, rather than a set of lab values. Acuity Oriented physicians prioritized technologies that would improve the ability to treat and manage the “sickest” patients that present to the ED. Given that a high percentage of ER patients present with non-life threatening conditions, it is notable that many clinicians would prefer to innovate in a manner that benefits a relatively small number of patients. Finally, Information Oriented physicians prioritized technologies that improve communication among clinicians within the organization as well as outside hospital boundaries (such as with EMS or primary care providers). These profiles provide insight into the distinct values held by providers in the same department and could be leveraged to inform change
management strategies when a potentially controversial technology is selected for implementation.

Despite these divergent definitions of care, nine technologies emerged as positive consensus items that should be considered high priority for radical innovation. Five items were consistently ranked as “unlikely” to improve care across innovation profiles and should be considered low priority innovations. Several controversial technologies were also identified and implementation strategies were recommended based on each factor’s stance on the technology.

The results for research question 2 demonstrate that, using Q-methodology, clinician opinions can be used to prioritize radical innovations. Each individual factor provided insight into unique definition of “care” that drive technology preferences, analysis across factors revealed department-level consensus on the technologies considered “most likely” to improve care.

B. **Study Limitations**

The initial results indicate that Q-methodology can be applied successfully to issues of technology preference to provide both opinion trends and insight into the motivation behind preferences, which can inform change management strategies. The study design has several limitations, however. Weaknesses in this study include potential for volunteer bias, non-respondent bias, interpretation bias, and inability to measure reliability.
1. **Volunteer Bias**

   During the recruitment phase, the subject of this study was made clear to potential participants. It is possible that clinicians interested in health care technology were more likely to complete a Q-sort than other physicians were. As a result, this study would not represent the views of disinterested clinicians. In addition, the workload during a given shift could influence which clinicians were available to participate in the study. Though participants could submit responses at any time through the website, the majority of the Q-sorts were completed during on-site recruitment efforts. On-site recruitment was varied across shifts to minimize the impact of volunteer bias, but the reality is that some shifts are busier than other shifts. During busy shifts, nurses and physicians take fewer and shorter breaks, limiting their potential to learn about the study and participate. In practice, a hospital-sponsored study could institute mandatory participation (and provide dedicated time for clinicians to participate) and avoid volunteer bias altogether.

2. **Non-respondent Bias**

   Since identifying information about the participants was not collected, it was impossible to determine whether any differences existed between those who completed Q-sorts and those who attempted to participate and did not submit a response. Q-Assessor provides a count of the number of times the study was accessed, but there is no way to determine if the same individual accessed the study multiple times before submitting a completed sort or if many different individuals attempted to complete sorts and did not finish. Since Q-Assessor is still in its beta version, there are some limitations to the user interface that
may have influenced participation. As an example, during the final sort in which items are entered into the grid, the software requires that the +3 and -3 columns be filled before the rest of the grid opens. Several participants who completed the sorts in the presence of the researcher did not read the instructions or did not understand the visual cues (the active spaces are white and inactive spaces dark gray), and became frustrated when the items wouldn’t stay where they were placed. Similarly, to place an item, the cursor has to hover over the grid. Spaces turned orange when the item was positioned correctly, but many participants did not notice this visual cue. Approximately one quarter of participants who completed Q sorts while the researcher was present requested some clarification on how to finish. It is reasonable that a substantial number of clinicians who attempted to participate in the study alone had similar difficulties and either ran out of time or became frustrated and abandoned the sort. After observing these interface-related difficulties, a short troubleshooting guide was provided to all participants, which seemed to improve the user experience to some extent. There remains the possibility that clinicians with a certain point of view were also, for some reason, more likely to misinterpret (or miss) the instructions and/or visual cues during the final sort. As with volunteer bias, this situation might be avoided in practice when surveys are not conducted anonymously.

3. **Interpretation Bias**

   The subjective nature of selecting and interpreting a factor solution is one of the most frequent criticisms of Q-methodology. As discussed at length in the results section, there are no “hard and fast” rules that guide factor extraction or define which sorts should be
counted in the calculation of the factor array. Many prominent Q-methodologists (Brown in particular) criticize interpretations that rely too heavily on statistical or mathematical criteria to identify factors. No matter how conservative the criteria are to identify a factor solution, the interpretation is always a product of inductive and abductive reasoning. There are no statistical tests that can be applied to the outcomes of Q studies to test how fully a researcher considered a given item in his or her interpretation. In practice, this is probably the greatest weakness of using Q as part of a procurement strategy. It is very likely that administrators will enter opinion gathering with one or more technologies in mind. It is not challenging to select the mathematical model and defining sorts that will favor these technologies. In order to avoid this type of interpretation bias, a group should establish criteria for an ideal solution prior to data collection and follow factor analysis guidelines in selecting a factor solution. These criteria can then guide factor extraction and the ultimate selection of a less biased factor solution.

Likewise, a group, to avoid letting the desire for a specific outcome cloud more inclusive interpretations, should conduct the factor interpretation. Alternatively, administrators could bring in a neutral party to facilitate interpretation and ensure that a full range of items is considered.

4. **Reliability**

A final weakness in the study design is the lack of any reliability measure. One of the challenges of measuring subjective experience is that an individual’s perceptions and preferences fluctuate. A Q-sort represents one person’s subjective experience in one moment in time. This makes it hard to identify definitively whether the change in a sort from one time
point to another reflects a true change in opinion or is the product of an unreliable measure. Given that Q-methodology is designed to be self-referential, as compared to a Lickert-style survey, however, it is more likely that changes in a sort over time are intentional. It is also difficult to assess how anomalous experiences might influence any given sort. In this study, for example, it is possible that an abnormally high number of chest pain patients seek care in the ED. A clinician that completes a Q-sort on that day might favor technologies more that help diagnose the causes of chest pain than they would on an average day, which might ultimately influence factor interpretation. Conducting data collection over an extended time period and monitoring departmental activity to identify fluctuations in case load should improve reliability.

C. Future Directions

1. Instrument and Methodology

Additional evidence that Q-methodology is an effective tool to inform policy decisions is still necessary. Several strategies could validate this particular study and the methodology in general. First, two follow-up studies could provide data to validate the interpretation presented in this work: 1) repeating the study with additional participants, and 2) conducting a case study of the adoption process for the consensus technologies. If one were to repeat the study with additional participants and find the same preference patterns emerge, it would support the outcomes in this study and increase the probability that the positive consensus technologies reflect the desires of a majority of clinicians in the ED. A case study of the adoption process in this ED could provide validation for the general trends identified in the consensus analysis; for example, if one of the positive consensus technologies were
implemented, a relatively fast adoption process would be expected. If a negative consensus technology were implemented, a relatively slow adoption process would be expected. If observational and interview techniques generated data that aligned with the factor interpretation, it would validate the results in this study. As an example, if a point-of-care test was implemented and some clinicians expressed discomfort with techniques that emphasized treatment algorithms rather than a clinician’s intuition, this would add credibility to the Holism Oriented interpretation. Second, the Condition of Instruction and Q-set could be validated by repeating the same study in other EDs. Unlike R-studies, validation would not rely on a repetition of results from the initial study site. It is very possible that clinicians within another organization would have a significantly different frame of reference that would influence their technology preferences. Instead, if the Condition of Instruction and Q-set demonstrated a continued ability to generate strong factors (such as a large proportion of significant factor loadings and clear opinion patterns within and between groups), it would indicate that the instrument itself is a valid measure of opinions in EDs and could be used as part of acquisition decisions with greater confidence. Third, the overall validity of Q-methodology as a policy tool at the hospital level could be tested by repeating the entire methodology in other departments. Similar interview and focus group questions should reveal the relevant themes to guide a market review and, ultimately, Q-set development. Q sorts conducted by appropriate clinicians should generate strong factors and a manageable list of consensus technologies (both positive and negative). In conclusion, while additional work is required to validate this instrument and methodology, the studies necessary to confirm validity are feasible. These initial results support the use of Q-methodology to systematically gather clinician opinions for inclusion in
health technology assessment efforts as recommended by the IOM, AHRQ, and other professional bodies.

2. **Theory and Philosophy**

In addition to the practical applications of this work, there are also theoretical and philosophical implications to Q-Methodology and dissemination science. This work poses an argument that PCA may be a more appropriate factor extraction technique than the centroid method in policy applications, specifically, when the goal of a study is to incorporate subjective experience as part of an optimization problem (in this case resource allocation). Unlike most Q studies that are designed to explore individual subjectivity, this work seeks primarily to link individual subjectivity with organizational behavior. Most interpretations do not incorporate assessment of overall trends between items. In most traditional Q studies, that comparison would not be meaningful; however, this type of interpretation is as valuable (if not more) to the intended audience than is the interpretation at the individual level. There is no procedural hindrance to applying Q in this manner, but the philosophical implications of this use should be explored further. As the scientific community as a whole moves toward more collaborative and multidisciplinary approaches to research, Q-methodologists should be prepared to adjust methodologically and philosophically to remain relevant in such an environment.

The ability to explore the link between individual experience and organizational behavior is also important to dissemination sciences. Most measures of technology dissemination are dichotomous. This does not allow researchers to explore in any meaningful
way why a technology is adopted or how to influence adoption behavior in other cases. In contrast, the methods implemented in this study provide data at the individual level and possibly at the organizational level. Reviewing the consensus technologies provides a global overview of the health care innovations the department should readily adopt (organizational behavior), but assessment of the individual factors shows that clinicians arrive at their preferences from very distinct vantage points (indirect measure of individual behavior). A wider adoption of Q in health technology assessment would generate additional data for the research community to consider when studying dissemination. Advocating the use of Q in technology adoption decisions in other industries could provide unique insights into innovation dissemination and change management theory. It may also be worth assessing the value of using technology preferences as an indirect measure of cultural norms. In this study, the factors are generated by similarities in preference, but seem to represent four different ways to approach the provision of care in emergency medicine. This implies that a Q-set of technologies could be sampled purposively to test or generate a theory about the cultural frameworks that exist among a professional body. Many well-established theories of adoption behavior include a variable related to social or cultural norms; greater understanding of such cultural norms would provide new avenues for improving innovation adoption in practice.

D. Summary

In summary, Q-methodology combined with the market survey and analysis of existing technologies, appears to be effective for systematically gathering clinician opinions regarding preferred health care technology when faced with choices and determining clinicians’
innovation profiles. The four innovation profiles revealed in this study are significant in two ways. First, most change management “best practices” implemented in a hospital setting to support technological innovation assume that since physician and nurse responsibilities and workflows are different, achieving end user buy-in with each group is a separate process. For example, many guidelines for health IT implementation recommend identifying both physician and nursing “champions”. This study reveals that physicians and nurses share several different underlying values related to care that actually may be a more important predictor of adoption behavior. Second, the innovation profile provides insight into what each group values. This knowledge can help hospital leaders tailor their communication about a radical innovation so that the overarching goal of the implementation resonates among a greater number of affected clinicians.

Clinicians were able to complete Q-sorts independently using a web-based instrument in typically under 20 minutes. Participants represented a variety of backgrounds and experience levels. Quantitative analysis supported a four component PCA solution that explained 53% of the study variance and contained 33 significantly aligned sorts. The results were interpreted from two frames of reference: 1) in terms of the unique innovation profiles reflected by members of each factor; and 2) in terms of consensus and controversial items. The four innovation profiles were Innovate for Speed, Innovate for Holism, Innovate for High Acuity Patients, and Innovate for Information Availability. Nine positive consensus items were identified in the areas of health communication, point-of-care and laboratory tests, and imaging. Six negative consensus items were identified in the areas of health communication,
non-invasive monitoring, and treatment options. One significant and extremely controversial item remains, which is a government-controlled database that contains a comprehensive patient history. Of the four innovation profiles, only Speed Oriented and Holism Oriented providers (46% of significantly aligned participants) felt that access to a government-controlled patient record was very likely to improve care (both ranked Item 9 at +3). The Acuity Oriented and Information Oriented providers ranked the same item as -3 and -1, respectively.

