

Comparative Evaluation of the Content and Structure of Communication using Two Handoff Tools: Implications for Patient Safety

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Competing Interests

All authors have completed the Unified Competing Interest form at http://www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: all authors were supported by a funding from the James S. McDonnell Foundation (JSMF); no financial relationships with any other organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Abstract

Purpose: Handoffs vary in their structure and content, raising concerns regarding standardization. We conducted a comparative evaluation of the nature and patterns of communication on two functionally similar, but conceptually different handoff tools: SOAP (Subjective, Objective, Assessment and Plan), based on a *patient problem-based* format, and HAND-IT (*Handoff Intervention Tool*), based on a *body system-based* format.

Method: A non-randomized pre-post prospective intervention study supported by audio-recordings and observations of 82 resident handoffs was conducted in a MICU. Qualitative analysis was complemented with exploratory sequential pattern analysis techniques to capture the characteristics and types of communication events and breakdowns.

Results: Use of HAND-IT led to fewer communication breakdowns [$F(1,80) = 45.66, p < 0.0001$], greater number of communication events [$t(40) = 4.56, p < 0.001$], with more ideal communication events than SOAP [$t(40) = 9.27, p < 0.001$]. Additionally, the use of HAND-IT was characterized by more request-response communication event transitions.

Conclusion: HAND-IT's body system-based structure afforded physicians the ability to better organize and comprehend patient information, and led to an interactive, and streamlined communication, with limited external input. Our results also emphasize the importance of information organization using a medical knowledge hierarchical format for fostering effective communication.

Keywords

Handovers, Care Continuity, Information transfer, Critical Care

Background and Significance

Patient handoffs refer to the transfer of care services between providers during care transitions (1-3). While handoffs are key to maintaining continuity of care (4), they are considered a threat to patient safety due to the inherent breakdowns and errors in their execution. Earlier reports have suggested that handoff breakdowns contribute to nearly 35% of medical errors and adverse events (5). These errors arise as a result of a variety of communication challenges caused by differences in hierarchy, language and general communication skills, and expectations between oncoming and outgoing clinicians (6-12).

Recent research has suggested the key role of handoff content frameworks in standardizing the structure of communication (4). While clinician conformance to these content frameworks has been questioned (13), these frameworks impose an information organizational format with a list of items that have to be communicated during handoffs (such as patient identifiers, illnesses, labs, and management plans). The *problem-based* and the *body system-based* models are two commonly used content frameworks. The problem-based model (14) (15-18) supports the structuring of information around the key patient problems, while the body system-based model (19), allows the organization of information by body/organ systems (e.g., cardio-vascular, pulmonary, and neurology).

Informed by these frameworks, several handoff tools have been developed to support communication between clinicians during transitions. These tools manifest in the form of checklists (20, 21), templates (22-25), and EMR-integrated systems (26-30). While a majority of handoff tools utilize the problem-based model as a mechanism for structuring communication (24, 31), the system-based tools have been used sparingly for supporting handoffs (32). Despite such efforts, several researchers have highlighted shortcomings in the development and evaluation of handoff tools based on these frameworks (33-36). For example, problem-based tools have been criticized for their open-ended

yet limiting structure of content organization, which increases the potential risk for information loss and inconsistencies in communication.

While there are several research studies that report on the various types of handoff tools, there is limited research on (a) the differences in the patterns of communication fostered by different handoff tools and (b) the impact of these differences on handoff communication breakdowns. Our research objective is to compare the *effectiveness* of the nature and patterns of communication using two functionally similar, but conceptually different handoff communication structures: a patient problem-based model, and a body system-based model. To compare the effectiveness of communication afforded by two content models, we evaluated a problem-based, *SOAP* (Subjective, Objective, Assessment and Plan) and, an indigenously developed, system-based *HAND-IT* (*HAND*off Intervention Tool) (37). Our methodological approach contrasts with prior evaluation studies on handoff tools that have primarily used survey-based and self-reported measures (17, 23, 32, 38, 39). We focus on the analysis of the content of communication and the inherent communication breakdowns during these interactions. Communication breakdowns represent the gaps in available information and provide a systematic basis for evaluating the impact of the tool structure on communication effectiveness.

