

**Simulation-based Endourological Skills Training: Does Timing Of Expert
Feedback Matter?**

BY

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THESIS

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TC – time to completion

EFG – early feedback group

LFG – late feedback group

LIST OF ABBREVIATIONS

SBT – simulation based training

fURS – flexible ureteroscopy

DIP – deliberate independent practice

OR – operating room

EFG – early feedback group

LFG – late feedback group

TC – time to completion

SUMMARY

Effective simulation-based training (SBT) methods include the provision of expert feedback. However, the impact of removing content experts from patient care to provide such feedback can be very prohibitive in the long term. As such, it behooves the medical education community to optimize the timing of expert feedback during SBT, for the benefit of the learner as well as the educator and patient.

The main objective of this study is to determine the impact of providing early versus late expert feedback to novice learners engaged in a simulation-based flexible ureteroscopy (fURS) training curriculum.

Senior medical students were recruited to participate in this pre- and post-test study design. After reviewing an online, fundamentals of fURS lecture, all students received an interactive, hands-on introduction to fURS. Each student then completed an initial standardized pre-study “baseline” skill test (left renal fURS with stone manipulation) followed by 3 deliberate, independent practice (DIP) sessions on fURS, each session lasting 30 minutes and separated by 1 week. After the 3rd DIP session, each student completed a final standardized post-study skill test.

Prior to the start of the study, students were randomized to either the “early” feedback group (EFG) or “late” feedback group (LFG). EFG was provided expert feedback immediately following the pre-study skill test while LFG was given feedback before the final DIP session.

All pre- and post-study skill test performances were timed and video-recorded, then later scored by 2 blinded, expert endourologists using a validated assessment tool.

SUMMARY (continued)

A total of 18 senior medical students completed the study (9 EFG, 9 LFG). Overall, both mean skill task scores (8.0 ± 1.4 vs 11.8 ± 2.7 , $p < 0.01$) and mean skill task time-to-completion (TC - 23.9 ± 3.7 vs 20.3 ± 3.4 mins, $p < 0.01$) improved after the simulation-based fURS training curriculum.

There were no demographic differences ($p > 0.05$) and mean pre-study skill task scores were similar between groups (7.9 ± 1.5 vs 8.0 ± 1.5 , $p = 0.938$). Mean pre-study TC was also similar between groups (24.1 ± 4.4 vs 23.6 ± 3.1 mins, $p = 0.798$).

Mean post-study scores were significantly better for EFG (13.1 ± 2.6 vs 10.5 ± 2.2 , $p = 0.034$) but there was no significant difference in mean post-study TC (19.4 ± 3.1 vs 21.3 ± 3.6 mins, $p = 0.243$). ANCOVA analysis demonstrated that feedback group strongly predicted post-study TC and performance score ($p = 0.005$ and 0.001 , respectively).

The seven performance dimensions assessed by the assessment tool were internally consistent for both pre- and post-study test scores with an ICC of 0.974 and 0.983 , respectively.

This study examining the impact of expert feedback timing during simulation-based fURS skills training demonstrates preliminary evidence that suggests novice learners may benefit more from early feedback when learning a novel skill. Further study is required.

INTRODUCTION

Along with increasingly complex surgical patients, a renewed focus on physician accountability, and the introduction of many novel surgical technologies, mandated changes to trainee working hours has resulted in a new surgical training landscape (1-3). The largest and most obvious drawback of this new training milieu, particularly in surgical training, has been the reduced amount of meaningful clinical exposure for trainees.

In the current training paradigm, with ever increasing clinical content to be covered, the traditional Halstedian model of apprenticeship-style surgical training is neither adequate nor responsive to the needs of the modern surgical trainee. In order to obtain enough exposure to develop the required clinical skills for both novel and traditional surgical techniques, many surgical programs have shifted learning and competency development outside of the clinical realm into simulation-based settings.

As such, the utilization of simulation-based training (SBT) modalities has increased in recent years, with many institutions building high-tech surgical skills centers or laboratories in order to teach medical students and residents various surgical techniques outside the operating room (OR). Benefits of this method of training include the ability to engage in deliberate, independent practice (DIP) in a low-stress environment, without the time constraints imposed in the OR and without the ethical concerns surrounding the development of competence at the “risk” of patient safety.

