Which renal access technique for percutaneous nephrolithotomy is more difficult to teach using simulation in surgical training?

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ABSTRACT

Introduction: Percutaneous nephrolithotomy (PCNL) is a challenging procedure that urology trainees should be familiar with during residency. Simulators, such as the PERC Mentor, allows the development of this competency in a safer, stress-free environment. There are two primary fluoroscopic methods of gaining percutaneous renal access: the triangulation method and the bull's eye method. Our goal was to assess which method is easier to teach novices by using the PERC Mentor simulator. A secondary goal is to assess differences in subjective and objective outcomes.

KEY MESSAGES

- Obtaining percutaneous renal access is a challenging competency for urology trainees to obtain. Both the fluoroscopic techniques of bull's eye and triangulation are equally well taught and received by trainees.
- Both techniques are associated with similar outcomes and complication rates; however, the bull's eye is associated with a faster operative time and fluoroscopic time compared to the triangulation technique.

Methods: Fifteen simulator and procedure-naive medical trainees were randomized into two groups using a crossover, randomized study design. Participants were provided with written, video, in-person demonstrations and hands-on practice for each technique. They then performed each method and were assessed objectively using the PERC Mentor performance data report and

subjectively using the PCNL global rating scale (GRS) scoring system. Statistical analysis was performed using Student's T-test and non-parametric Wilcoxon signed rank test.
Results: There was no statistical difference in the outcomes and complication rates between the two methods. The bull's eye method of obtaining percutaneous access was associated with a significant decrease in operative time (91 seconds vs. 128 seconds, p=0.03) and fluoroscopy time (87 seconds vs, 123 seconds, p=0.03) compared to the triangulation method.
Conclusions: Teaching of both techniques was equally well-acquired by students. Both techniques had similar outcomes; however, the bull's eye method was associated with less operative and fluoroscopy time when compared to the triangulation method among novices.

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) is considered the gold standard for treatment of patients with larger renal stones. Gaining percutaneous access (PCA) is an essential, yet challenging step in the PCNL procedure.[1] There are two primary fluoroscopic methods utilized to obtain PCA: Eye of the Needle (Bull's Eye) or Triangulation.[2] To date, no significant difference has been shown in terms of outcomes and complication rates when comparing the 2 fluoroscopic methods.[2 3] Various anatomical considerations exist that make gaining PCA difficult. The kidneys are well vascularized with many vital structures nearby. Proper orientation and puncture needle placement are therefore necessary to avoid complications such as hemorrhage and visceral injuries.[4 5] The difference of couple of millimeters in needle placement can distinguish between a successful procedure and a complication.[6] Optimal placement also ameliorates the ease of PCNL, stone-free rates and decreased bleeding due to less torque on the renal parenchyma.[7 8 9]

However, even though 70% of urologists perform percutaneous procedures, only 11-17% actually establish their own access.[5 10] It has been shown that urologists obtaining their own access are associated with lower complication rates and shorter hospitalization stays.[10] Reasons for this discrepancy can be attributed partly to the lack of training as a resident as well as the steep learning curve associated with mastering such a technique.[5, 11] A literature review compiled of 14 articles determined that the learning curve for PCNL procedure plateaued at around 30-60 cases for operative time, 20-115 cases for fluoroscopic screen time and 30-105 cases for stone free rates. Successful puncture plateaued at 120 cases and radiation dose plateaued at 115 cases.[12]

The introduction of simulators for surgical training allows trainees to address a portion of the discrepancy mentioned above: by practicing in a stress-free and radiation-free environment.[13] Prior to computerized simulators, biologic and non-biologic bench models such as porcine or bovine kidneys and 3D printing were used as training material. However, these methods did not

negate the risk of radiation and body fluid exposure to the user.[14, 15] The PERC Mentor (https://www.okbmedical.com/percmentor.html) is currently the only virtual reality (VR) simulator that has been validated for training and assessment of PCA skills.[16] With its accurate visual imagery and realistic equipment replicating tactile feedback and movements associated with respiration, the PERC Mentor simulator has been used in many urology training programs to improve PCA skills.[17, 18] The PERC Mentor is also capable of generating a performance report for each attempt, looking at operative time, fluoroscopy time, time spent introducing needle into collecting system, number of attempts to puncture, complications and types, and amount of contrast injected.