Method

This study was part of a larger study involving the evaluation of handoffs in critical care settings. In this paper, focus on the comparative evaluation of two handoff tools: SOAP and HAND-IT.

Study Setting

The study was conducted in a 16-bed, closed MICU (Medical Intensive Care Unit) of an urban academic hospital in Texas with approximately 55,000 emergency department visits per year. Patients

in this unit stayed for an average of 4 days and required multiple handoffs (additional details in Section 3 of appendix).

Handoff Tools used for Evaluation

SOAP: SOAP uses the problem-based information organizational format that includes subjective information (e.g., patient history), objective information (e.g., vital signs), assessment information (e.g., differential diagnosis) and plan-related information (e.g., new procedures, orders). A detailed description can be found in the appendix (See Section 2).

HAND-IT: HAND-IT was designed and developed at this research site as part of a multi-year longitudinal study that evaluated the overall handoff process (40, 41). The tool content was structured based on the body system model that mirrors the medical school training curriculum (42) in supporting standardization of content (43). The order of the body system information is based on importance and relevance to critical care workflow: pulmonary, cardiovascular, infectious disease, renal/genitourinary, GI/liver/nutrition, neurology, endocrinology and hematology. The fundamental content categories are organized in a *checklist format* that includes physical exam/labs, medications, problem list, assessment and plan and system diagnosis for each body system. Furthermore, we included categories such as patient admission, pending tasks, and important management events during the past shift and contingency plan, to support summarization through patient-case narratives. A detailed description can be found in the appendix (See Section 2).

Physician Handoffs in MICU

As there was no formal resident “sign-out” procedure at the study site, morning rounds were used for handoffs between resident teams. During these group handoffs, an outgoing team (resident and/or intern) presented patient care-related information by verbalizing the written content on a handoff tool to an oncoming team (attending, fellow, resident and intern). Patient nurses, pharmacists and respiratory

therapists also attended these sessions. The attending physician moderated the discussion, which often involved follow-up questions on the information presented. The rest of the oncoming team played a “passive” role, by interjecting into the discussion when necessary to provide supporting information or clarification (40) (See section 1 in Appendix).

Participants

There were 10 participants over the study period of 2 months: 2 attending physicians, 4 interns and 4 residents. The participants were divided into two teams: each team was in the MICU for a period of 1 month and consisted of 5 core participants who participated in the rounds for that entire month (1 attending, 2 residents (PGY 2/3) and 2 interns (PGY 1)). In addition to this, there were 2 fellows, 12 nurses, 2 RRTs, 6 medical students who participated in the rounds. Each intern/resident was responsible for up to 8 patients at a time¹. A total of 82 individual handoffs were conducted across both tools (41 for each handoff tool). The institutional review board of the hospital and university approved the study and written consents were obtained from all participants.”

Study Design

We used a *non-randomized pre-post prospective* intervention study to compare the effectiveness of communication between two handoff tools. In the *first* month, team 1 (5 participants: 1 attending, 2 residents and 2 interns) used SOAP for 4 days as part of their training, followed by 2 days of testing. Immediately after this, team 1 used HAND-IT for 4 days as part of their training, followed by 2 days of testing. In the *second* month, the tools were presented to team 2 (a new set of 5 participants: 1 attending, 2 residents, and 2 interns) in the reverse order for counterbalancing the effects of tool use. The training period helped the participants become introduced to and familiarized with the information

¹ While residents were primarily in charge of all the patients in the unit, interns were allocated half of the MICU patients to their care. This allocation was based on a number of factors including patient criticality and intern expertise.

content and structure of the tool. This also helped them understand the information categories that were required from various information sources, and the information expectations of the oncoming team. Data for analysis were collected only during the testing days (additional details can be found in Section 3 in appendix).

Data Collection

Data collection involved audio recording of interactions during handoffs. The first author took copious field notes on the contextual features underlying these communication exchanges. A total of 96 hours of data were collected. Handoffs during morning rounds commenced around 8AM and lasted approximately 4 to 5 hours. The MICU team moved around the unit as they progressed through the list of patients. There were 41 patient handoffs over 4 days using SOAP ($M = 10.25$ /day, $S.D. = 3.51$) and 41 patient handoffs over 4 days using HAND-IT ($M = 10.25$ /day, $S.D. = 2.22$). All data were transcribed verbatim for further coding and analysis.