One of the biggest limitations of SBT, however, remains the significant cost associated with this training modality. This not only includes the financial resources needed to build and support such advanced simulation centers but also includes a significant human resource burden as well. Rather than providing training content concurrently with the provision of patient care, as was

done in the traditional apprenticeship-style training model, SBT requires faculty educators to provide additional educational content outside of the OR, in a non-clinical setting.

Though SBT has its significant advantages, it is not an educational panacea. It is not a remedy for poorly designed curricula nor does it forego the need for dedicated educators; rather it augments the learning experience provided by such educators (3-5). The provision of timely expert feedback and both formative and summative assessments is critical to any successful educational curriculum, be it SBT or otherwise (6-8).

Kneebone provided a conceptual framework from which many SBT programs have been developed (9), and two central tenets of this theory-based approach include the following:

- 1) allow for sustained, deliberate practice within a safe environment, ensuring recently acquired skills are consolidated within a defined curriculum.
- 2) provide access to expert tutors when appropriate, ensuring such support fades when no longer needed.

These two principles are not independent of one another, but rather are interrelated. Outside of the confines of a structured curriculum, compliance among trainees to continue with DIP can be a challenge. Van Empel and colleagues demonstrated that expert feedback was not only valuable as an educational tool but as a motivation tool to increase compliance with DIP as well (10).

The ability to provide trainees with timely, individualized, expert feedback is paramount to the success of SBT, and it is most effective when combined with deliberate practice (1-3,11,12). DIP without expert feedback, no matter how good the fidelity of the simulation, has limited effectiveness for the early learner. However, the provision of such feedback requires dedication and commitment from educators, and can be seen as a detractor from patient care, as it requires removing the clinician from the clinical sphere. As a result, the quantity and quality of expert feedback is often compromised and there is mounting evidence that learners are dissatisfied with the feedback they

receive (3-5,11). So how do we optimize such a valuable resource, so that we maximize learner benefit and minimize impact on clinician educators and their ability to provide patient care?

For certain basic surgical skills, such as suturing and surgical knot tying, DIP with minimal expert feedback has been shown to be adequate (6-8,13,14). Interestingly, one study purported that proctored training may not provide any added benefit over independent training alone for more basic tasks (9,15). While there are a few contradictory studies, most educators agree on the importance of expert feedback and the majority of studies support this notion, particularly with respect to technical skill development (10,16-25). For example, Strandbygaard and colleagues demonstrated that the addition of instructor feedback significantly increased the efficiency of training for complex operational tasks on virtual-reality (VR) simulators (1,2,18), resulting in fewer errors when performing a VR procedure. The impact of SBT with feedback has not only resulted in improved trainee performances in the laboratory setting, but has also translated into improved performances in the OR as well (3-5,26).

Early thoughts on expert feedback were that the more frequent the feedback, the more useful it was, given that it could steer the trainee towards correct behaviours. More recent studies (6-8,27-29), however, have indicated that more may not necessarily be better and that feedback, when too frequent, may actually cause learners to become dependent on feedback for performance. As the concept of performance “guidance” suggests, when that feedback is withdrawn, performance may suffer from the lack of guidance or cueing (29-32). Wierink and colleagues studied the frequency of feedback on the ability of dental students to learn a specific procedural task (dental cavity preparation) and they found no significant difference in performance between groups that received continuous and intermittent feedback, both immediately and on retention testing 4 months later (9,28).

With respect to the form of feedback provided, studies suggest that there may be no significant difference between the provision of negative or positive verbal feedback on laparoscopic skill development, though there was a trend favouring negative feedback (10,33). There has also been interest in utilizing peer feedback to reduce the burden of needing content experts, and initial studies suggest that feedback may not always have to come from experts in order to be effective (11,12,34-36).