Despite some weaknesses in study design, the results in this study support the method as a potential solution to the difficulties facing hospital leadership who wish to include clinician opinions in technology acquisition decisions. The sampling bias that is of concern for this particular study could be readily addressed in practice, but mitigating interpretation bias will remain a challenge to the validity of any results. Though neither the instrument nor the methods for this study are validated by replication in other contexts at this point, the additional studies required to provide validity are feasible and could be performed in a reasonable amount of time. The results of this study provide streamlined guidance on specific technologies for administrators to explore as well as valuable insights into the underlying attitudes clinicians hold that may influence their technology adoption behavior.

In addition to the health policy implications, the results should encourage new discourse in Q-methodology and dissemination science. Since Q-methodology was initially justified as a measure of individual subjectivity, should there be a new conceptual justification developed to explain its use in organizational measurements? In addition, does the manner in which the
results are interpreted (to emphasize consensus and controversial items in addition to individual factor interpretation) create a new measure of organizational innovation that bridges individual belief and group behavior? If so, the methods described in this study could broaden understanding of the innovation process outside of the health care sector.

In conclusion, this work demonstrates a novel application of Q-methodology that provides a framework that hospital administrators can use to systematically gather clinician opinions. If validated and with time, this instrument could predict organizational behavior in EDs (i.e., which health care technologies would most likely be adopted or rejected) and provide deeper understanding of individual preferences. Likewise, the method can be applied in other health care settings and potentially across industries. Long term, this method may provide an alternative to dichotomous measures of organizational innovation and create a bridge between individual and organizational variables. Overall, the results of this study indicate great potential to improve health care innovation as well as the understanding of innovation.
CITED LITERATURE


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APPENDICES
CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE: Q-sort for “Systematically Gathering Clinician Opinions on Iterative and Radical Technology Innovation”

PRINCIPAL INVESTIGATOR: Melissa Naiman, MS, EMT-B

SUB-INVESTIGATOR: Erik Kulstad, MD

INTRODUCTION

You are being invited to participate in a research study. Researchers are required to provide a consent form such as this one to tell you about the research, to explain that taking part is voluntary, to describe the risks and benefits of participation, and to help you to make an informed decision. You should feel free to ask the researchers any questions you may have.

You are being asked to participate in this study about health care innovation in hospitals because you are a physician or nurse who spends a majority of your time assigned to the Emergency Department.

Your participation in this research is voluntary. Your decision whether or not to participate will not affect your current or future dealings with the University of Illinois at Chicago or Advocate Christ Medical Center. If you decide to participate, you are free to withdraw at any time without affecting that relationship. Up to 300 subjects may be involved in this research at ACMC and it is expected that participation will require about 20 minutes.

The purpose of this research is to capture a variety of opinions related to the equipment and medical devices available in the Emergency Department. The goal of this research is to help determine what types of completely new equipment/devices should be introduced. The results of this study will be shared with hospital administrators and may guide future purchasing decisions.

This study has been reviewed and approved as Exempt by the Institutional Review Board of Advocate Health Care (IRB), 205 W. Touhy Ave., Park Ridge, IL 60068. An IRB is a group of people, independent of the study investigators, whose role is the review and oversight of research to ensure the safety and rights of study participants.

PROCEDURES

This research will be conducted in the Advocate Christ Medical Center. If you agree to participate, you will choose between a computer-based survey and a paper-based survey; these surveys are identical. The computer-based survey may be accessed through the following link: http://q-assessor.com/studies/739/responses/new. You may use your own computer or a computer provided by the researcher. If you choose the paper-based survey, you will be provided with an answer grid, a set of cards, and a set of instructions.
Appendix A (continued)

The computer and paper survey are identical. In both cases, you will be asked to sort the cards based on your opinions on the following topic:

“When thinking about technology and techniques to support improving care in the emergency department, which of the following do you feel would be most likely / most unlikely to improve the care you provide?”

After you sort the cards according to your specific topic, your responses will be recorded and included as part of an analysis of the opinions across the entire Emergency Department.

RISKS
To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life, though you may feel some discomfort sharing unpopular or negative opinions about the Emergency Department.

BENEFITS
This study will not benefit you directly. This study is designed to learn more about clinician opinions and how they can best be used to provide guidance to hospital administration during technology purchasing decisions.

ALTERNATIVE THERAPY
You have the option to not participate in this study.

COSTS/COMPENSATION
There are no costs or compensation for participating in this research.

CONFIDENTIALITY
The people who will know that you are a research subject are members of the research team. No identifying individual information will be recorded.

RESEARCH RELATED INJURY
As the study consists of completing a survey, there is no risk of injury.

QUESTIONS
For questions about the study, you can contact the principal investigator, Melissa Naiman, at 312-355-0078 or by e-mail at mnaima1@uic.edu

For information on your rights as a study subject, you may contact the Chairman of the Institutional Review Board of Advocate Health Care at 847.384.3534.

VOLUNTARY PARTICIPATION/WITHDRAWAL
If you decide to participate, you are free to withdraw your consent and discontinue participation at any time. If you are completing a computer-based survey, you can close the window in which the survey is being completed. If you are completing a paper-based survey, inform the researcher
that you no longer wish to participate and return the survey materials. No data will be recorded in either case.

**RESEARCHER CONFLICT OF INTEREST DISCLOSURE STATEMENT**

None of the researchers asking you to participate in this research study have received or will receive money or other benefits for personal use from the study sponsor.

**RESEARCH SUBJECT’S BILL OF RIGHTS**

_The rights explained below are the rights of every person who is asked to be in a research study. As a research participant I have the right:_

1. to have the purpose of the study clearly explained; to learn what the study is attempting to find out;

2. to be told what choices for care I have and how they may differ from participating in the research study;

3. to be told what will happen to me and whether any of the procedures, drugs or devices used in the study will be different from the routine care I could expect;

4. to be told about any risks, side effects or discomforts that may occur that are due to my research participation and how these may differ from routine care;

5. to be told whether I can expect any personal benefit from participating in the research study and the likelihood of such a benefit;

6. to ask any questions I have before consenting to participate and throughout my time in the study;

7. to know what medical treatments are available to me and how they will be paid for, if any complications arise due to my participation in this study;

8. to have all records bearing any information that could identify me held in confidence by the researcher(s) and revealed only if necessary for review by appropriate governmental oversight authorities such as the Food and Drug Administration (FDA), and by authorized representatives of the Institutional Review Board of Advocate Health Care;

9. to be kept informed of any new medical or technical developments that may affect my condition or my willingness to participate in the research;

10. to refuse to participate or to withdraw from the study at any time without affecting my regular medical care;
11. to receive a copy of the complete consent form;

12. to be free of pressure while considering whether I wish to agree to be in this study.

CONSENT

After reading this form, I acknowledge that this study has been described to me, including the procedures, and potential risks and discomforts. I have read this consent form in its entirety and have spoken to the investigator or his/her representative and have had all questions answered to my satisfaction.

Continuing my participation by completing the survey indicates my consent to participate.
Appendix B

A. **Introduction Screen**

Thank you for your participation in this study: *Clinician Opinions on Innovation*

When thinking about technology and techniques to support improving care in the emergency department, which of the following do you feel would be most likely / most unlikely to improve the care you provide?

You may assume the following about the descriptions:

- Technologies are FDA approved
- Technologies are HIPAA compliant
- Full integration (any results automatically enter the patient record)
- Each technology works as well as you can imagine

*By clicking on "Let's Get Started" below, you acknowledge that you have received and reviewed the Consent Form and consent to participate in this study.*

[Let's Get Started]
B. **Initial Sort**

*Instructions*: Read each statement, decide how you feel about it, and then drag it to the most appropriate box. You can scroll through the statements using the arrow buttons. When you drag a statement, the available destinations where you can drop it will highlight.

- **Most Unlikely**
  - A mobile application that receives real-time ECGs from EMS and integrates automatically with hospital records.

- **Uncertain**
  - A mobile application that records video of an EMS encounter, including vital signs and ECG, which is sent to the ED during transport.

- **Most Likely**
  - A networking website that provides verified contact information for physicians including: phone, fax, back office numbers and a secure text or messaging system.
C. **Final Sort**

Instructions: Sort each statement from one of the three general categories into the grid based on the degree to which you feel the statement qualifies. Scroll through the statements using the arrow buttons. Drag the statements into the grid. Available destination spots are highlighted in white; the spot where you drop a statement will highlight in orange. First you need to fill the most **Most Likely** spot(s), then the most **Most Unlikely** spot(s), and then all the rest. When placed in the grid, the statements will shrink to fit, but you can read them in detail by moving the cursor over them. To move a statement within the grid, drag it from one spot to another.
D. **Demographic Questions**

![Image of questionnaire with questions and options]

**Your Responses**

Note: You cannot change your ranking at this point. Do you want to try again?

**Additional Questions**

Thank you for participating in the first phase of the "Clinician's Opinion of Innovation" study.

We would like you to answer all questions to complete the study. Please refer to your ordering of the statements as needed.

1. Why did you choose these 4 statements as the Most Likely to Improve care in the ED?

2. Why did you choose these 4 statements as the Most Unlikely to Improve care in the ED?

3. What is your license?
   - MD
   - DO
   - NP
   - PA
   - Other

4. How long have you worked in the ED?

5. Do you primarily work in the Pediatric ED?
   - Yes
   - No

6. Which innovation style best describes you?
Appendix B (continued)

6. Which innovation style best describes you?
   - I am typically at the frontier of my field, "first on the block with the latest." I readily want to be involved in clinical trials, and use experimental protocols in my practice.
   - I seek my role during colleagues to test an idea and take the risks. I will move ahead with an innovation even when all the science is not fully supportive.
   - Most often I wait until an innovation has been proven (e.g. scientific evidence is clear and persuasive; there is prescriptive acceptance by peers or someone I trust—medical experts).
   - I am a skeptic about innovations. I wait for proof from clinical trials or other definitive research before I will adopt an innovation.
   - I let my own experience of the innovation will be of value to me. I don't compare my practice against peers.

7. Did you participate in a Focus Group during this study?
   - YES
   - NO

8. Did you participate in a one-on-one interview during this study?
   - YES
   - NO
Appendix C

Introduction:

A small set of statements representing a collection of technologies are provided in the attached envelope, labeled “Healthcare Innovations”. These technologies are likely to be marketed to emergency room clinicians in the next 10 years. Each technology statement is numbered; the numbers run 1 – 43. You will complete one survey using these statements.

These statements represent 43 possible responses to the question:

When thinking about technology and techniques to support improving care in the emergency department, which of the following do you feel would be most likely / most unlikely to improve the care you provide?

You may assume the following about the descriptions:

- Technologies are FDA approved
- Technologies are HIPAA compliant
- Full integration (any results automatically enter the patient record)
- Each technology works as well as you can imagine

Please follow the sorting instructions on the next page to complete the survey.

Acronyms:

POC= Point of Care. Refers to technologies that allow clinicians to perform diagnostics or obtain lab values on the floor instead of sending samples to the lab.
Appendix C (continued)

**Sorting Instructions:**

1. Look at all the opinion statements to familiarize yourself with the range of technologies.
2. Sort the statements into two (2) piles. One should contain the statements that you feel are Likely, for any reason. The other pile contains statements you find Not Likely for any reason. These piles do not have to contain an equal number of statements.
3. From the pile of statements you find Likely, select the four statements (only 4) that you find Most Likely. Place them in a four-item column at the extreme right hand of your workspace.
4. From the remaining Likely pile, select six (6) more statements that are now more likely than the others in the pile. Place these 6 statements in another column just to the left of the four already selected in Step 3, above.
5. Next, select from the remaining Likely pile the seven (7) statements that you now feel are Most Likely. Place these 7 statements in another column just to the left of the six already selected in Step 4, above.
   - If you have run out of statements in the Likely pile and cannot finish step 5, proceed immediately to the next step.
   - If you have extra unsorted statements at the end of this step, combine the extras with the Not Likely pile and go on to the next step.
6. Now, work with the pile of statements you feel are Not Likely. Begin by selecting the four (4) statements you find Most Unlikely. Place them in a three-item column on the far left side of your work area.
7. From the remaining Not Likely pile, select six (6) more issues that are now less likely than any others in the pile. Place these 6 statements in another column just to the right of the four already selected in Step 6, above.
8. Next, select from the remaining Not Likely pile the seven (7) statements that you now feel are Most Unlikely. Place these 7 statements in another column just to the right of the six already selected in Step 7, above.
9. Place the remaining nine (9) statements in the middle of your grid.
10. Now, look at your arrangement. Feel free to move statements around to make sure that your opinion is reflected correctly.
11. When everything is sorted as you want it to be, write the statement numbers in the blank boxes of the grid on your SORTING ANSWER SHEET. In addition, please respond to the additional questions on the back of the answer sheet.

