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ORIGINAL RESEARCH

# Preclinical Simulation Training of Medical Students Results in Better Procedural Skills Performance in End of the Year Three Objective Structured Clinical Evaluation Assessments

**Peggy A. Seidman[1] · Lauren M. Maloney[2] · Doreen M. Olvet[3] · Latha Chandran[3,4]**

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**Abstract**
*Objectives* The Association of American Medical Colleges published guidelines for procedural skills to be included in medical school curricula; however, standardized training and objective assessments of procedural skills are limited. We implemented and evaluated a simulation-based mandatory procedural skills training program for preclinical medical students for nine procedures students were expected to gain proficiency before graduation.
*Methods* Students received didactic and simulated practice sessions on task simulators for each selected procedure. After completion of their primary clinical year of training, as part of the end of the year three clinical performance examination, students were tested using an objective structured clinical evaluation (OSCE) format on two of the skills taught in their procedural skills classes.
*Results* We report our educational experiences and the results of OSCE performance of five cohorts ($n$ = 529) of trained students using simulations compared to a historical class cohort who were informally taught procedural skills at the patients' bedside ($n$ = 96). Tested at least a year after completion of standardized skills training, all five cohorts of simulation-trained students obtained better performance scores on their intravenous insertion skills compared to the bedside-trained group. For the Foley catheter insertion skills, however, only two of the simulation-trained cohorts performed significantly better than bedside-trained cohort.
*Conclusions* Our results suggest that simulation-based procedural skills training can be effectively incorporated into preclinical medical school curricula with retention of skills in tested procedures at the end of the primary clinical year as assessed in an OSCE format.

**Keywords** Simulation · Procedural skills training · OSCE · Clinical skills

## Introduction

Medical students are expected to learn many clinical procedures prior to graduation; however, the method of instruction, incorporation into preclinical undergraduate medical education curriculum, and final assessment of skill competency varies greatly among US and foreign medical schools [1–3]. As lamented in a recent New York Times article, and reported in the literature, an increasing number of resident physicians beginning their intern year report feeling underprepared and lacking confidence in the performance of bedside procedures required of them [4–6]. The lack of uniformity in undergraduate medical school procedural skills training may contribute to this situation [3].

To address these shortcomings, the American Association of Medical Colleges (AAMC) initiated the Medical School Objectives Project (MSOP), recommending several basic procedural skills to be mastered prior to graduation from medical school, with verification of proficiency through appropriate assessment tools [7]. More recently, the AAMC has

✉ Peggy A. Seidman
Peggy.Seidman@UHhospitals.org

1 Department of Anesthesiology and Perioperativr Medicine, Rainbow Babies and Children's Hospital, Case Western Reserve University School of Medicine, 11100 Euclid Ave, Cleveland 44106, OH, USA

2 Department of Emergency Medicine, Stony Brook University School of Medicine, Stony Brook, NY, USA

3 Undergraduate Medical Education, Stony Brook University School of Medicine, Stony Brook, NY, USA

4 Department of Pediatrics, Stony Brook University School of Medicine, Stony Brook, NY, USA

designated the 13 Core Entrustable Professional Activities (EPAs) for Entering Residencies, of which EPA 12 is to “perform general procedures of a physician” [8].

The effectiveness of simulation-based procedural skill labs has been widely accepted by current medical educators [9]. Simulation-based medical education is most likely to facilitate learning when specific feedback is provided to the student, repetitive deliberate practice is offered, and the simulations are integrated into the medical curriculum [10]. Furthermore, the introduction of clinical skills training in preclinical years has been shown to decrease the anxiety medical students experience as they anticipate their roles on the wards [11, 12] by offering a safe learning environment that is mistake forgiving and conducive to deliberate practice [9, 13–15]. Additionally, procedural skills training has been shown to decrease time required to complete procedures [9] and to increase student confidence in the performance of skills [16]. It is theorized that confident students with advanced baseline skills owing to their simulation-based procedural skills training may be less hesitant to actively participate in patient care, be incorporated into treatment teams earlier, and be more positively received by patients compared to those students without such training. Therefore, trained students may perform a greater number of procedures than untrained students [3, 17–19].