The literature with respect to the timing of feedback has largely focused on concurrent versus terminal feedback; expert feedback provided to learners *during* or *upon completion of* a single performance, respectively. Most studies have demonstrated that terminal feedback may be more effective (11,14,25,37), and the cognitive load theory (CLT) (13,14,38-40) may explain this phenomenon best. These studies on feedback timing have only focused on “intra-sessional” feedback, however, where the timing was in reference to any one training session. Currently, there are no studies published examining the timing of “INTER-sessional” feedback; the timing of feedback as it relates to multiple, different training or DIP sessions.

While CLT, as it relates to working memory limits, may explain differences between terminal and concurrent feedback, Fitts and Posner’s conceptual framework on motor skills learning may better explain the impact of INTER-sessional feedback timing (15,41). The provision of expert feedback may be most effective when it allows the learner to build on existing knowledge, thereby promoting the analysis and synthesis of knowledge and skill. Such integration of feedback and skill occurs during the “associative phase” of motor learning, when technical movements begin to become more fluid and less erratic. Without prior knowledge or skill upon which to build, however, expert feedback may simply serve as an additional source of preliminary knowledge that the novice uses to understand the skill. Novice learners in this initial “cognitive phase” of learning often have

erratic performances as they struggle to deconstruct the skill and understand its component steps.

While many agree that integrating expert feedback into SBT is important, the optimal timing of such feedback is unknown. And with the significant human resource costs associated with this aspect of SBT, it behooves the medical education community to determine whether the provision of expert feedback can be optimized. Namely, does the timing of expert feedback, as it relates to DIP sessions, affect technical skills acquisition? Is expert feedback provided *after* several DIP sessions as effective as *early* feedback provided to learners prior to their engagement in DIP?

In order to investigate this problem, we conducted a study to determine the impact of the timing of expert feedback on endourological skills acquisition, in the context of a SBT curriculum for medical students. The main objectives of this study were to determine the following:

- 1) utility of a multi-modal, simulation-based training curriculum for acquiring basic flexible ureteroscopy(fURS) skills
- 2) impact of providing early (before DIP) versus late (during DIP) feedback, in the setting of a simulation-based fURS training curriculum

METHODS

Senior medical students from the University of Toronto were recruited to participate in this study, which was conducted in the context of a comprehensive SBT curriculum that included a didactic lecture (focusing on the cognitive objectives of basic fURS and urolithiasis management), a hands-on demonstration of basic ureteroscopic instrumentation and skills and 3 DIP sessions using the Cook® URS model. All participants completed an initial intake questionnaire to determine demographic information such as age, gender, level of training, prior operative exposure, and self-assessment of endourological skills (Figure 1).

There were 3 phases to the study: a) an initial baseline (pre-study) assessment of fURS skill, b) three DIP sessions on an inanimate ureteroscopy training model (Cook® URS model) and c) a post-study assessment of fURS skill (Figure 2). Both the pre-study and post-study tests involved the same standardized task; placement of ureteral access sheath and flexible ureteroscopic manipulation of a lower pole stone to an upper pole calyx; herein referred to as the “fURS test task”.

Each DIP session was 30 minutes in duration, separated by a 1 week interval, and participants were permitted to practice any skill task(s) related to fURS and were provided with a full set of surgical instruments required to do so. A “surgical assistant” was also provided for each DIP session, however, this assistant did not provide any advice, feedback, or suggestions to the participants. Participants were also permitted to practice the fURS test task. After the 2nd DIP session, each participant was given the opportunity to practice the fURS test task under standardized testing conditions (mid-training test).

The pre- and post-study standardized task was performed using the Cook® URS model, an ureteroscopy part-task training model, and all performances were video-recorded for later review. All performances were scored by two blinded, expert endourologists using a previously

validated assessment device (30,31), which is a behaviourally-anchored rating scale with seven dimensions of performance. The two raters were endourologists with similar clinical expertise and both performed fURS in a very similar manner, clinically, with respect to approach and technique. Both were trained to use this validated fURS global rating scale (Figure 3) prior to making any assessments by reviewing several recorded fURS procedures and discussing their differences in scoring. Each blinded rater also provided an overall pass-fail assessment for each video-recorded performance.