Return the sorting answer sheet to Melissa Naiman in person, to the sealed “Survey Response” box in the break room, or to Dr. Erik Kulstad in the Research Office (Room 178W).

*Thank you!*
### Appendix C (continued)

**SORTING ANSWER SHEET**

<table>
<thead>
<tr>
<th>Most Unlikely</th>
<th>Uncertain</th>
<th>Most Likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>-2</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>+1</td>
</tr>
<tr>
<td></td>
<td>+2</td>
<td>+3</td>
</tr>
</tbody>
</table>

Please turn over to find additional questions.
Appendix C (continued)

1. Why did you choose these four statements as the Most Likely to improve care in the ED?
   _____________________________________________________________
   _____________________________________________________________
   _____________________________________________________________

2. Why did you choose these four statements as the Most Unlikely to improve care in the ED?
   _____________________________________________________________
   _____________________________________________________________
   _____________________________________________________________

Demographic questions:
Demographic questions are optional. Responses to these questions aid us in better applying the research results. It is possible, however, that there could be a unique combination of demographics that, with effort and the will to do it, could be connected with an individual.

1. What is your license? (check one)  MD_____ DO_____  RN_____  NP_____

2. How long have you worked in the ED? __________________________

3. Do you primarily work in the Pediatric ED? (check one)  Yes_____  No_____

4. Which innovation style best describes you? (check one)
   _____ I am typically at the frontier of my field, “first on the block with the latest.” I readily want to be involved in clinical trials, and use experimental protocols in my practice.
   _____ I await my more daring colleagues to test an idea and take the risks. I will move ahead with an innovation even when all the science is not fully supportive.
   _____ Most often I wait until an innovation has been proven (e.g., scientific evidence is clear and persuasive; there is presumed acceptance by peers or someone I trust— influential experts).
   _____ I am a skeptic about innovations. I wait for proof from clinical trials or other definitive research before I will adopt an innovation.
   _____ I set my own course and decide if the innovation will be of value to me. I don’t compare my practice against peers.

5. Did you participate in a Focus Group during this study?
   Yes______  No______

6. Did you participate in a one-on-one interview during this study?
   Yes______  No______

Thank you! Please return this sheet to Melissa Naiman in person, the sealed “Survey Response” box in the break room, or to Dr. Erik Kulstad in the Research Office (Room 178W).
Appendix D

One-on-One Interview Notes

Participant 1: Nurse, 3 years in ER, 6.5 years total experience

Regarding superficial items:

Rooms are too small, with kids there are lots of people around. You’re constantly jumping over people while you’re caring for the patient. So my overall biggest complaint about the rooms is the movement and flow when treating people.

The new monitors are a big benefit.

The new lights are also nice in these two rooms [pediatric trauma bays, rooms 10 and 11].

I like that there are no hall patients in this section [pediatric ER]. It increases privacy.

The new call buttons are nice, they added an audio feature so we can ask what the patient needs and just bring it, rather than go in and out and in again.

I really don’t like the placement of the sharps container, people are always hitting their heads on them. See how the chairs are under it? Adults when they stand up or lean back keep smacking into them.

I think the oxygen and suction are set up well.

It’s annoying to have things on both sides of the bed, you’re always on the wrong side.

I like the pictures on the ceiling, they’re good for distracting kids. [Referring to ceiling tiles with Where’s Waldo and other cartoons that nurses can direct a child’s attention during a blood draw or similar procedure].

Trash cans are always in the way.

Regarding stored items:

We’re mostly stocked on the basics.

I would like more urinals around.

I like the individual packaging usually, but I feel the ibuprofen in individual packets is a waste.

Inventory is more of a pain than anything. The closet is deep, we need to really look for things. We could also use more machines [vein finders, etc.] because people leave things all over the place.

Regarding portable items:
Portables? I like the trauma cart.

The scales are fairly convenient.

The rapid infuser [Level 1] stays put, we don’t use it much.

The ultrasound is a bit big so it’s hard to work around.

We now have a formal storage room for portable items, so it’s easier to find things. Now we know where it is.

We have a ventilation machine, and infant warmer, we have a Broselow cart outside the trauma bay door.

We have a COW [computer on wheels], but it has power issues. Sometimes people leave it unplugged so when you need it, it’s not ready.

Everyone knows to get what you need and come back.

Everything is easy to use, space is always an issue.

I’d like to see something like the PICU, where there is a med car that needed a code to get into, but it had needles, Tylenol, etc. all easily available.

**Participant 2: MD, 32 years in ER, 32 years total**

**Superficial:**

The first thing I think about in these rooms is that they are too small.

When you bring in an ultrasound machine, it’s a big machine and takes lots of room.

I feel that these days there are more family members coming in and there are more personnel involved in every case. So moving around is a problem.

Lighting is never set up correctly. If I had to suture in this room [Room 15, non trauma-bay, no movable overhead light], it would be too dim, no way to add light. In this room, the track for the IV makes the light even worse. You need to be able to illuminate better.

The doors in these rooms are heavy, they have lead for X-ray protection. I’m concerned that kids might get their fingers caught, but I’m not sure that’s ever happened.

The soiled linen carts take up lots of space, we need more things that are dual use.
Appendix D (continued)

For example, Mayo stands on stainless steel trays on wheels. You need to put equipment on trays. There should be some other improved device, that comes out of the ceiling or the wall, like an ironing board.

The biohazard bin is reasonable.

There’s a clothes closet in the corner that is a waste of space. How is this useful? I guess if people are staying here for a long time it’s nice to have a place to put coats and things, but maybe hooks on the wall would be a better choice?

The TV is a good addition, it’d be even better to have some sort of web-based access for ipads and smart phones. Signal is definitely desired, and people are often trying to charge things, but finding an open outlet can be hard.

But they have these smart TVs and Apple TV wireless that will interact with devices and project to the TV. So for me, to show an X-ray, I need to take the patient or their family to a terminal where I have the right security and access to. It’d make things simpler to use the existing TV monitor and beam the image up there from my phone.

The eraser boards are okay [used to show the name of the doctor and nurse for the area, other info. It’s covered in a plastic case that locks so that the writing isn’t accidentally erased or altered on purpose.] It would be nice if they were electronic so the nurses could centrally update them, rather than walking from room to room. So right now it’s Dr. Dean, but next shift it’s someone else and someone has to walk around and update each by hand.

The sharps disposal was a good update. The old one we used to get a lot of needle sticks because it was made for clinics that only use needles and syringes. Scalpels, needles, central line kits all need sharps disposals but didn’t fit well into the old sharps containers. Everything is the same size in clinics, the ED has tons of things.

We used to have 1 garbage, but we’ve switched to 3 garbages which takes up more space. I understand the reason, you want the least amount of biohazard waste for cost purposes, but it’s hard to get around them.

These hanging IV holders are awful. They are standardized for the hospital, but if you look at the height, you don’t have to be too talk to constantly bang your head on it. The track is always beat up, so it gets stuck when you try to move it [participant demonstrates, the IV track abruptly stops about 2 feet from starting point]. Is the track really needed for the ER? It’s more for inpatient when people will be in place for awhile.
When thinking about layout and technology, the ER gets lots of use per space. For example, commercial real estate considers food traffic...so like a barber shop is high volume, so they see more foot traffic per square foot in a given time. So there’s a premium on durability and flexibility. Often the equipment in the ER is retrofitted into the space. So imagine that this room sees 10 cases per day, which is probably 20 family members, maybe 30 healthcare professionals... it adds up.

The room has a battery powered clock which isn’t bad, it’s nice that it has a second hand.

The glove placement is good, easily accessible.

I don’t like that the hand sanitizers are outside all of the rooms. I would prefer to come into the room and that patients see me wash my hands. The door handle is probably dirtier than anything in this room. So now, I put some sanitizer in one hand [demonstrates, puts the foam sanitizer in left hand] then I open the door [with right hand], shake hands, then use the hand sanitizer while they can see it. If it were inside the room, I wouldn’t have to walk around with goo in my hand. Also, the family would be more likely to use it and they’ll see the doc wash their hands, if they don’t do what I do. In some places there is a culture of patients policing hand washing, not so much here, but they should see us do it.

**Regarding portable items:**

We’ve made good progress with the carts and things. They have foot controls and are more standard across the hospital. It’s good to have standards.

The mattresses are better [on the gurneys], but still not too comfortable.

EKGs are fairly portable, but the techs do them so I don’t use them. But like everything else, it’d be nice if they were more flexible/durable, simpler, smaller. However, smaller is easily stolen.

Regarding the ultrasound, again I’m interested in smaller size and more durability. A smaller footprint. There are some cord problems, there are a few ER-focused companies, but theft is a concern. Maybe you could put in some type of GPS computer chip that will tell you where the thing is and will disable the device if removed or damaged.

The crash carts are more ER-friendly than other technologies here. They start with pre-hospital simplicity and make sure it’s easy to use. There are general instruction modules for all devices that help clinicians switch between brands and show order of operation in 1, 2, 3 steps. [Participant illustrates point on the defibrillator, which has large numbered labels next to buttons to indicate the order needed to turn the device on, use the pacer, administer shock, etc.]

**Going back to the stored items:**
Appendix D (continued)

The Joint Commission says you can’t have stuff exposed to air, it maintains cleanliness. However, it helps to visually see things. It’d be nice to switch to plastics that are clear to increase visibility to help find things.

**Participant 3: MD, 3 years in ER, 3 years total**

*Superficial areas:*

The monitor shows all the vital signs, including tidal CO2, which is very awesome. Our airway management is great.

On that wall is the otoscope and opthalmoscope. When I first got here I felt like half of the otoscopes didn’t work, but it’s better now. The suction canisters...when they don’t work it’s a problem. The O2 port is good. I’m not sure why the sphygmomanometer is still there.

The sharps container is fine. The bag valve mask in the corner doesn’t get used much back here.

The beds...you just get used to the beds, though it can be hard to move carts around the beds.

The TV keeps patients happy, so that’s good.

*Stored items:*

Towels and blankets are over there [points to the right side of the bed], it’s nice to have sheets and things nearby.

I don’t have any real comment on the packaging, except for gauze. I don’t use the packed gauze because of the packaging.

*Portable Items:*

When you have to do an eye exam, the slit lamps are a disaster here. You have to worry, is it working? In other hospitals I’ve seen hand-held slit lamps that are really nice.

The glide scope is housed in the inventory, it’d be nice if it was in the room, more readily available in the resuscitation bay.

With hallways patients on the main floor, you have to find the portable scopes and hope that they’re working. We now keep them centrally located, which helps a lot.

With pelvic exams you used to have this plug-in light that you’d have to find, make sure it worked, make sure it was clean... now we have these disposable speculums that has a light built in. That’s really nice.
Appendix D (continued)

The crash cart works well and we also have a difficult airway cart. There’s a fiberoptic thing that is hard, it’s always missing a part, so we tend to use the glide scope.

I like when pharmacy is around to bring drugs to a code, it’d be nice if it were 24/7.

As far as the pacer box, we’re all comfortable with that, remembering indications, pads, how to connect chargers, knowing synchronis vs asynchronis pacing.

I think sometimes with certain technologies, since the nurses are good here the docs don’t know how to use things.

I’d like more ultrasounds around. They are very indispensible. I’d like an ultrasound on the wall in every room. Here, there are only 2 on the main floor and 1 in pediatrics. They can be hard to find. I could even see implementing a bunch of simpler ultrasounds, like the ones used for finding veins.

**Shared Resources:**

For the resuscitation bay, I’d like the IO kit in inventory instead of in the closet, under lock and key.

**Participant 4: RN, 6 years in ER, 6 years total**

Superficial areas:

The x-ray light box, I don’t know why we even have it.

The monitors are excellent, but they took away our desk control.