Data Analysis: Qualitative

Qualitative analysis was based on a structured *handoff communication framework* that captured the communication events (CE) (10) and breakdowns. This framework was developed and validated in a previous study (40, 41). The framework reflects the evolution and progression of the “process” of handoff communication activity and accounts for the nature and distribution of the *communicative events* that unfold during the conversation, the *communication breakdowns* during these interactions, and the roles played by the different participants.

The framework (Figure 1) captures the communicative exchanges between a *sender* (i.e., outgoing resident/intern) and a *receiver* (i.e., oncoming attending), and the rest of the team including oncoming fellow, resident/intern (and other participants during rounds). The sender presents information that is evaluated by the receiver (i.e., attending) for accuracy and completeness. The attending makes one of

three decisions based on the initial presentation: *accept*, *reject*, or *request* information. If the decision choice is *accept*, then presented information is accepted towards the assessment and plan (A&P). If the decision choice is *reject*, then a communication breakdown results (*Type 3* – inappropriate/ irrelevant information presented by the sender). In such situations, a decision-making cycle is initiated where multiple options are examined and evaluated against the criteria, and a suitable decision option is selected. If the decision choice is *request* additional information, then the sender (i.e., outgoing resident) can respond with additional information, which is further evaluated. If the additional information is accurate and sufficient, it is accepted by the attending and added to A&P (referred to as *accept 2*). If the additional information provided is inaccurate or insufficient, it results in a *communication breakdown* (*Type 1* or *2*); in such situations, other team members can provide the required information to address this breakdown. In cases where the team is able to provide supporting information, it is accepted by the attending and added to A&P (referred to as *accept 3*). Alternatively, if the team is unable to provide complete and accurate information, a *team communication breakdown* occurs (*Type 4*), forcing the entire group (oncoming and outgoing teams) into a *collaborative problem solving cycle*, which involves seeking, reviewing and critiquing information, making sense of it, and applying it back to potentially address the problem. All verbal transcripts of handoff communication using both SOAP and HAND-IT were coded using this framework.