Several schools have published reports on brief isolated introductions to procedural skills prior to the start of clinical clerkships [9, 13, 16–18, 20–23]. The literature supporting the use of standard, valid, reliable objective assessments of learner competence in performing the recommended procedural skills is limited [1, 2, 24]. The few articles that discuss the use of objective evaluations for assessment of student procedural skills have small sample sizes using student volunteers and skills testing immediately after or within 3–6 months after the training [25, 19, 20].

To address these educational gaps in the medical school curriculum, we developed a standardized simulation-based procedural skills training program integrated into the preclinical years. We conducted this mandatory training program on five cohorts of the entire student body. We used scores on the Clinical Performance Exam (CPX), administered after completion of 1 year of clinical clerkships, as an objective measure of the effectiveness of the training program and retention of skills. We report on our experience implementing the training program and its outcomes.

## Materials and Methods

### Environment

This study was conducted at the Stony Brook University School of Medicine, a state university allopathic medical school located in a suburban area of Long Island, NY.

### Subjects

Students taking the 2011–2015 CPX exams received mandatory formal procedural simulation-based training during their preclinical years and are our “simulation-based training” cohorts.

Students taking the 2010 CPX exam served as the historical group. Procedural skills were informally taught to these students at the patient bedside during their clinical clerkship year by the clinical preceptor they were working with when the opportunity to perform a skill presented itself. Given the ad hoc nature of the clinical experiences on the patient care floors, there was no consistency in the instructors, instructional methods, or frequency of such training. As such, great variability existed in when, where, how, and with whom medical students received instructions on how to perform procedural skills. These students are referred to as the “bedside training” cohort. Students were required to log into an electronic “passport” all their procedural experiences. Students were expected to log in a minimum number of specific required procedures in an electronic “passport” along with other clinical experiences that they had in each clerkship.

All students were tested on their procedural skills as part of the mandatory, standardized summative multi-station examination (CPX) at the end of year three, after completion of 1 year of clinical clerkships. A simulation-based summative exam was chosen as to ensure standardized assessment settings for all students. In addition, the simulation-based summative exam was designed as mock testing for high-stake board examinations. The final sample included 625 students, with 529 students in the simulation-based training group and 96 students in the bedside training group. This study was approved by the Stony Brook University Institutional Review Board (IRB).

### Selection of Procedures

We selected a subset of procedures for training preclinical medical students based on the AAMC MSOP report, which we believed to be common and basic procedures that all medical students should be competent in regardless of their intended specialty choices [7]. This subset included nine skills: airway management, orogastric/nasogastric placement, Foley catheter placement (both male and female), subcutaneous injection, intramuscular injection, intravenous catheter placement (IV), arterial blood sampling, lumbar puncture, and knee aspiration.

In the first training session, students were properly sized for gloves and instructed in sterile gown and glove technique. Additionally, students were given short didactics on informed consent and procedural “time out” as these topics were considered critically important to the performance of any procedure in actual patient care situations. Sterile gown and gloving was then practiced at every subsequent simulation training session along with the specific procedure being taught at that session.

Figure 1 shows the timeline of when each procedural skills training session took place, as well as the time lag between the training and the testing during CPX.

### Simulation Training

Didactic education consisted of training videos which focused on the critical steps for proper completion of each skill. Students were expected to watch the video prior to the practice session. Training videos were obtained from available standard resources such as the *New England Journal of Medicine* video library, YouTube videos vetted by content experts, and in-house videos developed by faculty experts. As an example, a senior orthopedic surgeon developed our training video on knee aspiration. All videos were accessible through a password-protected secure server.

Training sessions involved practicing the skill on commercially available task trainer mannequins with verbal instruction and course correction provided by selected supervising faculty members or senior residents. The supervisors were selected based on teaching faculty consensus regarding their perceived expertise in each specific skill. Each supervisor was instructed to watch the training video of the skill being taught in class and encouraged to discuss additional "clinical pearls" for successful completion of the specific procedure.