All participants were randomly assigned into 2 study groups, the early feedback group (EFG) and the late feedback group (LFG). The EFG received individualized feedback immediately following their baseline skill testing session and then completed three 30-minute DIP sessions. The LFG received similar feedback but following their mid-training test, which occurred immediately following their 2nd DIP session. All participants completed the post-study test 1-week after their final DIP session (Figure 2).

The feedback provided to all students was standardized, though did remain somewhat individualized. All feedback was provided by a single expert endourologist, in order to ensure standardization, and only included comments on the domains in which participants were assessed during testing: level of respect for tissue, time and motion efficiency, instrument handling abilities, ureteroscope handling techniques, overall flow of procedure and forward planning, and the use of assistants. Feedback was always provided upon the completion of the test task (terminal feedback), rather than concurrently. A minimum of 10 minutes of individualized feedback was provided to each participant, however, no more than 15 minutes in total.

Upon completing the 3 DIP sessions, and prior to the final post-study assessment, participants completed an exit questionnaire detailing not only their evaluation of the SBT curriculum, but their self-assessed performance and skill level (Figure 4).

Pre- and post-study performance scores were compared to discern the impact of the simulation-based endourological skills training curriculum. Performance scores between EFG and LFG were also contrasted to determine the impact of the timing of expert feedback. Demographic data was correlated with performance scores to determine the significance of such variables on skills acquisition.

Using SPSS v21 software, student t-test, chi-squared test or Fisher's exact test and ANCOVA analysis were used to compare performance metrics. Inter-rater reliability scores were also calculated for all performance assessments made utilizing the global rating scale (Figure 3).

RESULTS

A total of 18 medical students participated in the study, 9 each in EFG and LFG, and 14 of the students were male (78%). The majority of participants were in 4th year medical school (78%), with only four third year students (22%). Most had no prior exposure to fURS, 78% had never observed fURS and 100% had never performed fURS, and when asked to provide a self-rating of fURS skill (as compared to their peers) using a standard Likert-scale, the mean score was 2.55 out of 5.

Overall, the mean pre-study time-to-completion (TC) was 23.9 minutes (SD 3.70) and the mean pre-study performance score was 7.97 out of a total 35 points (SD 1.44). After the simulation-based fURS training curriculum, both mean TC (20.3 minutes, $p<0.01$) and mean performance scores (11.8, $p<0.01$) demonstrated significant improvements (Table 1).

Using Fisher's exact test we compared the EFG and LFG groups, which were normally distributed, and found no significant differences on pre-study performance; mean TC was 24.1 vs 23.6 minutes ($p=0.47$) and mean performance score was 7.94 vs 8.00 ($p=1.00$) for EFG and LFG, respectively (Table 2, Figure 5). Mean post-study TC did not differ significantly between groups (19.4 vs 21.3 minutes for EFG and LFG, respectively, $p=0.24$) and there was no difference in the pass-fail rate, as determined by the expert scorers ($p=1.00$) (Table 2, Figure 5). However, mean performance scores were significantly better for EFG (13.1 vs 10.5, $p=0.04$) and on ANCOVA analysis, feedback group was a significant predictor of post-study TC ($p<0.01$) and performance scores ($p<0.01$).

The seven performance dimensions assessed by the assessment tool were internally consistent for both pre- and post-study test scores with an intraclass correlation coefficient of 0.974 and 0.983, respectively.

DISCUSSION

The main objectives of this study were to evaluate the utility of a simulation-based training curriculum for fURS skills acquisition and to determine the impact of providing early versus late expert feedback to novice trainees during simulation-based skills training.

We found that for novice fURS learners, the provision of “early” expert feedback prior to engaging in DIP sessions was more beneficial than “late” feedback, provided after several DIP sessions. The novice participants, with minimal to no background experience in fURS, likely benefited more from early feedback as it provided them with further task-specific knowledge, which they could then use to shape and direct their DIP sessions. Without prior existing fURS skills the novice students, still in the “cognitive phase” of learning as outlined in Fitts and Posner’s conceptual framework, were likely unable to make effective use of their DIP sessions. Further to this point, on the exit questionnaire, we asked when each trainee felt would have been the ideal time for expert feedback. All 18 participants unanimously reported that they believed the best time was *before* they were given independent time to practice.