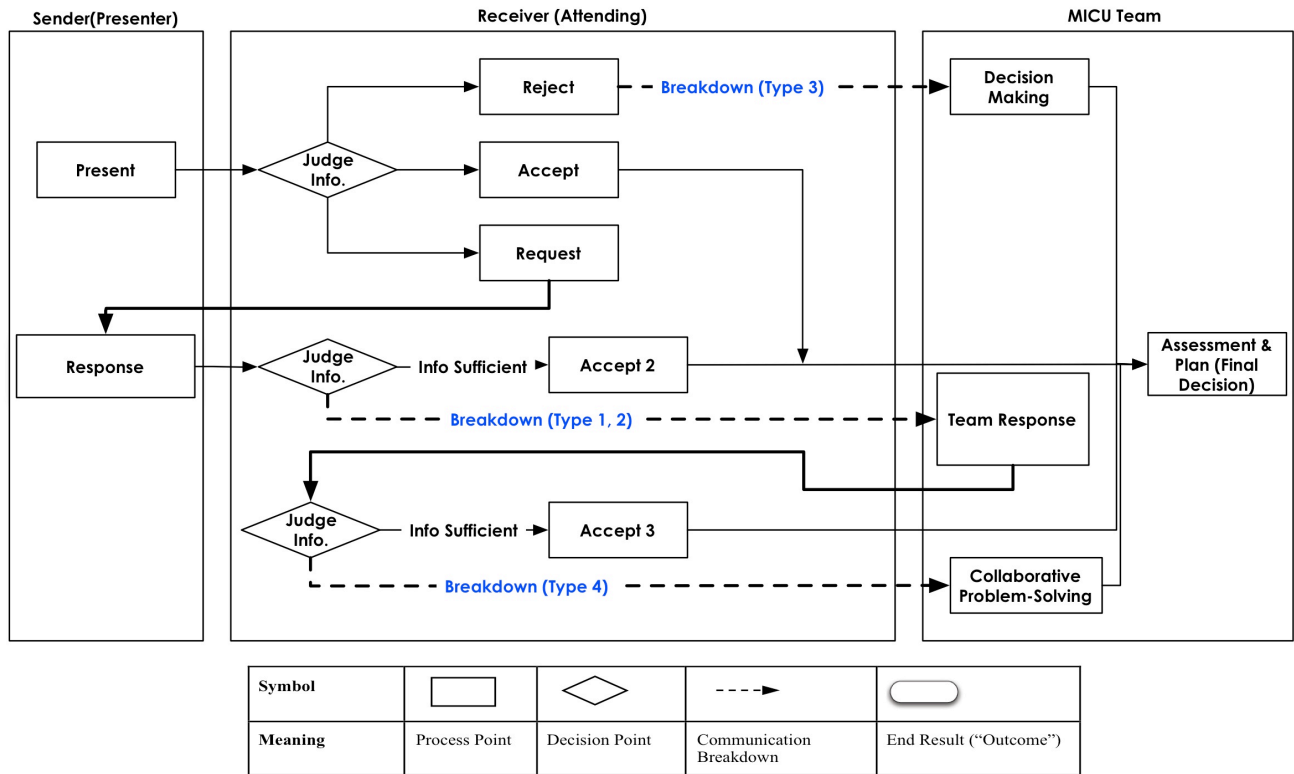


Figure 1. Handoff communication framework that evolves between the sender (resident/intern) and receiver (attending): the framework shows the range of communication events that arise during the process of handoff communication. The figure has been adapted from Abraham et al. (40) with permission [Reprinted from *Journal Biomedical Informatics*, 45, Abraham et al., *Bridging gaps in handoffs: A continuity of care based approach*, 240-254, (2012), with permission from Elsevier.]

Communication Events during Handoffs

A *communication event* refers to the passing of a message through a channel for a particular purpose. Based on the framework, communication content was classified into eight unique CEs (Table 1). Of these, “present” and “response” events were always attributed to the sender (i.e., resident/intern), “accept,” “accept 2,” “accept 3,” “request,” and “reject” were attributed to the attending physician, and “team response” was attributed to an MICU team member. For clarity “accept” events after multiple deliberations were categorized as “accept 2” (secondary accept) or “accept 3” (tertiary accept).

CEs were categorized as ideal or non-ideal CEs based on their impact on communication effectiveness and efficiency. The ideal/non-ideal categorization emphasizes the quality of transfer of information within a noisy channel (44) and must be interpreted within the handoff communication framework (Figure 1). *Ideal CEs* were instances where information presented by the outgoing team was sufficient and accurate (including their responses): “present,” “accept,” “request,” “response,” “accept 2.” In other words, the presence of more ideal CEs was representative of *streamlined* communication with limited extraneous discussions (e.g., from the team) in response to a communication breakdown. *Non-ideal events* referred to instances that required information from the team and were representative of a *communication breakdown* (e.g., requested information not provided by the resident): “reject,” “team response,” “accept 3.” Two researchers (JA, TK) coded the data with a high degree of inter-rater agreement (Cohen’s *Kappa* = 0.972). Inter-rater reliability was calculated based on TK coding 25% of randomly selected content (equivalent to 2 full transcripts).

Table 1. Communication events (10) during handoffs (from the handoff communication framework).

Communication Event	Description
<i>Present</i>	Sender presents patient information
<i>Accept</i>	Receiver acknowledges and accepts presented information by sender
<i>Request</i>	Receiver requests for additional information from sender
<i>Response</i>	Sender responds to the requested information by the receiver
<i>Accept 2</i>	Conditional accept of response information provided by sender based on its accuracy, relevance and completeness
<i>Team response</i>	External team responds to the requested information by the receiver
<i>Accept 3</i>	Conditional accept of response information provided by team based on its accuracy, relevance and completeness
<i>Reject</i>	Receiver rejects the information presented by the sender for its irrelevance/inappropriateness

Communication Breakdowns during Handoffs

A *communication breakdown* is a gap or failure in conveying a message by the sender (or team) to the receiver. These were categorized into *four types* based on the nature of the information gap: incomplete information, inaccurate and conflicting information, irrelevant information (all from the sender) and incomplete, inaccurate, or irrelevant information from the team (See Table 2).