The infusor... it doesn’t get used often, it’s scary to use. It makes me cringe. It’s not as easy as it could be, you have to set up all of this tubing. I’ve never used it with an actual patient. The guidebook is useless [picks up and leafs through a 4-page booklet with laminated pages and small print]. Can you imagine me picking this up during a trauma? That won’t inspire patient confidence. It takes a lot of focus to set up, and that’s not possible during a trauma.

I’d like to change where the garbage cans are, the biohazard can is the most accessible, but they want the least stuff in it because it’s expensive to throw out.

I really don’t like this Deaf Talk system. Basically there’s a hook-up to video feed interpreters to deaf patients. The patients dislike it; I think actual interpreters increase patient satisfaction. There’s just a lack of personal connection, it’s not as fast as the other interpreters where you call on the phone. It takes me a bunch of time to set it up and then the patient doesn’t even like it.
Appendix D (continued)

I don’t like the lighting in here, you can’t adjust it. In some of the rooms on the other side [of the pediatric unit] you can dim the lights. Here it’s either on or off. It’s more soothing to have the lights dimmed, but total dark can be too much.

Stored Items:

I find the ice packs hard to crack, and I’m not a weak lady.

These urine cups drive me nuts. They are prepackaged by the manufacturer or something, but we don’t use these yellow-topped tubes. It’s a waste of money because we have to use the yellow/red instead because they keep longer. It just seems wasteful to me, we have a whole overflowing bin of unused yellow top tubes.

Portable items:

The adult scale is really hard to move. If they come through triage, they just get weighed up front but if they come in by ambulance, we need to weigh them back here. It’s really important in pediatrics because doses are so often based on weight. The scale is hard to move and it’s not user friendly. There is one on a cart, but it’s not accurate. The baby scale is great, it has wheels, moves easily, has a break...

The eye chart is kind of weird. We have one chart out in the hallway [points outside], but we don’t have the distance marked out, so you can’t easily tell where to make them stand. In other places I’ve seen the tiles marking where you need to stand relative to the chart, that doesn’t seem to be a hard solution.

The code cart is much better now. Before we had two types of code charts, now we have a combined medical and equipment cart...a Broselow. I like when pharmacy comes during codes, I can take care of the patient instead of drawing meds.

Shared resources:

Well, chest tubes make me nervous and the auto infuser, like I said before.

I also get nervous around med ports. It’s a very detailed sterile process. Maybe if you’re used to them it’s not a big deal, but we don’t see them that often. It’d be nice if the med port company included a quick-steps guide. I mean, you need to keep it sterile and I’d hate to cause an infection in some immune-compromised kid.

**Participant 5: RN, 3 years in ER, 4 years total**

Superficial:
The infusion pump is not easy to use.

The monitors are good, they detach for moving, so you can keep monitoring constantly during a transfer. I like the CO2 monitoring in particular, it’s more sensitive.

I often see where the otoscope isn’t working.

The suction is often missing or dirty.

I dislike the size of the things, space is limited. There are lots of sick people and no where to put them.

I feel like I’m always running out to find stuff and running to the main floor to get things.

Stored items:

Well, the cords [on the monitor] are neat now, but they’re almost always tangled.

It’s just all hard during a trauma, suction, vent, it’s all a mess.

Portable items:

Carts are hard to maneuver and hard to position.

It’s good that the code carts are close, so are the trauma carts.

The wheelchairs are awful, they’re all broken.

There is only 1 baby scale and that goes missing sometimes.

The big person scale that we use if the person is brought in on ambulance, that scale is heavy and hard to move.

There is some weird equipment around, you have no idea what it is or where it is. I’d like to have things more readily available.

I find the handheld vein viewer particularly useful.

**Participant 6: RN, 2.5 years in ER, 8 years total**

*Participant 6 began the interview but realized she had not be in the ER for quite 3 years (more like 2.5) and was removed from the study because she did not meet the inclusion criteria.*
Participant 7: MD, 12 years in ER, currently serves as the chief of the ED, 15 yrs total ER experience

Superficial:

The monitors are new and they’re nice ones. They’re modular with a full range of functions. They’re also networked with other monitors.

We have otoscopes and opthalmoscopes, the design is older now, some come standard with panoptic capability.

Overhead lights are nice, they’re good for suturing.

Level 1 is in the trauma bay, but nurses mostly set that up and use it.

We have the light box. I know most think that it’s unnecessary because our X-rays are digital now, but once in a while you’ll have a patient come in with hard copies of X-rays from other facilities.

There are good distraction items in the room, like the pictures on the ceiling and the TV.

However, the room is small. I don’t like the curtains, I feel it’s not as private.

The indirect lighting is good, it’s nice to alter the ambiance in a room. It can help calm patients.

We need more hand-washing stations.

I see the airway box there in the corner.

The thermometer is standard issue, the pediatric glide scope is in the corner.

Stored items:

We have standardized cabinets, so that cuts down on the time it takes to find things.

We keep the hemoculp developer in the room, so you don’t need to walk around with stool samples, so that’s nice.

However, I do find that during trauma patients, people get tunnel vision when looking for items in the cabinet, they’re throwing things over their shoulders and they’ll throw what they need along with it. On more than one occasion, when we debrief after a trauma case, someone will say “there wasn’t a chest tube in the cabinet” and we’ll go through what was on the floor and there it is.

In general, in the ED, equipment placement and identification is always a moving target. So we’ve moved endo tubes, chest tubes, ob kits after a bad experience.
Appendix D (continued)

The labeling is fine inside the cabinet, I don’t like labeling all over the place, though. I prefer a clean look for the ED. When you put the labels on the outside of the cabinets, the patient sits and obsesses over what’s in the drawer, so they see the label for urine cups or for IV’s or blood work supplies and they tense up as soon as you go for the drawer.

Portable:

The ultrasound is tough, you have to find a good parking spot where that’s out of the way, but still accessible. You pick a spot based on today’s experience and you’ll be wrong tomorrow. You have to understand that ultrasounds, computers on wheels, these things were not in the thought process 20 years ago.

Portable vitals machine is on a pedestal stand with wheels, those are usually stored in a hard to access place.

Overall, the department is built for a paper world. The e-world has different needs, some better, some worse.

The crash carts are well designed, the colors correspond with the different sizes. Adults are standardized throughout the hospital. However, these carts overall are not designed for our needs. So we put together tackle boxes with other equipment, like the airway equipment in the cart has a disposable laryngoscope. The physicians here prefer metal, they’re more durable... so we keep that on the side.

Other:

There are never enough computers, they’re never in the right locations. They need to be everywhere and portable. Everyone is documenting on computers, so usability of software platforms is pretty bad. Like logging in and logging out cuts productivity. If it takes a minute every time and you have to do that 50 times during a shift, you’re losing almost an hour. That’s like 10% of your time.

I’m very happy with the airway equipment here. I’m happy to use that.

Equipment wise, I guess the one thing I would change is that the ear and eye devices tend to burn out.

Participant 8: RN, 10 yrs in ER, 11 yrs overall

Superficial:

The monitor is useful.
Appendix D (continued)

The suction equipment is a necessity. When it’s not there, it’s really bad. Sometimes when the room was just cleaned, it wasn’t stocked properly.

I wish all of the cabinets were on one side, I have to run back and forth a lot.

The rapid infuser, it’s good to have one, it has to be there, but it’s a burden to work around.

The gloves in this room are in an inconvenient spot [over the biohazard trash bin]

The room is asymmetrical.

I’ve used the rapid infuser before, it works pretty well.

Stored:

The stored items are ok. You hook up the patient to the monitor and then you get the blood draw equipment ready. Nurses chose the arrangement, so we’re pretty happy with it.

The [adult] scale is a pain. You have to walk to the store room to get it.

There is only glucometer for 16 rooms, so you need to go look for it all the time.

The vein finder is in the storage room, it’d be nice to have that closer.

Additional O2 tanks are far away, quite a walk to get to those.

Additional chairs or other furniture can be hard to find.

Portable:

The rolling trauma carts are a nice feature.

The size of the room is always challenging, if there is more than one kid, it’s a problem. If parents have to spend the night, you end up with a cart and crib or two carts so the parent can sleep.

I really like the portable COW [computer on wheels]. This lets you have one nurse charting at bedside during trauma cases.

The infant warmer is big, it’s challenging to put in the room. It’s heavy and bulky, but it rolls.

The code carts are nicely condensed, we used to have 2 carts, but now we have just 1.

I like that the airway management stuff is in a tackle box, it’s much easier than going through drawers.
Appendix D (continued)

The capnography monitors can be a pain, there are only 2, so you have to look for that when you need it. It ends up in different rooms.

I really like the lab trays, we have them pre-set so everything is all at your fingertips.

**Participant 9: MD, 8 years ER, 8 years total**

Superficial:

Okay...so the emesis basins on the wall, I like those. They’re easy to find and get to when a patient is actively vomiting.

The X-ray box I’ve used maybe once, we’re mostly looking for big breaks, so even if we get a film, we can just hold it to the light.

I think the soiled linens cart is too big and the rooms are too small.

The transfusion pump is not used often back here [in pediatrics]. It really could be somewhere else, since you have time before it’s needed because we need to confirm blood type and get blood products.

The sharps container, those are fine... nothing bad to say about them, I’ve never had patients try to go through them or anything.

The overhead lights bother me a little. Sometimes they work, sometimes they don’t. If they don’t get moved often, they get dusty so when you do move them, it rains dirt all over the patient.

As far as suction, it’s important to have them all set up. Things get busy, it doesn’t get done. In the main room it’s not set up all the time.

Stored items:

I find I’m always opening cabinets to find things. I’d like to see labels on the front of the cabinets to streamline that. In other hospitals I’ve seen things labeled in towers, that’s pretty nice.

The otoscope and opthamoscope in the main room are often not ready for use. The heads are off, they’re not plugged in.

Portable:

The ultrasound, it’d be nice to have those everywhere. Usually I can’t find it, there’s no central place for it. If the trauma team was using it before you, it’s usually all bloody and disgusting.

Stocking the carts can be a little frustrating.
Appendix D (continued)

Other:

I hate it when I walk into the room and there’s a urinal full of urine just sitting there because housekeeping won’t touch it and they also won’t tell the nurses to deal with it. So I had this poor like 78 year old woman sitting in a room with a urinal full of urine that she clearly didn’t put there. It’s gross.

The biggest thing I’d like to change is for equipment to be where it should be. Everything stocked, labeled, no broken or dirty stuff.

Participant 10: RN, 12 yrs ER, 15 yrs Total

Superficial:

We have the cabinets with all the stuff at arm’s reach. Others have linens, buckets, etc. There is O2 and suction along the wall. The monitor is in reach. Then there’s blood pressure, pulse ox, nasal cannula… gloves, sharps box, all in reach. There’s a thermometer… everything works well.

As far as improvements… we can’t have needles in the room or meds. I’d like to find a way that we could keep those closer.

Stored:

As far as packaging, I really don’t like oral syringe packaging.

The new medicine cups are wasteful, they are 200mL, so you have to throw out the rest of the unit/dose if you don’t need it all.

I don’t like the rectal thermometers. They take too long, gets get anxious and I can’t blame them. They can take up to 60 seconds for a reading.

Portable:

It’d be nice to have 1 stand-up scale for each room.

I’m not a big fan of the vein finder. There’s no depth, you get false readings.

We have the trauma cart, code cart, and the airway kit.

We keep the glide scope in the trauma room.

There’s a latex-free and foreign body box shared with the main room.

There’s a ring cutter and the fluid warmer that get moved around.
With the bear huggers, it’d be nice to have blankets on them so they’re ready to go.

There are exam lights that wheel in and seem pretty useful.

The rape kits, I feel bad doing them. They’re pretty tedious.

The baby scale floats around, but that’s on wheels so it’s easy to move.

The Doppler is on the stand.

Those eye exam things... [researcher: Slit lamps?] Yeah! Slit lamps are running around.

The lights on the wall sometimes don’t work.

There is a vitals machine rolling around.

For the infusion equipment, it’d be nice if there were tubing taped to the back so things are ready to go.

As far as the Level 1, you don’t use that often, so you forget how to use things like that.

I hate giving bicillin shots. They’re hard to push, all cold and gooey, and it really hurts the patients.

I love the rolling vital signs cart. Everything is contained in one little area. The best thing they ever came out with, in my opinion.