While this study only included novice fURS trainees, one might hypothesize then that more advanced learners with some pre-existing fURS experience (eg urology residents) may have benefited more from late feedback, whereby the feedback information is used to refine the learning process (“associative stage”) not just as a means to acquire task-specific intellectual knowledge (“cognitive phase”). It follows then that depending on the trainee skill level, feedback may serve as either a means of better understanding a technical skill (intellectual information) or refining a skill (integrative information).

The concepts of knowledge of performance (KP) and knowledge of results (KR) in

motor learning may also aid in understanding the impact of feedback timing for surgical skills learning (32). KP is defined as information provided to the learner indicating quality or characteristics of the performance while KR is extrinsic information provided after a response, indicating the success of the action with respect to a goal (32). While both are important in the motor learning process, among novice performers, it is believed that KP may more important in facilitating early learning.

The novice learner in our study received some task-intrinsic visual feedback during DIP sessions (ie was I able to find the stone, grab it with the basket, and move it to the upper pole?), which can be considered KR, but limited task-intrinsic KP feedback is provided. The provision of early expert feedback then serves as a form of extrinsic KP feedback, which may facilitate skill acquisition among the novice participants.

We found that the EFG only outperformed the LFG with respect to mean performance score and there was no difference in mean post-study TC. This is likely a result of how truly novice our participants were. The extremely low performance scores in both groups is a reflection of how difficult this task was for these medical students as was the mean TC in both groups; approximately 20 minutes for both EFG and LFG. To put this into context, it took our expert endourologists less than 5 minutes to complete the same task. When an analysis of covariance was conducted, however, feedback group was a significant predictor of post-study performance.

There are several limitations to this study that need to be taken into consideration. Due to the single-center design and the limited number of participants, the study may have imprecise estimates of the various group means and the results may not be generalizable. Due to study resource limitations, we were also only able to include 3 separate DIP sessions. With

an increased number of DIP sessions, and thereby a larger methodological variation between EFG and LFG, the timing of feedback may have had a different impact on fURS skill acquisition. Similarly, only 1 feedback session was included in the study design. The impact of additional early or late feedback sessions is unknown at this time. We did not include intermediate or advanced learners, and so no comment can be made on the interaction of feedback timing and learner level of training. Finally, we did not conduct a retention test and as such the long-term implications of these findings warrant further study.

CONCLUSIONS

This preliminary study examining the timing of expert feedback during simulation-based fURS training demonstrates evidence that for novice learners, early feedback before participating in deliberate, independent practice sessions may be more beneficial than the provision of late feedback. Further studies are warranted.

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TABLE I**Impact of simulation-based fURS curriculum on skills**

Performance Test	pre-study (SD)	post-study (SD)	p value
mean TC (mins)	23.9 (3.7)	20.3 (3.4)	<0.001
mean performance score (out of 35)	7.97 (1.44)	11.81 (2.68)	0.001

mins – minutes

SD – standard deviation

TC – time to completion

TABLE II**Performance comparison between EFG and LFG**

Performance Test	EFG (SD)	LFG (SD)	p value
mean pre-TC (mins)	24.1 (4.4)	23.6 (3.1)	0.47
mean pre-performance score (/35)	7.94 (1.49)	8.00 (1.48)	1.00
mean post-TC (mins)	19.4 (3.1)	21.3 (3.6)	0.24
mean post-performance score (/35)	13.11 (2.58)	10.50 (2.18)	0.04
Failure rate	89%	100%	0.50

mins – minutes

SD – standard deviation

TC – time to completion

FIGURE 1. DEMOGRAPHIC QUESTIONNAIRE

Participant ID # _____ Date: _____

Level of Training?

☐ 3rd yr Med Student ☐ 4th yr Med Student

Gender? Handedness?

☐ Female ☐ Male ☐ Right ☐ Left ☐ Ambidextrous

Approximately how many FLEXIBLE cystoscopies/ureteroscopies have you observed?