Table 2. Types of communication breakdowns

Communication Failures*	Description	Example
<i>Type 1</i>	Incomplete information (from “sender”): <i>Inability of the outgoing team to provide requested additional information.</i>	<i>Outgoing Resident:</i> So, currently, her sodium is 134, her potassium is 2.9, chloride is 93, Co2 is 25, ...is 7, ...03:25:27 creatinin is 0.6 which is improving to 1.8, glucose is 138, calcium 8.2, phosphorus 60, mag 1.8, I am not sure if I requested it this morning so we have to check the orders <i>Oncoming Attending:</i> And her K, do you know if you replaced K this morning? <i>Outgoing Resident:</i> I don’t know. <i>Oncoming Team:</i> The K was at 145 this morning. <i>Outgoing Resident:</i> I haven’t written them down
<i>Type 2</i>	Inaccurate and conflicting information: <i>Inability of the outgoing team to provide correct information.</i>	<i>Oncoming Attending:</i> what’s her Tmax? <i>Outgoing Resident:</i> Her Tmax is 99. Her ABG was 7.33, 58, 119. And that’s all on 7 liters nasal cannula. <i>Oncoming Team:</i> so, actually that last one was on BiPAP 12, 5 and FiO2 40.
<i>Type 3</i>	Irrelevant information: <i>Inability of the outgoing team to provide appropriate information</i>	<i>Oncoming Attending:</i> I don’t understand what caused the raging tracheobronchitis, that’s all. That’s not what she went to the hospital with to start with. <i>Outgoing Resident:</i> So could it still be malignancy- because I know that the PAL is negative <i>Oncoming Attending:</i> I have to tell you this the first day we couldn’t see anything because there was so much blood but the repeat bronchoscopy actually was significantly improved, so you know if its malignancy its not going to get better
<i>Type 4</i>	Incomplete or inaccurate information (from “team”): <i>Inability of the rest of the team to provide complete and accurate information.</i>	<i>Oncoming Attending:</i> Pretty good bleeding then. I thought we are going to put SED in his arm. What happened to that plan? <i>Oncoming Resident:</i> No response [smiles] <i>Oncoming Attending:</i> ask IR to put a SED. If he has tumor he is at higher risk. <i>Oncoming Attending:</i> oh did we find out about if we have pulses. We cant put that. Just check it

with ultrasound..
Oncoming Attending: I don't think we have them. I have them in Southwest, other than putting an SED in his arm, we could only have it on one arm, the other arm we could put an IV in that. ...

Clinical Nature of Communication Breakdowns

We further classified the communication breakdowns to ascertain their clinical determinants. We analyzed the specific questions from the receiver that were associated with each of the breakdowns using Ely's taxonomy of generic clinical questions (45). The taxonomy was modified to address the information needs of in-patient settings – we did not include the “patient-directed” category, as we did not collect patient-related data (see Table 3).

Table 3. *Clinical relevance and characteristics of communication breakdowns*

Question Category	Description	Example
<i>Diagnostic Evaluation</i>	Assessment, factors related to diagnosis, the clinical workup	“What is the patient's agitation level?”
<i>Treatment</i>	Ongoing treatment	“What are the settings for the oxygen treatment?”
<i>Management</i>	Plan of care	“Are we dialyzing the patient?”
<i>Non-clinical</i>	Administrative issues in care	“Was a nutrition consult note written already on the patient?”
<i>Miscellaneous</i>	Other	“Who is the nurse for patient bed 5?”

Data Analysis: Quantitative

Once the CEs and breakdowns were categorized, descriptive statistics were computed. T-tests and analysis of variance (ANOVA) were used to investigate the differences between the tools in terms of CEs and breakdowns. Given that the members of the team (interns, residents) were at different stages of their training, we also investigated effects of their expertise on CEs and breakdowns.