**Participant 11: MD, 21 yrs ER, 26 years total**

Superficial:

First thing, the layout of the rooms. Every room should be the same. It should be like a car, so you can find equipment without leaving the patient, like you can turn on your wipers without taking your eyes off the road.

Second, doctors treat from the right, nurses on the left. Equipment storage in the room should reflect that.

Third, the lighting should be centered over the patient, not centered in the room.

It seems there always has to be a balance in equipment in terms of what provides the best patient care and what can be the most integrated. I think we need to integrate the hospital environment with the home environment- mHealth. We should be able to discharge patients with equipment that sends results back so you can send home some of the folks you’d otherwise keep under observation.
Appendix D (continued)

However, in Advocate, home health has a different budget from the ER, so that causes problems. You can’t integrate from the patient’s perspective.

I feel that practicing nurses and docs don’t have much input into the decision made regarding equipment. Once there was an ear thermometer that was really bad. Docs hated it. It took a long time to get that replaced. However, EZ-IO and the current intubation equipment was doctor and nurse driven, so we like that stuff more.

In general, Advocate takes a top-down approach to management. They believe in standardization. 10-15 years ago, the President of Advocate at the time and the head of Northwestern Hospital, which was at the time just starting to create a hospital system, had a debate between hierarchical vs. democratic management styles. Spivey (from NW) pointed out that when decisions are made centrally, some clinicians end up with equipment they don’t like or doesn’t work for them, and then they create work-arounds, which creates more variability in the end. He felt that the democratic process allowed for a more controlled variability. Advocate believed in central decision-making.

But going back to this, we don’t have dimming lights in half of the pediatric rooms. They’re either on or off. You can’t dim the rooms to create a different ambiance.

The monitoring is standardized, that’s mostly a nursing decision.

Stored:

When I think of packaging, suture kits come to mind. I guess there’s a weird compromise between options vs. cost. So suture kits come with a plastic tray for saline. The current kit has a tray that’s divided into three compartments. Why? Now I can’t put as much saline in there.

I’m also surprised how hard it is to keep the hospital stocked. They run out of stuff all the time. It’s a huge system, you’d expect better resupply. By and large it works, though.

I don’t like the IT systems, it’s a waste of my training for me to sit and be a typist.

I like the foreign body kit.

For pelvic exams and STD testing, I have to go fishing for pieces. If you want to be cost effective, you need to be efficient. When you go looking for things you lose efficiency. So, like the ultrasound, the slit lamp.

Portable:

In general, it’s just detrimental to go find something if it’s not in a central location or if it wasn’t put back correctly. There should be RFID or something so I can call up on the computer where it is.
Appendix D (continued)

I don’t like to go fishing through carts. You need to watch the patients. The carts are laid out based on size and weight of the patient, you’re familiar with the Broselow system? [research indicates affirmative] So there you go.

Other:

The computers aren’t laid out very ergonomically. I use bifocals, so I need the monitor a bit lower and I can’t adjust these well. Other people need the screen higher. It seems no one thought of it actually being used. And that matters when I spend 60% of my time in a chair on the computer.

It seems little things that are related are all over the place. For example, with sutures: needles, syringes, and anesthesia are in 3 different places.

Things that make me cringe? The computer generates a gibberish report that’s hard to put data into. You click on a button and it generates stuff. So, I can click “normal rectal exam” and it puts things into the chart that wasn’t what I did. The final product is awful.

I think the ED did a good job integrating lab and X-ray.

The RapidStrep test you have to hand document the QA, it could be 1 click. It’s redundant.

I really love the CPOE system, it’s great.
Appendix E

Focus Group Notes

Physician Participants

1) Describe the clinical conditions/presentations that you feel are challenging to treat, diagnose, or manage.

Participant 5: Psychiatric patients- they may have an underlying medical problem as well as psych condition, then you try to hand off the patient, you have a lack of previous information, patients use fake names and you don’t know the patient’s history. Then there is difficulty handing this information off and the patient can get stuck in limbo.

Participant 7: Past medical records and transfer of records between facilities.

Participant 6: Yes. Sometimes you end up calling County [Stroger Cook County Hospital] to get records from a dungeon.

Participant 3: In the last 10 years, health IT has exploded. It takes too much time to complete data entry. These programs are really designed to help with patient tracking but for the hospital...like to ease billing, not to aid docs.

Participant 7: Patients presenting with weakness are hard to diagnose.

Participant 3: Geriatric baselines are really hard to establish.

Participant 7: When you get patients from nursing homes, it’s really hard to diagnose and treat them. You have no ideas about their background. Sometimes you don’t even know why they were sent to the ER. You call the home, the person who called EMS is off shift, didn’t leave notes. The next person has no idea who the patient even is.

Participant 1: Patients from nursing homes are challenging. Especially if the nursing home is not affiliated with Christ [Advocate Health Care], so there are no records and no notes from the institution.

Participant 3: There is a huge IT disconnect between docs and nurses. When I look at an electronic health record, I have no idea what meds, fluids, etc. were given... Docs don’t even read the nursing notes. The important information is buried. Cerner sucks.

I want to know right away when were meds given? When were fluids given? When were vitals taken? I have to dig in the MAR to find this information. So there is a technical barrier, a cultural barrier, and then no one knows what’s going on.
Appendix E (continued)

So in Cerner we have these power notes and they disappear over time and the residents just do free text notes. For example, chest pain. We generated a power note. But what if it’s not normal chest pain?

So resident compliance is a big deal with that type of system.

Participant 6: If notes need to be redone, then the attending physician needs to redo them.

Participant 1: Pulmonary embolism is hard to diagnose, at least for me. I’m sitting next to a world expert on pulmonary embolism, so maybe it’s easier for him.

Participant 6: Strokes make me nervous. You have to decide when to give TPA and make sure you have a proper diagnosis.

Participant 3: Having no baseline on a [stroke] patient is really hard. You don’t know their “normal”.

Participant 6: And giving TPA is a life changing decision for the doc.

Participant 3: Sepsis or overwhelming infection is really hard to diagnose and treat. The standard protocols are great, but they presume you know sepsis when you see it.

Participant 7: Chest pain is hard to diagnose.

Participant 1: It [chest pain] can be hard, but you have to accept that there is a baseline non-diagnosis for chest pain.

Participant 3: Medical malpractice makes all diagnosis harder. You end up proactively admitting people just to cover your ass.

Participant 6: An unstable patient of any kind is hard to deal with.

Participant 7: Nose bleeds and pediatric fever are challenging to diagnose and treat sometimes.

Participant 1: Lower back pain. I hate when they present with lower back pain.

Participant 3: Yes.

Participant 3: And chronic pain is a waste of time and resources [in the ED]. IDPH has a login for opiate profiles for patients. You can look up opiate prescription history. But this access gives you more confidence to call out prescription pain medication abuse.
Appendix E (continued)

Participant 6: It’s [the opiate registry] helpful, but it would be nice to decrease the lag in prescription history updates. Currently I think it’s like 60 days behind. You also have to change your log-in and password a lot.

Participant 1: See, I never use it [the opiate registry] because I’m not law enforcement. I’m a doc, not a cop.

Participant 7: But I think it [the opiate registry] clears the air more often that implicates for me. I can check on a person who says “I saw this doc, at this time, and he gave me this...” and I can look it up and it’s true, so I feel better about prescribing.

Participant 7: I’ve had trouble with the drug shortage. There are certain meds we just keep running out of.

Participant 3: Apparently now that some of the drugs are older and have run out the patent, drug companies are slowing down production because these meds aren’t profitable. I’d love to see a research study across the country to see who is missing what drugs.

Participant 1: Paralytics in particular.

Participant 1: Strokes are really hard for me to deal with.

Participant 3: Yes. And there are guidelines, many of them conflict, there is just lots of information.

Participant 6: I have trouble with really obese patients. I can’t get access to start an IV or a central line [the needle is too short]. Usually an Easy IO will work even if the patient is fat, but they need a whole line of medical devices to deal with morbidly obese people.

2) Can you name evaluations or assessments that seem to be more time consuming than they should be?

Participant 1: Stroke. Neuro consult takes forever, CT scan, MRI takes forever.

Participant 6: Rape kits. You have to go through all these steps.

Participant 7: How did I become an evidence tech? For me, it’s often been bogus.

Participant 6: Multiple complaint patients take a really long time to evaluate.

Participant 7: Pediatric fever takes a long time to assess. Most of the time it’s nothing, but you want to be sure.

Participant 1: Same with pediatric hip pain.
Participant 3: Psych patients take a really long time. Also trauma patients: you do X-ray, CAT scan twice, serial exam.

Participant 7: Abdominal pain.

Participant 6: Anything that involves nuclear medicine. Ultrasound. Also, vaginal bleeding.

Participant 1: Especially if you try to figure out an ectopic pregnancy.

Participant 3: Typing and crossmatching for blood.

Participant 1: Any sort of transfusion related issue. If everything is perfect, it takes 40 minutes at least.

Participant 7: Deciding to administer RhoGAM.

Participant 3: We’re obsessed with patient safety and it’s causing delays. So we used to have antibiotics in the ED but now we have to get them from the pharmacy. Technology is supposed to be a fail-safe, but it’s massively redundant.

Participant 7: It’s like when my dad was in the hospital once and he needed pain meds. The nurse kept re-asking him his name because of the protocol... but I was like “Just give him his pain meds already, you spoke to him 2 seconds ago.”

Participant 3: I feel like safety is becoming one of those buzz words. We’re doing things without really knowing what is safe vs. what is efficacious.

Participant 7: Any time someone leaves the ER and then comes back, it’s a huge time gap. For example, going to radiology.

Participant 3: The concept of acute heart attack has potential to take a lot of time. So you have the EKG and if it’s a STMI it’s easy, there are guidelines and national standards, but how long it takes to get through that protocol probably varies a lot across the community. If you look at the time it takes to go from symptoms to the cath lab, I bet there is often a lot of wasted time.

3) Can you share an experience you’ve had treating a patient where you felt the outcome would have been better if different technology were available?

Participant 7: Airway management.

Participant 6: When we first switched to the glide scope, the hospital didn’t get this little extra piece, a stylette, and it was impossible to intubate this person. We could visualize [the larynx] but could not get the tube in. The patient ended up chriced.
Appendix E (continued)

Participant 6: I’ve also had trouble with suction.

 Participant 3: We need lots of help tracking inventory in the ED. Where are things? Where can they be found? The people who stock the rooms aren’t docs, they don’t know what stuff is, so they often don’t catch when things are missing or if it’s not quite the same thing.

 Participant 1: There is also variation from room to room [in terms of what is supposed to be present]. So anyone in a hallway bed is going to take longer to work up. There are mix-ups all the time with identifying people, giving the wrong meds., etc.

 Participant 3: Yeah, something like that led to giving CT scan information to the wrong guy.

 Participant 1: So, in our ED, the back hallway is our gynecological area: GC 18, GC19, and GC20. Patient in GC 18 has vaginal bleeding, patient in GC 20 was motor vehicle accident. GC 20 gets confused with GC 18. GC 20 is supposed to get X-ray of c-spine, ends up getting a pelvic ultrasound. She took off all of her clothes, got into the stirrups, had the full exam. The patient doesn’t say anything.

 Participant 7: So then you’re stuck not knowing how to bill your mistakes. The patient shouldn’t pay, but you need to account for the time and the procedure and the stuff used.

 Participant 3: I think we really need to find that balance in the culture of safety. Redundancy slows us down, but we need to find that safety “sweet spot” and layering technology really doesn’t help much.

 Participant 7: Yeah, like our CPOE, it has drop down menus that I have screwed up multiple times by clicking on the wrong thing. So, like on the request for CT, you then have to pick from a drop down list what type of contrast you need. And for some reason “NONE” is right next to “rectal administration”. So I end up ordering a CT scan of the head and rectally administered contrast. It’s not a big deal, radiology catches it and calls me, but you just look stupid.

 Participant 1: There is something like that on the discharge lists, where “nursing home” is below “home” so I’ve accidentally discharged pediatric patients to nursing homes. It just looks unprofessional.

 Participant 3: I wonder how all of this affects health services research. I mean, you have all of these people looking at data from all these records and you have to wonder how accurate some of it is.