PCNL-GRS is an evaluation system, modified from an endourological global rating scale that was validated to measure skill acquisition in ureteroscopy. [13, 19] This PCNL-GRS rubric looks at 5 different parameters: anatomy identification, planned needle puncture, use of instrumentation, ability to perform tasks and overall performance. It is a subjective assessment used in surgical education that has itself been validated to evaluate a trainee's performance.[13 20] Significant improvement in all facets of the PCNL-GRS score was seen in subjects who underwent training; whereas improvement in only 1 parameter was seen in those who did not receive training. This demonstrates the ability of the PCNL-GRS score to quantify and differentiate between skill levels. [19]

When the PCNL-GRS score is combined with the objective data obtained by the PERC Mentor, an improvement in 11 out of 14 tested spheres was seen in trained subjects whereas there was only an improvement in 1 out of 14 elements in untrained subjects, reinforcing the pervasiveness of parameters tested when both subjective and objective data reports are conglomerated.[19] Therefore, the PCNL-GRS score, along with the objective data obtained by the PERC Mentor allows for a global evaluation of trainee skills and has been previously proven to be successful in differentiating competency between urology post-graduate trainees.[19]
Given the difficulty of mastering PCA and the existence of 2 different yet similarly effective methods of gaining PCA, the goal of our study is to determine which method, Triangulation vs Bull's Eye, is associated with an easier ability to learn on the PERC Mentor simulator, thus allowing urology trainees to gain competency faster. This is particularly essential in the Canadian urological residency training landscape where a shift towards a competency by design evaluation model outlines percutaneous renal access as a necessary skill to obtain during residency.[21] This is the first study of its kind comparing the ease of learning of both methods with simulation-naïve medical trainees on the validated PERC Mentor simulator. Our objective is to determine whether there is a significant difference between teaching both the Triangulation and the Bull's Eye method in terms of objective and subjective assessment scores.

METHODS

Fifteen second year medical students from one Canadian, urban, medical university, participating in the Surgical Explorations and Discovery (SEAD) program were recruited. This two-week voluntary program aimed at exposing medical students early on to various surgical specialties in the goal of career exploration. They were all simulator-naïve and had never performed any steps of a PCNL before. Each student was given access to written instructional material and videos outlining both the Triangulation method and the Bull's Eye method of obtaining PCA a few days prior to performing the procedure on the PERC Mentor simulator. Simplified written instructions were also provided to the students on the day of performance (see appendix). They then observed an endo-urologist explain and demonstrate the steps of both methods on the simulator. Finally, they each were allowed one practice run utilizing both techniques on the PERC Mentor to familiarize themselves with the simulator. Each trainee was observed by a PGY-5 urology resident and Endo-Urology attending who were available to guide the students and answer questions from the participants. This PCNL curriculum was designed by two endourologists practicing at academic hospitals affiliated with the trainees' medical school.

Each student then performed both the Triangulation method and the Bull's Eye method of gaining PCA in the renal pole of their choice. Successful puncture was deemed by return of urine. Using a randomized controlled cross-over study design, the participants were sorted into two groups. Group A got to perform the Bull's eye method first, followed by the Triangulation method whereas Group B performed the Triangulation method first, followed by the Bull's eye. This was done to ensure that differences seen between the two methods were not due to confounding factors such as prior amount of exposure to the simulator. The techniques performed by each participant was compared to each other. The data was paired. Each participant was also therefore their own control.

Participants' performance was judged using the validated PCNL-GRS scoring system as well as the PERC Mentor's registered performance results. The PCNL-GRS is a subjective score given by the observing PGY-5 urology resident who is familiar with both techniques of obtaining PCA using a marking sheet. PCNL-GRS is comprised of 5 components looking at anatomy identification, planned needle puncture, use of instrumentation, ability to perform tasks and overall performance. Each component is rated on a Likert scale between 1 to 5, up to a total of 25 points. [20]

The PERC Mentor performance sheet, generated by the simulator, records objective data including total operative time, x-ray exposure time, time spent introducing needle into the collecting system, number of attempts to puncture the collecting system, number and type of complications and total amount of retrograde contrast injected.