Simulation training for the whole class (approximately 120 students) was provided in three 2-h sessions of approximately 40 students at each session to accommodate the entire class. To allow adequate time for instruction, observation, and practice for every student, every skill station had at least three identical mannequins with three instructors. This arrangement provided opportunities for every student to practice each skill as many times as she/he wished, with multiple opportunities to watch other students perform the skills and learn from their instruction.

### Assessment of Procedural Skills

The medical school had already established a 12-station OSCE assessment called the CPX, given to all students following their completion of 1 year of clinical clerkships. Given assessment time and scheduling feasibility, we were only able to test two procedural OSCEs within the CPX exam: male Foley placement and peripheral IV catheter insertion. During the OSCE, students performed the indicated procedural skill on a task trainer mannequin and were observed and graded by standardized patients (SPs) who had been trained to use in-house checklists. SPs were trained using the same videos students watched prior to attending training sessions, which demonstrated the perfect performance of each skill. The correct actions required for credit for each step on the procedural checklists were highlighted to the SPs, as they completed the checklist while watching the training video.

For the 2010 and 2011 exams, half the students were randomly assigned to the male Foley placement OSCE and half to the peripheral IV insertion OSCE. Due to developmental nature of our procedural curriculum and procedural OSCEs, we felt piloting the integration of the new OSCEs into CPX testing format was appropriate. All students taking the 2012 exam and later took both procedural OSCEs.

### Development of the OSCE Procedural Checklists

The 15-item checklists were developed in house and then piloted on ten medical student volunteers (from the graduating Class of 2009) by two trained faculty observers who independently rated each student's performance using the checklists (available from authors).

As part of curricular review and improvement, there have been several changes to the original checklists. Students can now earn partial credit on items that they perform incorrectly,

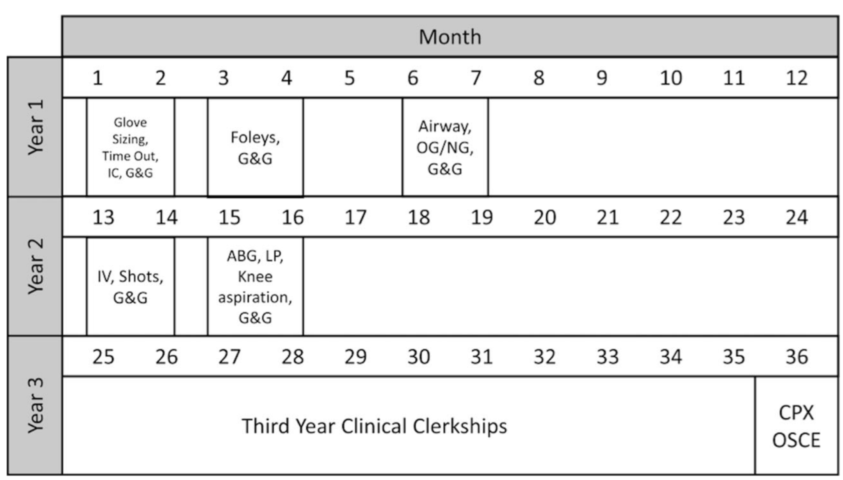


**Fig. 1** Timeline of procedural skills training sessions and end of Year 3 CPX OSCE. *ABG* arterial blood gas, *CPX* clinical performance exam, *G&G* glove and gowning, *IC* informed consent, *IV* peripheral intravenous catheter insertion, *LP* lumbar puncture, *OG/NG* orogastric/nasogastric, *OSCE* objective structured clinical evaluation

but later recognize the error and verbalize the correct action. Second, the Foley insertion checklist was originally 15 items, but for the 2011 exam, an additional item on maintenance of procedural sterility was added for a total of 16 items. Subsequently, for the 2014 exam, one item was removed ("Inflates and deflates balloon with water"), returning the total number of items to 15. This item was removed as there was inconsistency in the clinical application of the updated guidelines on the utility of the balloon check. Both items (i.e., maintenance of procedural sterility and inflates/deflates balloon with water) were removed from the current analysis because they were not assessed consistently across all cohorts. Students could earn a maximum score of 25 for the IV insertion CPX and 24 for the Foley insertion CPX.