 Participant 1: Overall, I think we need better system-wide communication.

 Participant 3: I had a patient once, who came in as a psych patient. The triage nurse sees her, the girl is not in good shape, saying all sorts of bad stuff to the nurse and the nursing note mentions suicidal stuff. The doc sees the girl, she denies suicidal thoughts, no depression, says she’s just drunk. The
psych consult didn’t see the nursing note, patient continues to deny suicidal stuff. She was discharged, and let’s just say there was a bad outcome. We need to be able to autofeed nurse notes into doc’s and psych’s notes.

Participant 1: We need like a data “push” function. Right now we can only pull, and only pull certain things.

Participant 3: Yeah. I really need to see important things. I don’t want everything, just important things pushed to my notes.

Participant 1: I had a guy once... it was early morning on a slow day. The patient was in the hallway, had an epigastric pain complaint. Medical student goes in and does the first interview, resident goes in and sees the patient, guy tells the doc he had epigastric pain but now he’s feeling better. Looks like a minor problem, nothing else is in the chart, no history. A few hours later the guys is back, he got hit by a car, so now he’s a trauma patient. His wife is complaining about the diagnosis. Turns out EMS was called to his house because he was suicidal, it’s on the EMS note. He attempted suicide at home, but the triage nurse didn’t get the EMS note.

Participant 7: Yeah. The paramedics write notes after the patient is admitted, sometimes not until the end of their shift. The hospital gets a piece of carbon paper. So you can’t move information easily from EMS to ED.

Participant 6: EMS is so bad with notes. I prefer to talk directly to the EMT, when you don’t know, you just ask for everything. Nurses don’t know what to ask.

Participant 3: Especially patients with dementia.

Participant 1: It can be like that game “telephone”. You know, the message gets changed a little each time?

Participant 3: I feel like hand-offs are a big problem. I’m not a fan of all this safety bullshit. There’s not much rigorous study. There’s a revolving door in health care, we need to think about how to loop in primary care. Information transfer needs to be seamless, efficient, and include some type of auto-feed. We need to identify key handoffs and emphasize critical, accurate things. Patient records end up full of crap, residents tend to just cut and paste notes and are sloppy about that. So if there were a universal single electronic record, it would be full of crap.

Participant 7: You need someone with a medical background to sort through that information.

Participant 3: You know, the financial sector came up with credit scores. So there are like 3 companies who do things a little differently, but really they can take all of this data about you and how you spend
money and they can key in on some critical things that make you credit worthy. They need something like that for health care, like a health care credit score... so you walk through the door and I know something about the way you live your life and your health in general.

Also, I’d like to see surgical history from other hospitals so that I know how that patient responds.

4) What type(s) of information do you feel clinicians should receive more rapidly?

Participant 3: Old medical records

Participant 3: Patient baseline

Participant 6: How they function at home

Participant 3: A&Ox3 [alert and oriented to person, place and time] doesn’t tell me shit.

Participant 3: Temporal data.

Participant 7: Lab tests, blood tests, radiology. The problem with blood draws is that they are a black hole. Then the doc has to search for the break down. For example, if phlebotomy misses the patient for some reason...they’re getting an x-ray, they’re in the bathroom, whatever... they say they’ll come back, but they don’t. Also, if the blood draw has a problem, like the blood is drawn but it clots in the tube so the test can’t be run, they won’t tell you until you ask.

Participant 1: Right, so that could be solved with the data “push” idea. Like send me a message that the blood draw for patient X didn’t work or hasn’t happened after some period of time or something.

Participant 3: I’d like to know when beds are clean. Why aren’t beds cleaned? They should start some sort of reimbursement by # of beds clean to incentivize getting it done faster.

Participant 1: I’d like to know when beds are available so we can get people out of the ED faster. Also, I’d like to know about antibiotics. Like we have the pharmacist come up and give a talk on what to give when...but I only hear it once and I forget which antibiotic to not give for right now...

Facilitator: So, I helped write a grant to create a regional, real-time antibiogram so that you’d get regional data for what’s going on at all hospitals in the area. Would that be helpful?

All: That would be awesome.

Participant 7: More regional data on the prescription drug network for narcotics. We only have information for Illinois right now. But in Chicago, it’s reasonable that someone might go to Indiana or
Wisconsin...even Michigan or Iowa is reasonable. So if we have someone who has some questionable behavior in another state, we can’t find that.

Also, I’d like to know why the FDA keeps taking drugs away. There were things that worked really well that just keep disappearing.

I’d also like alerts for drug-drug interactions. So they have okay alerts for allergies, but there is no priority on drug-drug interactions. They give the same alert for “there’s a 1% chance that the person will get dizzy” as “if they have both drugs, they’re going to have a heart attack”. The alerts don’t give enough information to allow me to assess risk, so I just don’t listen to them.

Participant 1: Not even color codes work [for alerts]. We need like a black box with smoke to indicate trouble.

Participant 7: I’d like better ways to communicate with other doctors and get feedback.

Participant 6: I’d like something that lets me know when an appropriate bed is open to let me transfer a patient.

Participant 1: It should be like a hotel, they know what rooms are open, clean, etc. We need that data “pushed” to us.

Participant 3: I’d like to have a better link with primary care docs and it’d be nice to know about beds being available.

Nurse Participants

Question 1: Describe clinical conditions/presentations that you feel are challenging to diagnose, treat, or manage.

Participant 3: Septic patients. It’s hard to find the source and to keep them from getting neurotensive. It takes constant care.

Participant 6: Trauma. There are so many different mechanisms and you have to check a lot of things.

Participant 1: Non-English speaking. You can’t talk to them right away... if they’re crashing, there’s no tie to find an interpreter and you have no real patient history.

Participant 4: Non-verbal or non-English speaking.

Participant 4: Just in general, space is a problem.
Participant 3: Yes. Space has been a problem for years.

Participant 1: I mean, I became a nurse 12 years ago and we were complaining about space back then. Now there’s even more stuff around.

Participant 6: I think a big challenge is the general barriers to care. Some people don’t seek out primary care, or they have no insurance, so we [the ED] are the follow up. People wait until they’re too sick to seek treatment.

Participant 1: We are the follow up. [Participant 2 nods head emphatically]

Participant 1: Meanwhile, someone came to the ER for an ear ache. They didn’t need to be here. Their doc told them to come.

Participant 6: But when you can’t get in to see your primary care doc for 10 days, what do you expect?

Participant 4: Well, there’s no copay when you’re in the ER, the primary care folks won’t see the patient until they pay the copay.

Participant 2: Yeah. They don’t have money for health care, but they do for other things that are less important. They have better phones than me.

Participant 6: Sickle cell is really hard to deal with.

Participant 1: Diabetics, especially when they’re DKA [diabetic ketoacidosis]

Participant 6: Chronic heart failure patients.

Participant 1: Doing septic workups for kids

Participant 2: Alcoholics.

Participant 4: Mental illness is the top of my list. You can’t talk to them, you usually don’t get patient history. Then if you have to restrain them you have to fill out restraint packets and I don’t want to fill those out. [all participants agree]

Participant 6: What about stroke?

Participants 2: No, stroke is not a big deal. They come in, they are or they’re not. [Participants 1 and 5 agree].

2) Can you name evaluations or assessments that seem to be more time consuming than they should be?
Appendix E (continued)

Participant 6: As ERs go, ours runs pretty good overall.

Participant 4: The NIH stroke scale, it’d be nice to have something faster with the same accuracy.

Participant 3: The CIWA for alcholoics. [Clinical Institute Withdrawal Assessment used in hospitals to assess and treat withdrawal syndrome and alcohol detoxification].

Participant 4: Psych evaluations. There is a lot involved, security, safety, resources, sitters.

Participant 1: Waiting for social workers, if they’re busy, they take a long time. 2 hours at least per patient, so if we’re third on the list, that’s 4-6 hours of waiting right there.

Participant 4: If a CAT scan is ordered, you need IVs in specific IV sites, done in a specific order. Sometimes you have to rearrange the patient’s IVs to accommodate this.

Participant 6: Managing diabetic patients, a lot of them develop comorbidities. They come in with a DKA situation and they are very critical patients. So there are many labs and lots of assessments to do. Also, if they miss a dialysis treatment, they end up short of breath, they’re critical.

Participant 4: Yeah. When a patient comes in and needs dialysis, the machine is now occupied for 4 hours.

Participant 6: Chemo patients are hard to manage, thinking about your last question. It’s really big when we have someone from oncology and you have to get them adequately and safely cared for in a filthy ER. And they’re all filthy ERs.

Participant 6: [in the ER] we know a little about a lot, so it’s difficult. Varied reasons people come in, varied things to do based on what we think is wrong.

Participant 3: Neuro and trauma assessments take a long time. Neuro in particular... you have to go through a bunch of steps to complete it.

Participant 6: The technology in place helps sometimes. We have template and charting system we follow as a guide.

Participant 3: It’s hard to answer, but if you’re following someone who isn’t good, yours won’t be good [referring to assessments in general]. It takes time. People won’t always be thorough, they have a lot to do, they are busy or maybe they don’t care. So checklists help with that.

3) Can you share an experience you’ve had treating a patient where you felt the outcome would have been better if different technology was available?
Appendix E (continued)

Participant 6: Well, the ER is affected when the OR gets backed up. They [the patient] need to be opened up, but there just isn’t space.

Participant 4: This is more a problem at South Suburban where I used to work, but they didn’t have a cath lab [cardiac catheter lab], so you end up treating patients without full information.

Participant 2: Patients come in unresponsive, with no history. It’d be very helpful to be able to access past medical history. Like dogs with those chips…scan their bellies and you know everything about them.

Participant 1: It’d be nice if you put in a name, date of birth and get the history with an icon you can click that gives you faster access to relevant records, not every single visit.

Participant 6: It’d be nice to determine if we should treat someone medically or transfer them out.

Participant 3: Well, I had one incident in a more rural hospital where I needed to use a rapid infuser for a trauma patient. A guy there laughed at me and said it had dust on it and he had no idea how to use it. Meanwhile I’m sitting here going “uh, this guy is dying here…” And he never brought it in. I don’t know if it was fear or ignorance or that he just didn’t use it that often, but my patient was dying.

Participant 2: I wish the COOLGUARD protocol was around before.

Facilitator: What’s that?

Participant 2: It’s a protocol to induce hypothermia in neuro patients

Participant 4: I’ve noticed more people being revived from new CPR. For example someone comes in who should be dead and we get them back. We revive them and then we need to cool them. We’re getting people back when we wouldn’t before.

Participant 6: We’re lucky, we’re in a teaching facility so the new technology and training is there.

Participant 4: Communicating EKG off the radio from EMS is very valuable. It’s not in Chicago, but the surrounding suburbs have it.

Participant 1: EMS is pretty good about calling in an MI or stroke. EMS is well trained and well versed around here, they call ahead and let us prepare.

Participant 4: The more info we have before they come in, the better. So the ones from the surrounding suburbs can transmit actual EKG readings on the way in.
Participant 1: I love having a PharmD in the department. Years ago, you had to wait a long time to get drugs, now they’re right there, drawing meds.

Participant 4: The problem is that you’re lost if you go elsewhere. You kind of forget how to work the drugs part of a code. However, I’ll take the pros over the cons.

Participant 6: Plus, the offer a huge cost savings in patient safety.

Participant 2: Getting meds out of Omni [Omnicell medication dispenser] is good. It asks questions for safety issues.

Participant 1: Yes, it asks for blood cultures before you get meds. However, you have to reprogram it for pediatrics. On the main floor it’s all critical care, it makes sure the appropriate dosage is taken out. It also has the allergies in the computer, like penicillin, it warns if there might be a cross reaction. We have a lot here.

Participant 1: The EZ IO instead of the cork screw chicken bone thing is really great. We also have vein finders.

Participant 4: Those are cheating.

Participant 1: I know, I don’t like them. You lose your skill.

4) What types of information do you feel clinicians should receive more rapidly?

Participant 6: It would be nice to have labs expedited. You can request this when a sample is drawn, so like with critical patients you can code to call for expedited labs.

Participant 4: Radiology, x-ray, ultrasound...you’re always waiting to get in.

Participant 6: It’s back to the space issue.