The results of the Triangulation method and the Bull's Eye method were compared and evaluated using the IBM SPSS software. Paired student's T test was used to assess differences in total operative time, x-ray exposure time, time spent introducing needle into the collecting system and

total amount of retrograde contrast injected. Non-parametric Wilcoxon Signed Rank test was used to compare PCNL-GRS global score as well as each individual component between the two methods. This test was also used to compare number of attempts to puncture the collecting system and number of complications. Additional statistics were done to assess whether there was an effect between PCA attempt number and group allocation (students being in Group A vs B) on objective and subjective performance results. A two-sided p-value <0.05 was considered significant.

RESULTS

15 medical students participated in the study. 60% were males and 40% were females. They were all in their second year of medical school.

All 15 participants performed both the Triangulation method and the Bull's eye method of obtaining PCA. The Bull's Eye method was associated with a statistically significant decreased fluoroscopy and operative time compared to the Triangulation method. On average, the total operative time for the Triangulation method was 128 seconds while that for the Bull's eye method was 91 seconds (p-value = 0.03). Fluoroscopy (x-ray) exposure time was also statistically significant between the 2 methods, with the Triangulation method at 123 seconds and the Bull's eye method at 87 seconds (p-value = 0.03).

There was no statistical difference in terms of PCNL-GRS total score, nor each individual component score between the two methods. As well, there was no difference in terms of number of attempts to puncture the collecting system, complication rates and amount of contrast injected during the procedure between the two methods.

Secondary analysis was done to see whether there was an appreciable learning effect that could be seen between a trainee's first and second attempt, regardless of the first technique performed. Within the objective measures, operative time and fluoroscopic time were analyzed given that there were statistically significant differences observed in those two parameters. Whereas, for subjective measures, only the total PCNL-GRS score was analyzed given there was no statistical difference between any subcategory, nor total score. Though there was a trend towards improvement with increased PCNL-GRS scores and decreased operative and fluoroscopic times on the second attempt, none of the measures were statistically significant.

Additional analysis looked at whether the group allocation had an influence on the PCNL-GRS total score as well as the operative time and fluoroscopic time for both the Bull's Eye method and the Triangulation method. Within each technique, there was no difference between Group A and Group B for operative time, fluoroscopic time and total PCNL-GRS score. The order of which a participant performed each technique had no impact on their execution.

DISCUSSION

Contrary to popular belief that teaching triangulation is more difficult than the bull's eye method for obtaining PCA, both methods were well obtained by the trainees. Either method can be

equally taught and learned without compromising outcomes. Our results however demonstrate that the Bull's Eye method in the hand of novice trainees is a faster and safer technique than the Triangulation method for trainees. Due to the lesser need for C-arm manipulations, it is associated with a decrease in total operative time as well as less fluoroscopy time, therefore leading to less radiation exposure for both the patient and the trainee. There was, however, no difference between the two methods in terms of subjective performance as demonstrated using the PCNL-GRS scoring system, nor in terms of complication rates, attempts to puncture and amount of radiocontrast material used. Given the similar success rates and adverse outcomes between both the Triangulation and the Bull's Eye method, our results show that the Bull's eye method is likely an easier skill for trainees to acquire. However, either method can be learned without increased adverse events. We then compared the subjective and objective data between a trainee's first and second attempt in order to see if there was a cumulative learning effect that could be observed. The PCNL-GRS total score, operative time and fluoroscopy time were parameters used. Though there was a trend towards a mild improvement in all 3 facets, showing that learnt skills were retained from attempt 1 to attempt 2, this was unfortunately not statistically significant, likely due to the study being underpowered. Nonetheless, this information can be useful for educators and attendings in teaching hospitals because the Bull's Eye method could be used as the initial teaching method for novice learners as it is associated with easier skill acquisition. Once the trainee feels more at ease and has gained confidence in this technique, they can implement the triangulation method. Trainees will likely be more proficient then since they are already familiar with the basic fluoroscopic key steps. By using the PERC Mentor simulator, which has been accepted and validated as a surgical model for PCNL,[20] our results can be extrapolated to the operating room.