### Statistical Analysis

Data were statistically evaluated using IBM SPSS Statistics (SPSS Inc., Chicago, IL, USA, Version 22.0). The Shapiro-Wilk test was used to examine the distribution of both Foley and IV CPX; however, the data significantly deviated from normality (all $p$ values <0.05). Levene's test for homogeneity of variance was significant for the Foley CPX data ($F(5516) = 2.79$, $p = 0.02$), but not the IV CPX data ($F(5520) = 0.75$, $p = 0.59$). Therefore, we used the Mann-Whitney rank sum test to examine group comparisons between the control (CPX 2010) and trained groups. Data are represented as median ± interquartile range (IQR). All $p$ values ≤0.05 were considered significant.

## Results

### Participants

Overall, there were 608 students in the simulation-based training group and 120 students in the bedside training group. Table 1 provides a detailed accounting of the number of students included and excluded by CPX year. Ultimately, 103 students were not included in the analysis for the following reasons: (1) students in the Sophie Davis Biomedical Program began their training at Stony Brook University in Year 3; therefore, they were absent for their preclinical training sessions ($N = 28$), (2) students in the Medical Scientist Training Program (MSTP) had at least a 2-year gap between Years 2 and 3 due to their research training ($N = 31$), (3) students who took a leave of absence in the first 2 years resulting in approximately four or more years between the onset of training and the CPX exam ($N = 34$), and (4) students whose CPX scores were missing ($N = 10$). The final sample included 625 students, with 529 students in the simulation-based training group and 96 students in the bedside training group.

### Foley Insertion CPX Scores

Median Foley CPX scores for each class year are presented in Fig. 2 and complete descriptive statistics are presented in Table 2. Mann-Whitney $U$ tests showed that the first simulation-based training group (CPX 2011) had significantly lower Foley CPX scores compared to the bedside training group (CPX 2010; $U = 848.5$, $p = 0.01$). Scores improved on subsequent years, with significantly higher scores in the simulation-based training group compared to the bedside training group (CPX 2010 vs. 2014: $U = 2026$, $p = 0.02$; CPX 2010 vs. 2015: $U = 1714$, $p = 0.002$). Higher scores were seen in the CPX 2012 ($U = 2225$, $p = 0.15$) and CPX 2013 groups ($U = 2390$, $p = 0.33$) compared to the bedside training group; however, the findings were not significant.

### IV Insertion CPX Scores

Median IV insertion CPX scores for each class year are presented in Fig. 3 and complete descriptive statistics are presented in Table 2. Mann-Whitney $U$ tests showed that all

**Table 1** Detailed breakdown of students included and excluded in the current study by CPX year

| Group | 2010 CPX Bedside training | 2011 CPX Simulation-based training | 2012 CPX Simulation-based training | 2013 CPX Simulation-based training | 2014 CPX Simulation-based training | 2015 CPX Simulation-based training | Total |
|---|---|---|---|---|---|---|---|
| Total no. of students | 120 | 122 | 124 | 127 | 122 | 113 | 728 |
| *Sophie Davis* | *9* | *5* | *7* | *4* | *2* | *1* | *28* |
| *MSTP* | *5* | *3* | *4* | *6* | *7* | *6* | *31* |
| *>3 years between training and CPX* | *2* | *9* | *5* | *9* | *5* | *4* | *34* |
| *No data* | *8* | *0* | *2* | *0* | *0* | *0* | *10* |
| Total no. of students included | 96 | 105 | 106 | 108 | 108 | 102 | 625 |