☐ None ☐ <10 ☐ 10-20 ☐ >20

Approximately how many FLEXIBLE cystoscopies/ureteroscopies have you performed?

☐ None ☐ <5 ☐ 5-10 ☐ >10

Have you ever participated in simulation-based training for ureteroscopy?

☐ Yes ☐ No

Compared to other medical students, how would you rate your technical skills in the OR setting for the following procedures?

Flexible cystoscopy:

Poor		Average		Excellent
1	2	3	4	5

Flexible ureteroscopy and stone extraction (handling of guidewires, basket, etc.):

Poor		Average		Excellent
1	2	3	4	5

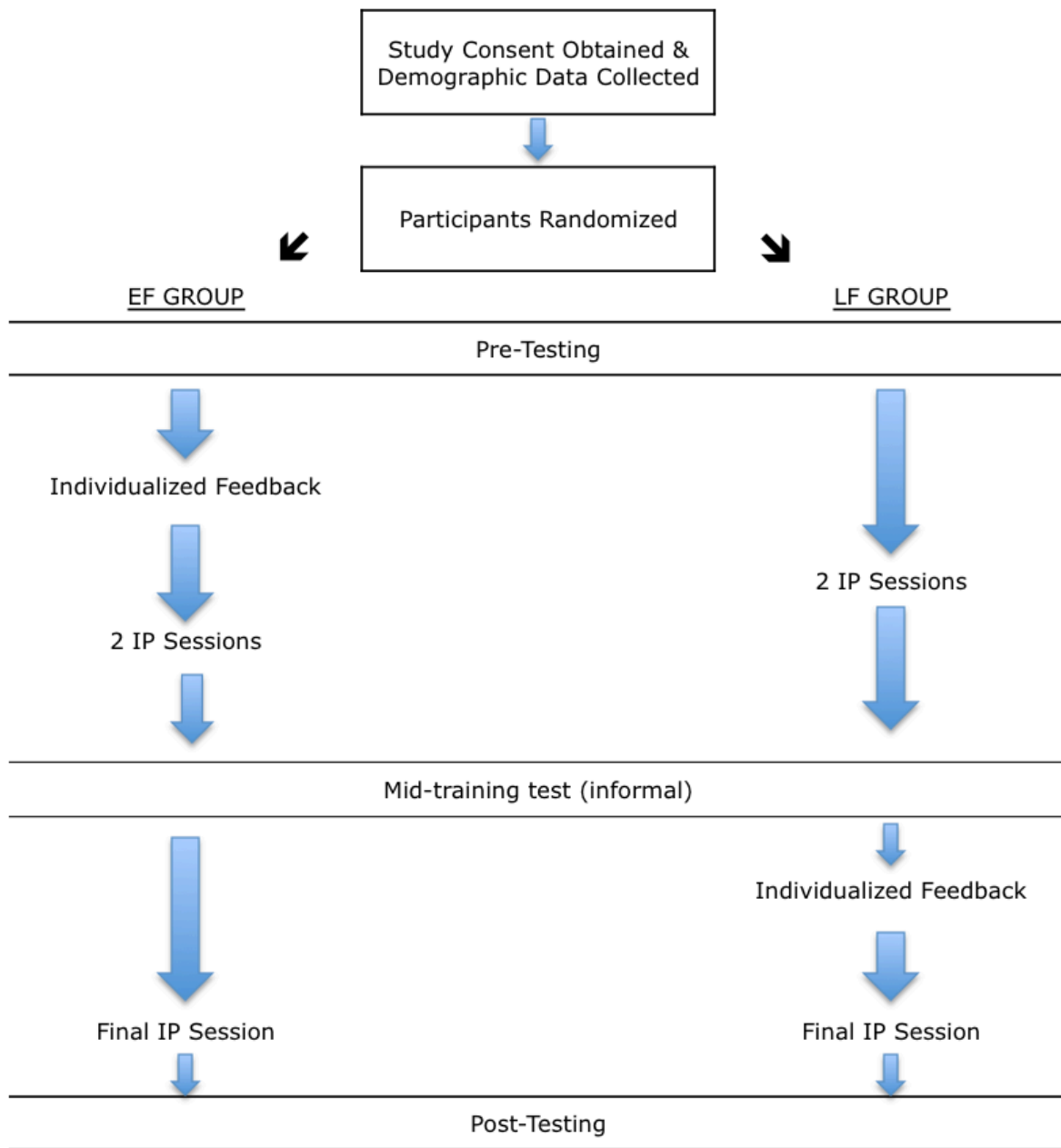
FIGURE 2. STUDY FLOW DIAGRAM

FIGURE 3. URS ASSESSMENT DEVICE

Please circle the number corresponding to the candidate's performance in each category, irrespective of level of training.					
Respect for Tissue	1 Scope frequently pushed into urothelial wall. Used unnecessary force with guidewire and/or basket.	2	3 Scope occasionally pushed into urothelial wall. Careful handling of guidewire and/or basket for the most part.	4	5 No trauma to urothelial wall with scope. Consistent and careful handling of guidewire and/or basket.
Time and Motion	1 Many unnecessary moves.	2	3 Made some unnecessary moves but time more efficient.	4	5 No unnecessary moves and time is maximized.
Instrument Handling	1 Needed to repeatedly attempt guidewire insertion and/or basketing of stone.	2	3 Able to insert guidewire and basket stone within first few tries. Occasional awkward movement.	4	5 Able to insert guidewire and basket with fluid motion and no awkwardness.
Handling of Endoscope	1 Frequently had scope pointing away from the centre of the urethra or ureter. Scope poorly aligned during procedure.	2	3 Had scope centered for the most part. Guidewire in view for the most part. Better use of scope angle during procedure.	4	5 Scope always centered and guidewire always in view. Scope always set at a good angle throughout the procedure.