Participant 4: The major barrier is that we’re competing with inpatient and outpatient for imaging.

Participant 2: It’d be good to have our own.

Participant 1: I mean, if you need a stat test for testicular torsion, it takes forever to get an ultrasound. Then, after hours, the EEG closes at 3am. They need to keep going. They need to just schedule people later, why can’t we have people come at 8pm after work for a CAT scan?

Participant 2: It all comes down to money.
Participant 3: I agree. Ultrasound and stress tests would be nice to get results from faster. Maybe we should just close at a certain point. [laughter from all]

Participant 2: Cardiac labs take a lot of time.

Participant 1: There is a machine that does cardiac markers.

Participant 4: We really care about triponin and H&H [hemoglobin and hematocrit]

Participant 6: I’d like a point of care electrolyte panel.

Participant 4: They have point of care tests that read cardiac enzymes in 20 minutes, which is better than an hour.

Participant 2: We just need to get through more patients, get them out faster.

Participant 4: ERs make money by volume.

Participant 6: It’d be good to get a UA [urinalysis] faster. It takes about 40 minutes right now.

Participant 4: Microscopic analysis takes a long time.

Participant 1: I’d like to get urine cultures faster.

Participant 4: H&H, pregnancy, creatine, triponens, electrolytes are what I want up front.

5) So, if you were to design the ER of the future, what would it have in it? Don’t worry about how it comes to exist, just what you’d have if anything were possible.

Participant 3: Lots of nurses in triage.

Participant 6: More preventative medicine. I don’t know what that would look like, but it’s what I would want. There’s just not accountability now.

Participant 1: I’d like simple stuff at the doctor’s office to be done better, like taking correct temperature and appropriate treatment for fever.

Participant 3: I’d like someone, an NP maybe, who says “You’re not ER material, go to our clinic down the block”.

Participant 2: I wish people would just take better care of themselves. I know that won’t happen.

Participant 3: Maybe just a hallway to connect people to other treatment options besides the ER.
Appendix E (continued)

Participant 4: I’d like a cart that can go into the CT scanner so I don’t have to transfer the patient.

Participant 6: Or a bedside CT.

Participant 5: Same with the MRI, being able to do an MRI without moving all the pumps, tubing change overs...

Participant 4: Better communication. A doctor gives orders, finishes with a discharge order. All you see is the last thing, the discharge order, so you don’t realize there were other orders first.

Participant 1: Also better communication with other physicians. For example, the ER calls a physician, they don’t talk to the nurse or the ER attending. They just waltz in and don’t even say “hello”. We go check with the family and they say “Oh, they were here.” But they never talk to the ER staff and we’re like “Well, can they eat? Can we give them pain meds?” Then they get pissed off that the ER calls them to ask what’s going on.

Participant 4: I’d like on my cart a ventilator that doesn’t trail behind...is attached somehow.

Participant 3: It would have a gurney with everything on it. Vital signs, etc.

Participant 6: We just saw an amazing talk from a physician here who just got back from a military hospital in Germany that had something like that. I think it was called a SMEED? [Special Medical Emergency Evacuation Device]

Participant 4: I’d like a bed that weighs the patient automatically [e.g., without taring].

Participant 6: I’d like more staff, extra hands around.

Participant 1: I’d like something that secures an IV for diaphoretics, keeps it in place and sticks until you take it off.

Participant 6: There would be a user friendly charting system.

Participant 2: A charting system that doesn’t require stop times for IVs, that they get charted automatically.

Participant 3: Verbal charting. Dictate notes where we’re standing.

Participant 1: Uh. I don’t know...we might end up with words in there that maybe we don’t want. Maybe it needs like “profanity check” or something. [group laughs]

Participant 6: There would be easier ways to move patients.
Appendix E (continued)

Participant 1: I’d like ways to sedate a child more easily, not Versed [midazolam], so that they don’t go nuts when there is a procedure that if they move it screws it up.

Participant 4: Maybe a memory foam bed like cement, they sink in and stay still.

Participant 4: I’d like to see more drugs where you don’t have to start an IV.

Participant 1: Like they sniff it and get what they need.

Participant 6: Well, maybe it should be that imaging should not be as sensitive to patient movement.

Participant 2: I’d like an EKG where you don’t have to be naked from the chest up...in triage.

Participant 6: Yes, maybe a different gown configuration.

Participant 1: Velcro instead of snaps, maybe?

Participant 4: I’d like to levitate patients. Like an anti-gravity bed. [group laughs] What? She said anything we want. I want them to float around and just stick a litter box under them and call it a day.

Participant 1: Like the scooping litter so we can clean it more easily?

Participant 4: Yeah! I want to float them down the hall to X-ray or CAT scan.

Participant 1: Well, that makes me think I’d like a way for females to pee without standing up. Like a urinal for women. The bed pan sucks to their butt, sprays everywhere. It’s awful.
Appendix F

Health Communications

Internal Communication Devices

Nervecentre (http://www.nervecentresoftware.com/index.html): Developed and implemented in the United Kingdom as a workforce management system, particularly to optimize staff during overnight hours. The software is customizable and can be modified easily to reflect hospital governance. The software provides four key capabilities: event capture and notification, mobile device integration, workforce management and optimization, and automated reporting. Tasks (e.g., consult, blood draw, etc.) can be ranked clearly via color scheme (green, yellow, red) to indicate priority, and task completion is easily monitored on a central dashboard.

PerfectServe (http://www.perfectserve.com/index.html): Designed to facilitate “clinician-to-clinician connectivity” by providing automated message routing to physicians based on their preferred methods of communication, such as a phone call or text message. PerfectServe also accommodates team communication; a single message is automatically routed to all members of the required team (e.g., cath team or trauma team). This software supports an “urgent” designation, but does not provide additional prioritization schemes.

Avaya Healthcare Solutions (http://www.avaya.com/usa/): Leverages communication products targeted to small and mid-sized businesses to create a suite of applications tailored to healthcare providers. Avaya designs solutions to address different aspects of the patient care cycle: prevention, pre-admission, treatment/care, discharge transition of care, and post discharge follow-up/home care.
Appendix F (continued)

The “treatment/care” features of Avaya Flare™ are the most relevant to the ED. Flare supports voice, text, and video collaboration through a common interface in both desktop and mobile formats. Users can drag and drop team members into the “spotlight” to automatically initiate communication. Avaya consolidates contacts from multiple sources (e-mail, phone contact list, Facebook, etc.) and also consolidates communication by patient record for easy review of all events related to a case. Avaya Flare prioritizes alerts and messages using “dynamic contextual message prioritization,” but does not generate alerts from patient records, such as when a lab result becomes available. Security and HIPAA compliance are uniquely highlighted; Flare can be removed remotely from a lost, stolen, or out-of-service mobile device (i.e., a provider leaves a hospital that has a Bring Your Own Device policy) and security profiles enforce password compliance, disable screen capture and camera capabilities, and blocks unauthorized app stores.

Patient Handoff Checklist: The literature describes implementing a simple checklist and establishing a quiet area as an effective strategy to improve physician-nurse communication during patient hand-offs (143, 144). It could be considered a radical innovation to mandate the occurrence and location of inter-professional communication; providing low-tech solutions to ER challenges will give providers who are not comfortable with Smartphones or other devices an opportunity to express themselves fully.

External Communication

transmission of EKG data from the field is well established in some hospitals (including the study site),
CodeHeart supports video and camera, allows teleconferencing with cardiologists, and creates a digital
archive of the entire session that can be appended to an electronic medical record. While CodeHeart is
designed primarily for suspected heart attack patients, the underlying capabilities could be adapted to
a number of conditions. Future applications include providing telemedicine support to first responders
and volunteers during disaster response.

AirStrip CARDIOLOGY (http://airstriptech.com/): Provides wireless mobile transmission of ECGs,
digital visual enhancement with touch screen capabilities, and access to historic data. AirStrip allows
simultaneous review of multiple strips and interoperates with lab and medication modules.

Surgichart (http://www.surgichart.com/): Mobile application that facilitates chart sharing and
consultation. Though it is designed to improve communication between surgeons, it could be adapted
to ED use and would allow physicians within the ED to review charts together or could facilitate
external consultation (Surgichart automatically deidentifies clinical data in collaboration mode) with a
primary care provider. Several social networking sites that could provide improved external
communication between ED physicians and PCPs and specialists.

Doximity (https://www.doximity.com/): Networking site with 707,000 physician profiles that
include office, fax, and back office phone numbers. Doximity also supports HIPAA-compliant messages
and images through text or fax.
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Sermo (http://www.sermo.com/): Hosts a network of 130,000 verified physicians. Sermo features an iConsult feature that allows sharing of lab and imaging results, photos, and other information through an iPhone app. There were no innovations found that were specifically designed to aid communication between the ED and nursing homes.

**Patient History**

Health Information Exchanges: Retrieval of *relevant* patient history was the third context participants identified as an area for technological improvement. Electronic health record interoperability is a cornerstone of modern health information policy and research; establishing EHR adoption and interoperability was the subject of a Presidential Executive Order (13335) and prompted the creation of the Office of the National Coordinator. Many concurrent efforts at local and regional levels to establish technical guidelines and governance will allow physicians or other appropriate providers to instantly access to prior patient information. Government-sponsored projects have not yet spawned a tangible product with defined or finalized specifications, but Massachusetts received funding to demonstrate the first statewide health information exchange (HIE) in August of 2012. The project is schedule to implement three phases: 1) establish a secure information highway; 2) use the data to improve healthcare; and 3) launch patient-specific information search and retrieval. Ultimately, access to the HIE will be made available through subscriptions.

MobileMD 4D HIE (http://www.mobilemd.com/): A privately held HIE that operates in “four dimensions”: care, service, economic, and technology. The 4D HIE has demonstrated the ability to
Appendix F (continued)

connect to a range of health information systems developed by different vendors and can also accommodate practices that are not currently using an EHR.

MedXCom (www.medxcom.com): Free app that allows individuals to create a personal health profile (PHP) based on medical records and lab results from a variety of sources that they could consent to share with physicians or other providers. PHPs can be viewed or modified through a web portal or Smartphone. Healthcare providers pay a subscription to access PHPs and other advanced features (e.g., scheduling, telephone system).

VueMe by MIM Software (http://www.mimsoftware.com/): A remote imaging tool designed for patient use. VueMe allows patients to obtain digital images from a doctor; store them on an iPad, iPhone, or iPod touch; and share them easily with a specialist or family members.

All of the HIEs described feature secure access to patient data over time, from a number of relevant sources, based on patient consent. There are two strategies currently emerging, however, to address physician access to patient history: 1) a provider-oriented model designed to accommodate the needs of clinicians, researchers, insurers, and others; and 2) a consumer-oriented strategy designed to facilitate communication only between patient and provider. Both strategies will likely advance in parallel during the coming years, but the distinction between the approaches should be reflected in the concourse, as a preference for one over the other will dramatically affect adoption.
Appendix F (continued)

**In-vitro Diagnostics**

**Laboratory-Based IVDs**

VYOO ([http://www.sirs-lab.com/english/products-services/vyoo.html](http://www.sirs-lab.com/english/products-services/vyoo.html)): Real-time polymerase chain reaction assay that simultaneously identifies the pathogen causing sepsis and its resistance profile in approximately 3.5 hours.


Randox ([http://www.randox.com/cerebral.php](http://www.randox.com/cerebral.php)): Markets two cerebral arrays—one that identifies whether a patient has had a stroke and a second that predicts their risk for future strokes or cardiovascular mortality.

**Point-of-care IVDs**

The point-of-care IVD market has rapidly expanded in the last five years and now includes many products relevant to EDs. While a trade-off between time and accuracy is expected in point-of-care products, some of the first-to-market diagnostics performed so poorly that many clinicians are highly
skeptical of the point-of-care concept in general. A broad range of point-of-care innovations were included to gauge what capabilities are sufficiently attractive to overcome any negative expectations based on previous experiences.