Data set in italics indicate students who were removed from the analysis

*CPX* clinical performance exam, *MSTP* medical scientist training program

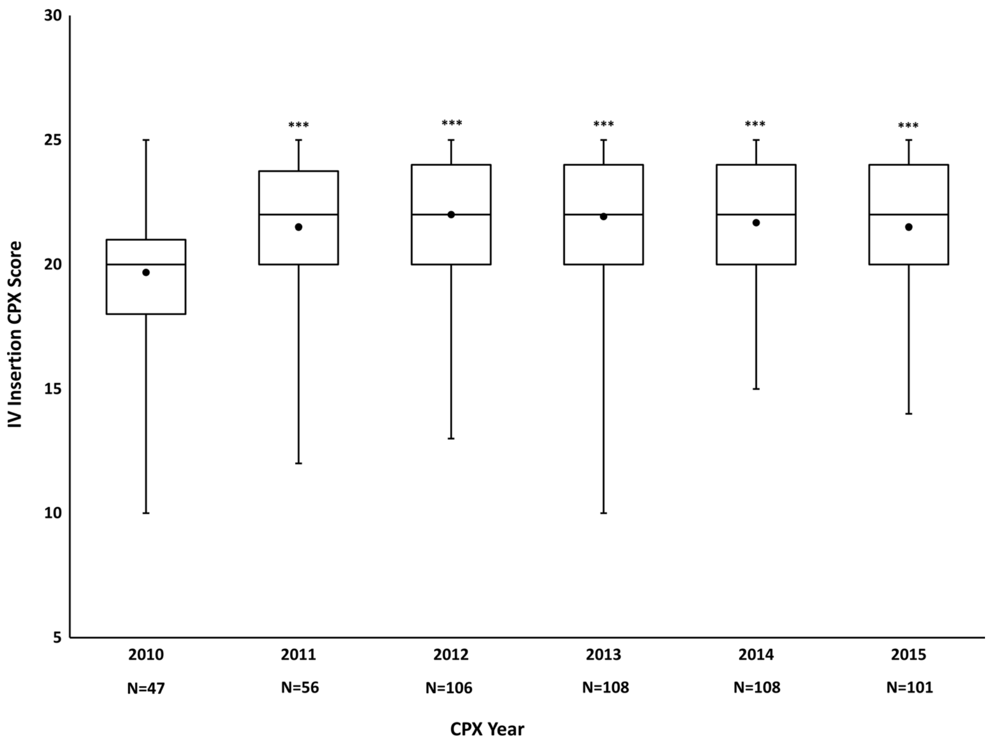


**Fig. 2** Box plot showing the Foley insertion CPX scores by exam year. Students taking the CPX in 2010 did not receive formal training in Foley insertion (bedside training group). Subsequent classes received formal training prior to the CPX (simulation-based training groups). The *box* represents the 25th, 50th (median), and 75th percentiles with *error bars* indicating the minimum and maximum scores. The mean is represented by *solid dots*. Group differences were assessed using the Mann-Whitney rank sum test. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. *CPX* clinical performance exam

simulation-based training groups had significantly higher IV insertion CPX scores compared to bedside training students (CPX 2010 vs. CPX 2011: $U = 835.5$, $p < 0.001$; vs. CPX 2012: $U = 1404$, $p < 0.001$; vs. CPX 2013: $U = 1452$, $p < 0.001$; vs. CPX 2014: $U = 1564.5$, $p < 0.001$; vs. CPX 2015: $U = 1556.5$, $p < 0.001$).

**Table 2** Descriptive statistics for the Foley insertion and IV catheter insertion data by CPX exam year

| Group | 2010 CPX Bedside training | 2011 CPX Simulation-based training | 2012 CPX Simulation-based training | 2013 CPX Simulation-based training | 2014 CPX Simulation-based training | 2015 CPX Simulation-based training |
|---|---|---|---|---|---|---|
| Foley insertion CPX | | | | | | |
| Median | 21 | 19 | 21 | 21 | 22 | 23 |
| Minimum | 14 | 10 | 12 | 11 | 12 | 13 |
| 25th quartile | 18 | 16 | 20 | 19.25 | 20 | 20 |
| 75th quartile | 23 | 21 | 23 | 23 | 23 | 23.5 |
| Maximum | 24 | 24 | 24 | 24 | 24 | 24 |
| Mean | 20.14 | 18.47 | 20.96 | 20.67 | 21.38 | 21.73 |
| IV catheter insertion CPX | | | | | | |
| Median | 20 | 22 | 22 | 22 | 22 | 22 |
| Minimum | 10 | 12 | 13 | 10 | 15 | 14 |
| 25th quartile | 18 | 20 | 20 | 20 | 20 | 20 |
| 75th quartile | 21 | 23.75 | 24 | 24 | 24 | 24 |
| Maximum | 25 | 25 | 25 | 25 | 25 | 25 |
| Mean | 19.68 | 21.5 | 22 | 21.92 | 21.67 | 21.5 |