In order to capture the nuances and patterns of communicative interactions, we also performed sequential pattern analyses of CEs (see Table 1). A custom software application was developed to

retrieve CEs and organize them into a *temporal event stream* according to the type of tool (SOAP, HAND-IT), time/day of the event, and associated bed number. The event stream was converted into a transition probability matrix (TPM) for further analysis. TPM is an antecedent-consequent matrix that provides the frequency of transitions between events. For example, each cell in the TPM of CEs provides the count of the number of transitions between two CEs (e.g., between “present” and “accept”). Given the limited understanding regarding patterns of handoff communication, we then used sequential analysis as an exploratory data analysis approach (46) to characterize the nature of temporal patterns of communicative interactions by computing the probability of transitions between the CEs. Researchers have used similar sequential analysis approaches to examine temporal co-occurring patterns of human interaction with tools and artifacts (47-53) (additional details can be found in Section 6 of appendix).

Results

We report on the differences in the nature and patterns of communication behavior using SOAP and HAND-IT. We report on four attributes: *communication interactivity*, measured by the type/distribution of communication events (i.e., CEs); *communication optimality*, measured by the type of communication events (ideal vs. non-ideal); *communication breakdowns*, measured by the number of missed, incorrect, irrelevant information from sender and team and; *communication support*, measured by the probability of “reject-” and “request-” sequences of CEs.

Communication Interactivity: Type/Distribution of Communication Events

There were a greater number of CEs when using HAND-IT ($M = 725.75$, $S.D. = 125.21$) than SOAP ($M = 422.75$, $S.D. = 54.21$) [$t(40) = 4.56$, $p < 0.001$] with a greater number of CEs for both attending

physicians [$t(40) = 4.45, p < 0.001$] and residents [$t(40) = 5.81, p < 0.001$] (See Section 4 in appendix for the distribution of CEs).

Communication Optimality: Type of Communication Events

HAND-IT had significantly more *ideal* CEs [$t(40) = 5.05, p < 0.001$] and fewer *non-ideal* CEs [$t(40) = -8.9386, p < 0.001$] than SOAP. As previously explained, ideal CEs included instances where the information presented by the sender was accurate and sufficient. Use of SOAP resulted in a greater number of team responses, requiring constant team input and involvement in addressing communication breakdowns in order to maintain the continuity of handoff communication [$t(40) = -9.27, p < 0.001$].

Distribution of Communication Breakdowns

We found significantly fewer communication breakdowns while using HAND-IT ($M = 0.83$, S.D. = 0.97) than SOAP ($M = 3.78$, S.D. = 2.62) [$F(1,80) = 45.66, p < 0.0001$]. Of these breakdowns, significantly more *type 1* [$F(1,80) = 46.68, p < 0.0001$] and *type 4* [$F(1,80) = 4.93, p = 0.029$] occurred when using SOAP. No significant differences were found in types 2 or 3 breakdowns.

Clinical nature of communication breakdowns: Based on the analysis of the clinical nature of the communication breakdowns, we found that there were significantly fewer breakdowns related to diagnostic evaluation [$F(1,80) = 34.66, p < 0.0001$], management [$F(1,80) = 10.97, p < 0.0001$] and treatment [$F(1,80) = 14.94, p < 0.0001$] when using HAND-IT than SOAP. No significant differences were found in the non-clinical or other categories. There was also no association between the clinical type and nature of breakdowns for either tool [Fisher's exact test, SOAP: $p=0.80$; HAND-IT: $p=0.61$] (See Section 5 in appendix for further details on the distribution of breakdowns across each tools in each category).

Effect of expertise on communication breakdowns: We also investigated whether communication breakdowns were associated with the level of expertise of the sender. Based on an *Expertise* (Intern, Resident) x *Tool* (SOAP, HAND-IT) two-way ANOVA, we found that the main effects of expertise [$F(1,80) = 4.098, p < 0.05$] and tool [$F(1,80) = 36.072, p < 0.0001$] were significant. Overall, interns had 0.89 more communication breakdowns than residents (95% CI of the difference = 0.015 to 1.7 breakdowns), and the use of SOAP led to more breakdowns than the use of HAND-IT (95% CI of the difference = 1.7 to 3.5 breakdowns). The interaction effects were not significant [$F(1,80) = 1.71, p = 0.195$] (See Section 5 in appendix for further details on the distribution of communication breakdowns across interns and residents).