Flow of Procedure and Forward Planning	1 Frequently stopped or need advice or assistance from examiner.	2	3 Demonstrated the ability to think forward with relative steady progression of procedure.	4	5 Obviously planned procedure from beginning to end with fluid motion.
Use of Assistants	1 Failed to have assistants help with guidewire insertion and/or stone basketing.	2	3 Appropriate use of assistants most of the time.	4	5 Strategically used assistants to the best advantage at all times.
Knowledge of Procedure	1 Deficient knowledge. Needed specific instructions at most operative steps.	2	3 Knew all important aspects of operation.	4	5 Demonstrated familiarity with all aspects of operation.

Pass Rating:

Would you feel confident in allowing this trainee to perform this procedure in the operating room?

YES**NO**

FIGURE 4. EXIT QUESTIONNAIRE

Participant ID # _____

Date: _____

During the URS simulation-based training course, approximately how many FLEXIBLE cystoscopies/ureteroscopies have you OBSERVED in the OR?

☐ None ☐ <10 ☐ 10-20 ☐ >20

During the URS simulation-based training course, approximately how many FLEXIBLE cystoscopies/ureteroscopies have you PERFORMED in the OR?

☐ None ☐ <5 ☐ 5-10 ☐ >10

Did you find the Simulation-based URS training course useful for clinical skills training?

Useless		Neutral		Very Useful
1	2	3	4	5

Did you find the URS training model realistic?

Poor		Average		Excellent
1	2	3	4	5

Did you find the URS training model useful?

Poor		Average		Excellent
1	2	3	4	5

Did you get enough expert feedback during the URS simulation-based training course?

☐ None ☐ Not Enough ☐ Almost Enough ☐ Right Amount

During simulation-based skills training, when do you think would be the BEST TIMING of expert feedback?

☐ Before I'm given independent practice time
☐ After I'm given some independent practice time