*CPX* clinical performance exam, *IV* intravenous

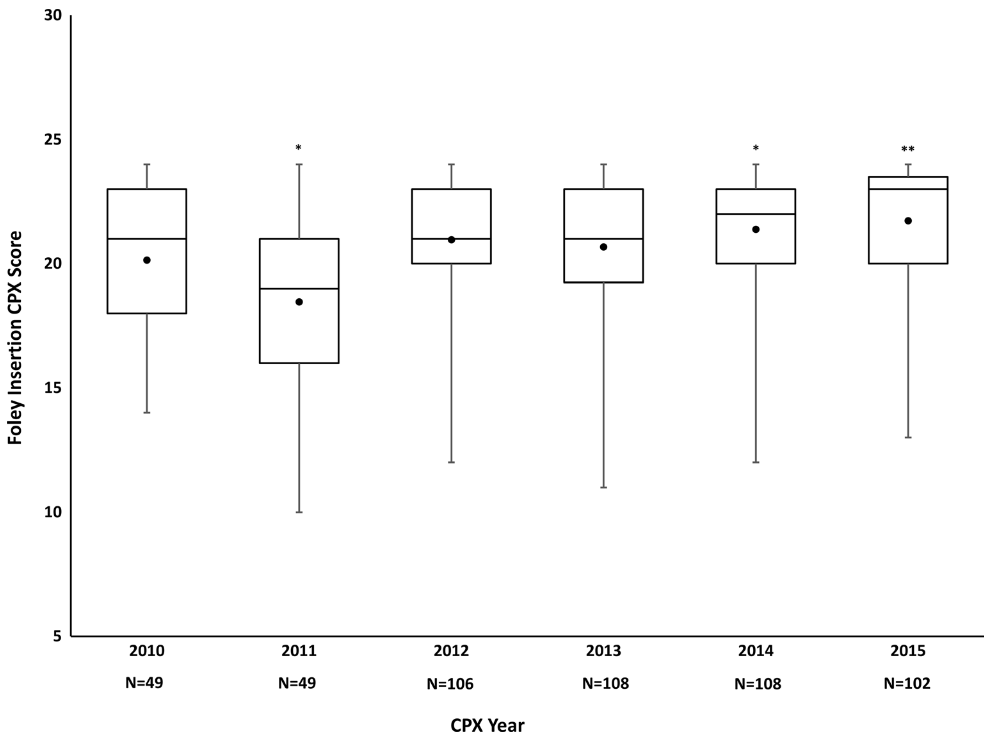


**Fig. 3** Box plot showing the IV catheter insertion CPX scores by exam year. Students taking the CPX in 2010 did not receive formal training in peripheral IV catheter insertion (bedside training group). Subsequent classes received formal training prior to the CPX OSCE (simulation-based training groups). The *box* represents the 25th, 50th (median), and 75th percentiles with *error bars* indicating the minimum and maximum scores. The mean is represented by *solid dots*. Group differences were assessed using the Mann-Whitney rank sum test. ***$p < 0.001$. *CPX* clinical performance exam

## Discussion

Our results demonstrate that compared to students who had no formal simulation-based procedural skills training, students who participated in our preclinical training program performed significantly better on OSCEs evaluating peripheral IV catheter and Foley catheter placement at least a year after training. Our results are similar to those of other authors, such as Herrmann and colleagues, who compared the immediate and long-term performance of IV catheter placement on task trainers by students who were initially taught the skills in a procedural skills lab, as compared to the traditional bedside “see one, do one” approach [21]. Herrmann and colleagues found that not only did students who were initially trained using simulation achieve higher scores on skill performance than those taught at the bedside but also they performed the skills faster and were rated more confident by observers [21]. Interestingly, they found that the superior performance of the simulated skill was most striking on 3- or 6-month long-term follow-up. Waters and colleagues demonstrated that undergraduate medical student OSCE performance was improved after using a urinary catheter task trainer, compared to didactic and “see one, do one” instruction, both immediately after the initial training, and on a 4-week follow-up OSCE [20]. Furthermore, Lund and colleagues evaluated the effectiveness of simulation training of IV catheter insertion compared to bedside teaching of the skill, finding those students with procedural skills laboratory training to have superior scores on procedural and communication skills [9].