Communication Support: Distribution of Reject and Request Sequences

Based on the TPM, we computed the transitions and their resulting probabilities between the various CEs. As expected, sender-receiver (i.e., attending – resident/intern) interactions were considerably greater while using HAND-IT. As previously stated, the *team response* event was much more likely while using the SOAP tool (See additional figures and details regarding the transitions in Section 7 in appendix). Two salient sequences provide particular insights into the pattern of communication: *first*, there was a higher probability of *reject* → *request* transitions in the SOAP tool ($Pr = 0.62$; in contrast, for HAND-IT, $Pr < 0.25$). In HAND-IT, the prominent event after a *reject* event was *present* new information (i.e., *reject* → *present*, $Pr = 0.67$ in contrast to SOAP, $Pr < 0.25$). As previously explained, a *reject* event occurred when the attending physician preliminarily deemed presented information as inappropriate during the handoff communication, thereby discounting the information. For SOAP, information rejection led to the physician requesting additional information, while for HAND-IT, even when information was rejected (usually partly), there was a higher probability that the attending physician developed (or proposed) a care plan without additional information (based on the order of the presented information in the medical hierarchical format). In other words, in HAND-IT, even when part

of the information was rejected, the presented information was sufficient to develop the A&P without any new information.

Table 4. Significant communication sequences and their transition probabilities

Communication Sequence (normalized freq.)	Handoff Tool	Probability of Transition
Reject (0.001) → Present (0.17)	HAND-IT	0.67
Reject (0.001) → Request (0.24)	HAND-IT	0.2
Reject (0.01) → Present (0.19)	SOAP	0.2
Reject (0.01) → Request (0.23)	SOAP	0.62
Request (0.24) → Response (0.23)	HAND-IT	0.97
Request (0.23) → Response (0.14)	SOAP	0.62

Second, the sequence *request* → *response* was more prominent in HAND-IT ($Pr=0.97$) than in SOAP ($Pr=0.62$), providing further supporting evidence of HAND-IT's greater ability to support the attending in requesting relevant information and also support residents and interns in effectively responding to attending physicians' requests for additional information. Table 4 provides a summary of the sequences and their associated probabilities.

Discussion

Based on a comparative evaluation of the communication behavior between handoff tools, we found that an indigenously developed system-based handoff tool, HAND-IT, was characterized by greater communication interactivity, greater communication optimality, fewer communication breakdowns and greater communication support. Furthermore, we found that the communication breakdowns with HAND-IT were only marginally related to the diagnostic, treatment or management aspects of patient care. Based on our results, we draw the following implications regarding HAND-IT for care continuity and safety during transitions: support for *interactive*, *streamlined* and *effective* communication.

First, information organization with HAND-IT supported *interactive communication* during handoffs resulting in better common ground (54) regarding the presented patient information. In other words, HAND-IT provided support to achieve a *symmetry in dialogue* during handoff communication (i.e., balance between the sender and receiver) – an instrumental factor in achieving a highly interactive, bi-directional, seamless coordination of communication that is encouraged by The Joint Commission (TJC) (4).

Second, HAND-IT afforded a *streamlined communication* by aiding in both identifying the inconsistencies between the various information pieces, and inter-relating these discrete pieces of information to develop an evidence-based care plan. This was achieved through a checklist-based organization of information with an assessment and plan for each body system. Such a structure helps physicians in documenting the patient case and developing a clear understanding of the causal determinants of the patient condition through diagnostic reasoning. It also encourages physicians to consider information both discretely (individual patient-related data), and holistically (the overall representation of the patient condition) – assisting them in identifying potential discrepancies between clinical concepts and patient conditions that were spread across body systems.

Finally, HAND-IT supported *effective communication* with its system-based information organization that triggers structured seeking, organization and documentation of communication content by the sender. It also improves the ability to sustain interactive communication between the sender and receiver – driven by more clarifications (i.e., requests) leading to more conversational switches and turn taking (i.e., sender responses), yet with enhanced resilience to communication breakdowns. Our results provide preliminary evidence for the use of system-based tools such as HAND-IT in providing opportunities for improved handoff communication and better care transitions.