This is the first study to our knowledge that has compared both methods using a virtual reality model in simulator and PCA procedure naïve trainees. None of our participants have used the PERC Mentor or performed any steps of a PCNL in the operating room prior to the conduction of this study, thus allowing our results to truly reflect the ease of learning of each method. Though studied on medical students, our results can be useful to guide urology residency curriculum as all trainees start their learning journey with minimal knowledge. A urology resident's first exposure to percutaneous renal access and percutaneous nephrolithotomy is likely during residency. A previous study conducted by Abdallah et al using a bovine kidney as a biological model compared both the Triangulation method and the Bull's eye method using trainees and concluded that there was no statistically significant difference between the two models in terms of total operative time, though the Bull's eye method used significantly less fluoroscopy time compared to the triangulation method.[22] These results are concordant with our findings.

Other studies have compared the two techniques in terms of adverse events, hospitalization time and success rates defined as stone-free rates and shown no difference

between the two methods in any of these spheres.[2 3] They concluded that there is no preferred method to gaining PCA. Our study echoes similar results, showing no difference in outcomes between the two results, however we were able to demonstrate that the Bull's eye technique in the hand of novices is associated with a faster technical skills gain. Given the steep learning curve of PCNL skill acquisition [9] and limited residency training, being able to identify a technique that is faster to achieve while still providing the same outcomes is essential for skill acquisition.

Limitations

Some limitations exist with our study. We had a small sample size of 15 medical trainees from one institution. However, due to the cross-over study design, each trainee was their own control, thus minimizing confounding factors. This is additionally seen in Table 2, where there was no difference between performance scores and group allocation. This reinforces that the cross-over design was able to avoid bias and washout the experience gained from prior attempts. As well, all trainees had no experience performing any steps of PCNL and had never used the PERC Mentor simulator, therefore avoiding any prior knowledge bias. We were unfortunately unable to report whether the trainees accessed the written instructional material and videos prior. However, the teaching was re-explained and demonstrated in person where all trainees were in attendance. Other limitations included having only one resident observe the trainees and give the PCNL-GRS score. Therefore, we were unable to prove inter-observer reliability. However, having only one evaluator allowed consistency in the scoring metric. Though our study only had one observer, Matsumoto et al. showed that the PCNL-GRS system had high inter-rater reliability with two attendings and two fellows involved in their study.[13] As well, the use of both subjective and objective performance evaluation methods allowed for a more global approach of each trainee's true competency level. This study did not look at a specific renal calyx of interest which could be explored in future studies.

CONCLUSIONS

Our study shows that both methods of obtaining PCA were well acquired by trainees. However, in the hand of novices, the Bull's Eye method of gaining PCA was associated to a shorter operative time as well as shorter fluoroscopy exposure time by almost 30% compared to the Triangulation method. The rate of adverse events for both methods were similar as well. Either method can be taught safely to novice trainees to acquire the necessary skills to perform PCNL without increased complication rates however the Bull's Eye method was associated with less radiation exposure and operative time compared to the Triangulation method.

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FIGURES AND TABLES

Figure 1. Participant allocation methods

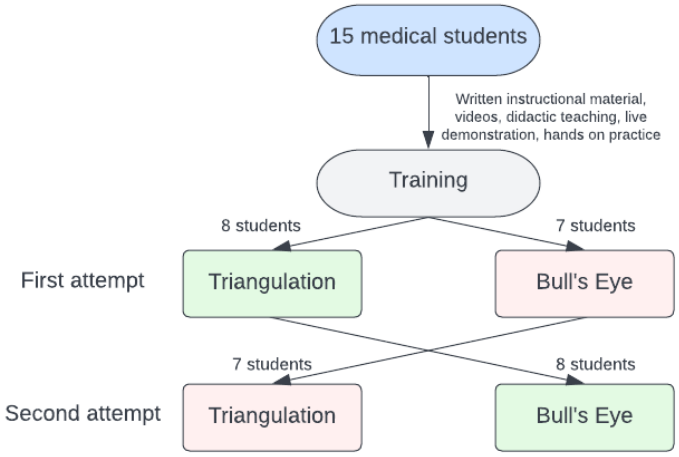

Figure 2. Effect of percutaneous access (PCA) attempts on objective and subjective performance. PCNL: percutaneous nephrolithotomy