**BRAHAMS PCT by bioMerieux** ([http://www.biomerieux-usa.com/](http://www.biomerieux-usa.com/)): Point-of-care assay that measures Procalcitonin (PCT) levels to stratify the risk of sepsis. The assay requires a 200uL blood sample, which is processed by the VIDAS line of automated, tabletop immunoanalyzers, providing a result in approximately 20 minutes. There are several FDA approved point-of-care diagnostics for cardiac markers designed specifically for ER use. bioMerieux markets the

**Troponin I Ultra by bioMerieux** ([http://www.biomerieux-usa.com/](http://www.biomerieux-usa.com/)): Provides Troponin I, CK-MB, Myoglobin, NT-proBNP levels in approximately 20 minutes. Samples are processed by the VIDAS automated, tabletop immunoanalyzer.

**Abbott i-STAT** ([http://www.abbottpointofcare.com/](http://www.abbottpointofcare.com/)): Provides a series of test cartridges, which are processed by a handheld reader. The i-STAT system uses separate cartridges for congestive heart failure (measuring BNP) and acute coronary syndrome (measuring cTnI); each test takes 10 minutes.

**Alere Triage System** ([www.alere.com](http://www.alere.com)): Handheld immunofluorescence reader that uses disposable plastic panels to perform multiplexed quantitative analysis of cardiac and pulmonary embolism markers (Myoglobin, CK-MB, Troponin I, B-type Natriuretic Peptide and D-dimer) that can be completed in 15 minutes.
Another challenging diagnosis mentioned was obstetric complications. Recently discovered biomarkers may provide a new diagnostic option to complement, or possibly replace, ultrasound.


Nursing participants emphasized the need to decrease the amount of time it takes to obtain laboratory values; implementing point-of-care diagnostics to obtain critical lab values is one strategy to accomplish this. Specific values of interest included hemoglobin and hematocrit (H&H), creatinine, troponins, and electrolytes.

Piccolo Xpress ([http://www.piccoloxpress.com/](http://www.piccoloxpress.com/)): Uses “reagent discs” to perform assays of blood or urine in approximately 20 minutes. The provider places a few drops of fluid on the disc, places the disc in the analyzer drawer (similar to a CD player), and the analyzer completes the assay and provides digital and printed results. The assays performed depend on the selected reagent disc, but the comprehensive metabolic panel (ALB, ALP, ALT, AST, BUN, Ca, Cl⁻, CRE, GLU, K⁺, Na⁺, TBIL, tCO₂, TP) would provide most of the laboratory values identified above. The analyzer is about the size of a shoebox and is used currently in forward military hospitals.
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EKF Lactate Scout+ ([http://www.ekfdiagnostics.com/Lactate_Scout_121.aspx](http://www.ekfdiagnostics.com/Lactate_Scout_121.aspx)): Provides lactate readings in approximately 10 seconds. The Lactate Scout+ platform is similar to a blood glucose monitor: a sensor strip is placed in an analyzer, the sensor strip collects the proper amount of blood following a finger prick, the analyzer displays the reading, and the sensor strip is discarded. The analyzer is Bluetooth enabled to allow data transfer to an EHR. Its measurement range is 0.5 - 25 mmol/L, with imprecision of ±3% (minimal standard deviation 0.2 mmol/L).

EKF Hemo Control ([http://www.ekfdiagnostics.com](http://www.ekfdiagnostics.com)): Provides a simple handheld diagnostic that uses blood drawn from the finger to provide H&H results in 25 seconds.

**Non-invasive Monitoring**

Mobile CareGuide 3100 ([http://www.reflectancemedical.com/](http://www.reflectancemedical.com/)): Provides continuous monitoring (once per minute) of muscle oxygen saturation (SmO₂), muscle pH (pHm) and blood hematocrit (Hct). A reusable sensor, slightly smaller than a graphing calculator, is placed in a disposable pocket that is affixed to a patient’s calf, shoulder, or thigh, using a durable skin adhesive. The sensor never touches the patient, making it easy to clean. Data can be transmitted wirelessly to the patient monitor or to an EHR.

Masimo HEMOGLOBIN ([http://www.masimo.com/hemoglobin/](http://www.masimo.com/hemoglobin/)): Provides non-invasive hemoglobin monitoring either continuously (using an adhesive sensor) or intermittently (through a finger clip probe, similar to a pulse oximeter).
Collecting ECGs is a standard of care in EDs to monitor heart function. Given that chest pain is among the most common patient presentations, a large number of ECGs are performed daily. ECGs require the placement of electrodes across the chest and on the arms and legs. Wires connect the electrodes to a recorder and signals are interpreted to assess cardiac health. The problem with this configuration is that patients must disrobe (at least from the waist up) and remain unclothed during the assessment; the triage area in the study site ED does not have a private area to conduct ECGs, so patients may have to spend some amount of time exposed in a semi-public area. Several configurations of wireless technologies can address this challenge.

Mini-MEDIC by Athena GTX (www.athenagtx.com): Forehead-mounted triage monitor that links to a 5-lead ECG. The monitor measures SpO2, pulse rate, heart rate, skin temperature, and contains internal algorithms that calculate pulse wave transit time and Murphy Factor (essentially a patient status summary that ranges from 0-5 with 5 indicating critical condition). The forehead monitors communicate with a wristwatch that serves as a monitor capable of tracking up to 10 patients at a time, and alerts providers to sudden deterioration in patient status.

ViSi Mobile from Sotera Wireless (www.sonterawireless.com): Continuously monitors ECG (5-lead), heart rate, non-invasive blood pressure, respiration rate, SpO2 and skin temperature using electrodes, an arm-mounted sensor, a thumb sensor, or a wrist monitor. Near-term upgrades will include continuous non-invasive blood pressure and patient posture/activity readings (these capabilities have been demonstrated and are under FDA review). ViSi Mobile also supports monitoring of multiple patients and can track patients who are not assigned a location.
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“E-Bra” prototype: Integrates sensors into a sports bra or vest to collect ECG, EEG, body temperature, heart rate, and blood pressure data, which can then be sent wirelessly to a cell phone. Demonstrated recently by researchers at the University of Arkansas.

LifeSync (http://www.lifesynccorp.com/index.html): Provides a 12-lead ECG with disposable electrodes that can stay with the patient throughout the continuum of care. The leads plug into a transceiver (placed in a gown pocket or worn on an armband) that communicates wirelessly with a monitor that attaches to any standard ECG monitor to create traces.

InfraScan (http://www.infrascanner.com/): Designed as a triage and screening tool to determine the need and priority for a CT scan to confirm intracranial bleeding. The InfraScan couples wirelessly with a PDA for data processing and result display; green regions indicate no hematoma detected, red indicates a possible hematoma.

DynaDx (http://www.dynadx.com/): Multimodal Pressure-Flow technique for the diagnosis of stroke and other conditions that disrupt cerebral autoregulation. The technique applies complex signal processing to blood pressure and blood flow velocity and then calculates the phase difference between those two oscillatory modes to create a phase shift index. If a patient experiences an event that disrupts cerebral autoregulation, such as a stroke, the phase shift index decreases. Research is ongoing to establish whether phase shifts for different clinical conditions differ (e.g., whether hypertension can be distinguished from stroke). This is a relatively immature technology, but if a consistent difference is discovered, clinicians could use this technique during routine examination to diagnose stroke.
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**New Treatment Options**

In addition to being identified as a challenging diagnosis, sepsis was also identified as challenging to treat. This perception is reflected across the medical industry as increased public and private funding has supported the development of several companies with different strategies for treatment. The majority of the new generation of treatments focuses on extracorporeal blood purification.

*Cytosorb* ([http://www.cytosorbents.com/tech.htm](http://www.cytosorbents.com/tech.htm)): Designed to selectively filter cytokines when infection or injury causes them to be elevated to toxic levels. While this treatment is not specific to sepsis, it can protect the patient from organ failure or death while a definitive diagnosis is sought. The broad applications of this treatment strategy may make it more appealing to the ED, where multiple applications for a single technology are considered very favorable.

*Toraymyxin* ([http://www.spectraldx.com/toraymyxin.html](http://www.spectraldx.com/toraymyxin.html)): Sepsis-specific therapeutic hemoperfusion device that removes endotoxin from the bloodstream as an adjunct to conventional therapy.

*Aethelon Medical* ([http://www.aethlonmedical.com/](http://www.aethlonmedical.com/)): Signed a contract with DARPA in September of 2011 to modify its hemopurifier to prevent sepsis in wounded soldiers, but no details about the technology are currently available.
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Nursing participants identified a desire to improve drug delivery mechanisms. Several novel medical devices are emerging to assist with drug delivery. There are three emerging methods for drug delivery

“Solid-in-oil nanodispersion” prototype: Enhances the permeability of proteins (in this case insulin), so they can be administered through a cream, spread on the skin. Demonstrated by a research group in Japan.

Pantec Biosolutions P.L.E.A.S.E. Professional (http://www.please-professional.com/): Uses lasers to condition the skin with micropores to facilitate drug delivery.

Echo Therapeutics Prelude SkinPrep System (http://echotx.com/prelude-skinprep-system.shtml): Uses ultrasound to disrupt the stratum corneum to facilitate drug delivery.

Needleless injection is another popular area for drug delivery innovation. Needleless injections are intended to be more comfortable for patients and less risky for health providers. These technologies rely on a pressurized stream of air or fluid to force drugs through the skin.

Sumavel DosePro (http://sumaveldosepro.com/): Subcutaneous delivery of sumatriptan (a migraine medication).

Jet Injector Prototype: Engineers at the Massachusetts Institute of Technology have demonstrated a jet injector that is powered by a Lorentz-force motor will accommodate liquid or powder formulations and allow control over injection depth and volume. Finally, there are several medical devices on the market designed to facilitate inhaled drug delivery.

Aerogen OnQ (http://www.aerogen.com/technology/on-q/) uses vibration to aerosolize inhalational drugs.

OptiNose (http://www.optinose.com/): Uses breath-powered nasal delivery to administer drugs to the nasal cavity and overcome current challenges in mucosal drug delivery, such as drug deposition on the throat or in the stomach. The OptiNose offers both liquid and powder delivery devices.

Finally, there is a growing body of evidence that mild hypothermia induced following resuscitation improves survival and neurological outcomes. The goal of therapeutic hypothermia is to reduce a patient’s body temperature by 4°C for 24 hours. There are currently several methods to induce hypothermia, but each method also introduces significant risks; for example, chilling blankets induce shivering which requires the administration of paralytics. Introducing chilled saline through the circulatory system (via a central line) increases the risk of blood clots and infection.
Advanced Cooling Therapy (http://advancedcoolingtherapy.com/): Developed the Esophageal Cooling Device to mitigate both of these risks by circulating chilled saline through a closed system placed in the esophagus to induce hypothermia.

**Imaging**

**Handheld Imaging**


MobiSante MobiUS (http://www.mobisante.com/): A single crystal ultrasound probe that interfaces with a Smartphone through a micro-USB port.

Aribex Nomad Pro (http://aribex.com/): Handheld x-ray system, currently cleared for dental applications. Aribex has developed a more powerful unit, intended for imaging extremities (e.g., hand, wrist, arm, foot, ankle, etc.), which is currently under FDA review and is anticipated for release in 2014.

**Portable Imaging Technologies**

Several portable x-rays and CT scanners are commercially available and allow patients to receive diagnostic imaging without leaving their room.

MinXray, Inc. (www.minixray.com): Streamlined, portable, digital X-ray units that are mounted to a stainless steel stand designed for use in austere environments. These units are deployed currently
with forward military medical units. System set-up takes less than 1 minute and image acquisition takes less than 10 seconds.

Mobilette Mira ([www.medical.siemens.com](http://www.medical.siemens.com)): Powerful, high resolution x-ray with flexible positioning, a wireless detector option (for easier placement under a patient), and wireless communication options. The unit is motorized to aid with movement from room to room. GE has produced a similar mobile x-ray platform, the Optima XR220amx.

Neurologica Portable CT Scanners ([http://www.neurologica.com/](http://www.neurologica.com/)): CereTOM is an 8-slice head and neck CT that is safe for use in patient rooms, is wireless (no power or data cables are required during operation), plugs into a standard outlet for recharging, and integrates with hospital gurneys so that patients need not be transferred to another bed during the scan. BodyTOM, also by Neurologica, supports 32-slice full body imaging (2 meter maximum scan length). BodyTOM is also safe for use in patient rooms and plugs into a standard wall outlet, with a battery power option, but does require patient transfer to another bed to complete the scan.
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