Our study is distinguished from prior studies due to our large sample of students who received mandatory simulation-based training integrated into their preclinical curriculum. This obviates the selection bias when using student volunteers as was done in prior studies. Additionally, our study provides evidence of skill retention after a longer time period between the training and the assessment. We have demonstrated consistency of results across multiple large cohorts thereby enhancing the reliability of the results. In response to the variability of the early results with the Foley CPX scores in 2011, we changed our curriculum to reinforce the importance of handwashing and sterile technique at every procedural station. That change may have contributed to the improved results in the future cohorts.

Miller’s pyramid discusses four levels of clinical competence, where the baseline level is cognition and the final level is real-life performance [26]. Our learner assessment strategies in the simulation center allowed us to test the learners at the “shows how” level. Although our results show that training in a controlled setting enhanced acquisition of procedural skills among our preclinical students, we do not have reliable data on the actual number of attempts by these students during their clinical rotations. Therefore, we do not have learner assessments at the highest level of the Miller pyramid. Anecdotally, several students reported increased confidence levels in making such attempts; however, we did not measure their self-confidence before and after the training. Having the procedural skills assessment integrated with an existing summative assessment schedule was very helpful in ensuring that all students over several cohorts received the same standardized assessments. Due to time constraints, however, it was not practical to test the students on all of the procedural skills taught. Therefore, we do not know if these results would hold for the other seven procedural skills.

Several additional limitations to our study exist. First, we must consider that although students who participated in our preclinical simulation-based procedural skills training program demonstrated statistically significantly higher OSCE scores than those who had informal bedside training of procedural skills, it is unclear if this statistical significance is indeed clinically significant. Unfortunately, we are unable to provide exact numbers of procedures students performed during their clerkship year, which occurred between the training sessions and the OSCEs. Although all students used the passports to document their clinical experiences, many students only documented the minimum required numbers for procedures while some others continued to log in every procedure they participated in. Due to its variability, this data was not included in the analysis. It should be noted that there were no significant curricular changes in clerkships concurrent with initiation of preclinical procedural skills curriculum for the cohorts of students we evaluated that could have changed the clerkship experience altering procedural skills practiced. Additionally, the authors recognize that it would have been best to assess all nine procedural skills that students were trained in; however, adding this many OSCE stations into a pre-existing multi-station OSCE would have been cost and time prohibitive. Peripheral IV placement and male Foley catheter placement were chosen as they were the two skills it was felt all students should have been able to perform several times during their clinical clerkship year. Finally, the authors acknowledge that while it would be ideal to have several years of "bedside-trained" group data to account for possible individual performance variability, given that this was a retrospective study, we do not have reliable data for the cohorts prior to the one bedside-trained year we included.

## Conclusion

Our proposed program is being offered as a practical way for medical schools involved in EPA curricular efforts to address concerns regarding the implementation and learner assessment strategies surrounding EPA 12: perform general procedures of a physician [27]. The AAMC discusses an ideal implementation and assessment system as one that allows students many opportunities for repeated low-stake practice and formative assessments such that they eventually reach entrustment prior to entering residency. Olle ten Cate describes five levels of entrustment for EPAs [28]. Starting procedural skills training in the preclinical years enabled our students to achieve level two entrustment with EPA 12. Simulation-based preclinical procedural training such as that offered by our program allows students to start their clinical experiences at a higher level on the entrustment continuum. We speculate that with such early training, further skills refinement in the clinical years should enable students to acquire higher levels of entrustment more rapidly than if the skills training is initiated during the clinical years. In addition, standardized procedural training allows all students a baseline of skill education to build from when approaching clinical care. As more schools implement strategies to teach and assess the core EPAs, including procedural skills training, there might be collaborative opportunities in the near future to assess the pace at which students' progress through the entrustment continuum and the factors that influence this pace in regards to procedural competence.

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**Compliance with Ethical Standards** This study was approved by the Stony Brook University Institutional Review Board (IRB).

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