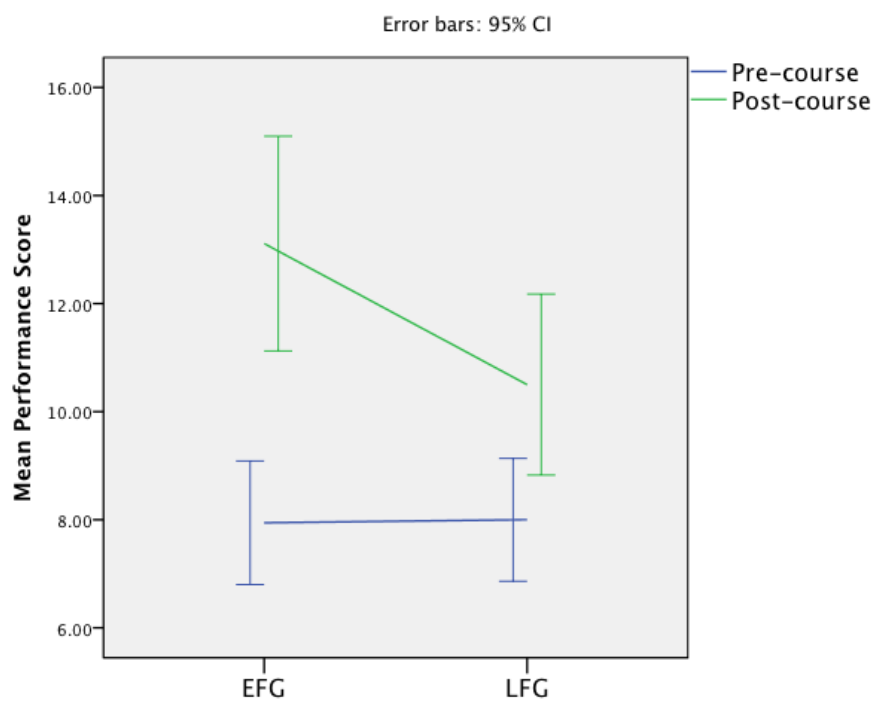
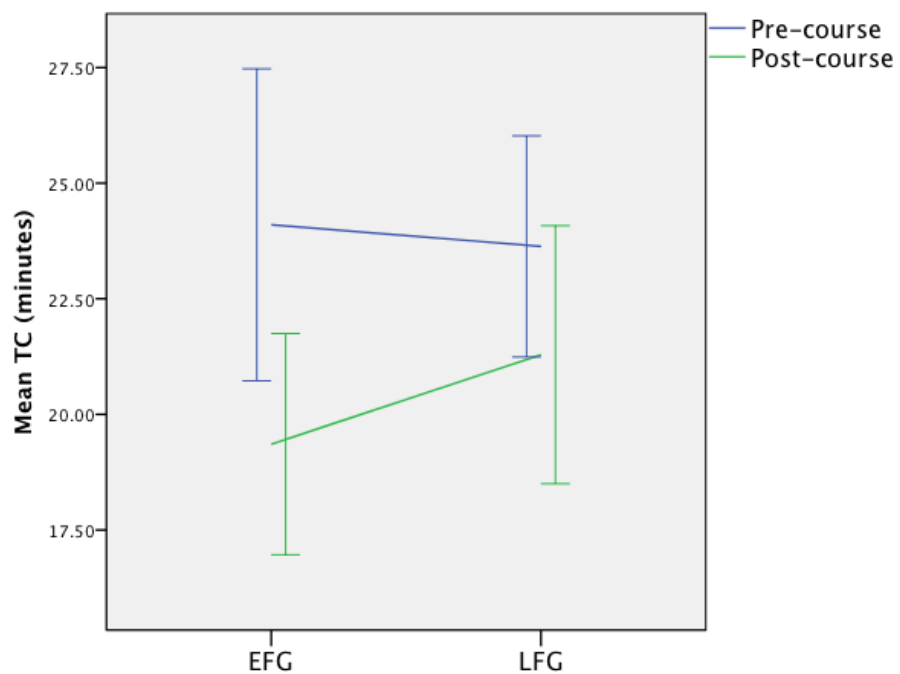
How would you rate your technical skills in the OR setting for the following procedures?

Flexible cystoscopy:

Poor		Average		Excellent
1	2	3	4	5

Flexible ureteroscopy and stone extraction (handling of guidewires, basket, etc.):

Poor		Average		Excellent
1	2	3	4	5

FIGURE 5. Performance Metrics of EFG and LFG

Error bars: 95% CI

VITA

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PROFESSIONAL MEMBERSHIP: American Urological Association
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