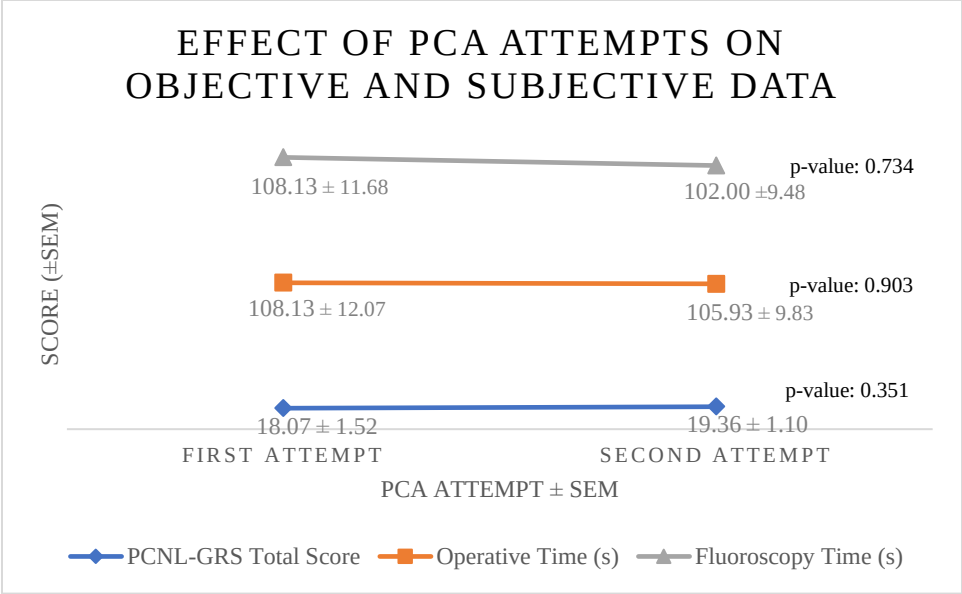

Table 1. Objective and subjective results of various percutaneous nephrolithotomy methods			
	Percutaneous nephrolithotomy method		
	Triangulation (± SD)	**Bull's eye (± SD)**	**p**
PCNL-GRS score			
Total	18.00±4.94	19.38±4.80	0.474
Identify anatomy	4.87±0.52	4.53±0.83	0.102
Plan needle puncture	3.60±1.06	3.93±1.10	0.336
Use of instruments	3.47±1.19	3.79±1.25	0.314
Ability to perform task	2.67±1.59	3.20±1.26	0.2
Overall performance	3.40±1.24	3.67±1.05	0.248
Objective data			
Operative time (s)	128.07±35.53	91.33±40.99	**0.033**
Fluoroscopy time (s)	123.07±33.63	87.07±39.87	**0.031**
Time spent introducing needle into collecting system (s)	17.80±9.67	15.00±10.68	0.42
Attempts to puncture (#)	1.87±0.64	2.27±1.10	0.262
Complications (#)	1.73±0.96	1.73±0.80	0.914
Amount of contrast injected (mL)	46.33±11.72	41.00±11.21	0.22

SD: standard deviation.

Table 2. Effect of randomized PCA technique sequence on objective and subjective outcomes			
	Group allocation		
	Group 1 (± SD)	**Group 2 (± SD)**	**p**
PCNL-GRS total score			
Bull's eye	19.57±5.56	19.14±4.34	0.875
Triangulation	19.57±4.24	16.57±5.80	0.291
Operative time (s)			
Bull's eye	95.71±54.63	87.50±27.67	0.714
Triangulation	127.00±38.99	129.00±34.92	0.918
Fluoroscopy time (s)			
Bull's eye	92.14±53.41	82.63±26.19	0.662
Triangulation	124.14±35.72	122.13±34.14	0.913

PCA: percutaneous access; PCNL-GRS: percutaneous nephrolithotomy global rating scale; SD: standard deviation.