Study Limitations: There are several limitations to our study. *First*, the study was conducted at a single, academic MICU setting. While a generalized application of HAND-IT would require further evaluation, we believe that the results would be directly transferable to similar academic MICU settings that use group handoffs during rounds. In other settings, setting-specific modifications of the tool (with respect to the content) may lead to comparable results. The theoretical foundation behind the design of HAND-IT was to help residents gather and organize information for effective and streamlined patient-case presentation and collaborative interactions. An important takeaway from our study is the positive role of information organization and representation on communication and collaborative interactions. Externalizing pertinent information in a standardized structure that supports the ICU clinical workflow can reduce the cognitive demands and the working memory requirements of information seeking, documentation and reasoning about the discrete pieces of information while developing a plan of care (55). Information organization also fosters better information presentation and knowledge about the patient condition due to significantly better prospective memory (56), as clinicians are encouraged to reason about and document the condition and status of the patient. Given the positive outcomes regarding communication effectiveness, we believe that these aspects would be transferable to other clinical settings.

Second, we used a non-randomized study with only two teams, which may have influenced the results. Nevertheless, we had a significant number of handoffs during this period (a total of 82 handoffs across two tools) that provide validity for our preliminary results. *Third*, the non-verbal cues in communication that may have an impact on the information presented/requested were not captured. Our theoretical framework of information processing could be extended to include non-verbal cues. *Fourth*, we did not capture or report on the unintended consequences of the use of HAND-IT. For example, the detailed nature of HAND-IT may have potentially resulted in increased time and effort for gathering and aggregating information, as well as for presenting information. However, as one of the physicians

mentioned, significant time is lost and the potential for errors is increased when the required information is not presented during rounds and residents (or other support personnel) have to scramble to find the missing information. Some of issues related to increased time can be potentially mitigated by use of integrated electronic tools that minimize the copious information entry during information aggregation². *Fifth*, HAND-IT was designed and developed based on longitudinal studies at this setting, and hence the results that were achieved may be more pronounced than in another setting. We are currently expanding the use of HAND-IT in a new academic MICU setting. *Finally*, it is also likely that the group handoff format of the morning rounds may also have contributed to the results. As previously mentioned, our focus was on investigating how the better information gathering and organizational capabilities of HAND-IT can lead to effective and resilient handoff communication.

Conclusion

Our results suggest that HAND-IT supports a holistic and comprehensive head-to-toe, evidence-based assessment of a critical care patient. Such an information framework for patient data organization and documentation supported consistent, systematic and streamlined communication with fewer breakdowns, potentially leading to better continuity and coordination of care. While further longitudinal evaluation, and evaluation in other settings is necessary for establishing the long-term viability of this tool, we believe HAND-IT provides an initial framework for developing such extensions. Of significant interest is the potential utility of using a bottom-up, evidence-based information structure (such as the one used in HAND-IT) for information organization that can lead to more effective, interactive and streamlined communication during transitions.

² During the time of the study, the research site did not use a CPOE.

Results from this study can have significant implications for patient safety. *First*, as recommended by TJC, the structured format of HAND-IT not only enhances communication interactivity, but also minimizes breakdowns. *Second*, as confirmed in previous research, handoffs are a forum that supports the function of information processing and transfer through a noisy channel (e.g., (57, 58)). System-based format also improves the efficiency and effectiveness of information transfer (i.e., characterized by more ideal communication events) despite the challenges and complexity of the critical care environment. *Third*, it sustained both senders and receivers in their interactive communication. In other words, the use of HAND-IT enhanced the ability for senders to quickly respond to receivers' requests without the need for external information support (e.g., from the team). Correspondingly, it also afforded receivers the ability to ask pertinent questions that led to speedy problem resolution and decision-making. We believe that such structured and transparent attributes enhance the resiliency of HAND-IT not only for supporting information gathering and documentation (reported elsewhere, see (37)), but also for engaging clinicians in safe communication practices.

Contributors

JA conceived the study and collected the data. JA coded all transcripts while TK coded 25% of the transcripts for reliability analysis. JA and TK performed all qualitative and quantitative analysis. All authors participated in the interpretation of data, helped to draft the article or revise it critically for important intellectual content, and gave final approval of the version to be published.

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