

A Simple, Non - Biological Model for Percutaneous Renal Access Training

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Purpose: Percutaneous renal puncture (PRP) is one of the most important and critical step of urology, especially while performing percutaneous nephrostomy and percutaneous nephrolithotomy (PCNL). In the learning period of this procedures, there is a need for validated, effective, economical models for such training. This study describes a simple non - biological model for learning PRP. The aim was to determine the effectivity of this model as a training and assessment tool, and to assess its cost relative to other models.

Materials and Methods: We designed a training box, made of foam and rubber with two open sides and performed radiopaque pelvicalyceal system maquettes to insert inside it. Experts in PCNL (i.e., > 100 cases) and novices (i.e., pediatric surgeons and urologists without PCNL experience) performed percutaneous renal puncture. Novices performed a pre - test and a post - test (i.e., after 2 hour training). Data recorded were total procedure time, X - ray exposure time, and number of puncture attempts. Experts who performed PRP successfully were asked to rate the model using a questionnaire.

Results: Five experts and 21 novices completed the study. Four experts rated the model as an "excellent" (score 5) training and assessment tool; one expert rated these as "very good" (score 4). Comparisons of novices' pre - and post - test median results revealed significant skill acquisition with shorter procedure time, less X - ray exposure, and fewer attempts for successful puncture (all $P < .001$).

Conclusion: This new non - biological training model is an effective training tool that helps learners improve skills in PRP. The model is simple to construct, economical, and highly re-useable compared to others. It provides good visibility and imaging, is portable, and could be used widely in training centres.

Key Words: education; model; percutaneous; kidney; training.

INTRODUCTION

Percutaneous renal access (PRA) is one of the most important attempts in endourological interventions. PRA is also the most important step of percutaneous nephrolithotomy (PCNL). The learning curve for PCNL mainly depends on the quality of the PRA, which depends on the skills of the individual who performs the PRA (i.e. the radiologist or the urologist).⁽¹⁾ An American survey demonstrated that only 11 % of urologists performed percutaneous access by themselves.⁽²⁾ Reasons for this may include lack of training. Waterson et al. had evaluated percutaneous access for PCNL obtained by interventional radiologists or a urologist and emphasized that despite similar access difficulty, complications were less and stone free rates were improved during urologist acquired PRA.⁽²⁾ Urologist, obtaining access himself/ herself also eliminates requirement and reliance on a second hand. Schilling et al. evaluated 49 PCNL procedures performed on live patients by experts

and 35 performed by novices, and documented four complications (Clavien grade 1-2) in the expert group and 12 complications (Clavien grade 3) in the first 20 patients of the novice group.⁽³⁾ This difference underlines the importance of training on simulators before attempting to perform PCNL on human patients. A review by Rosette et al. in 2008 recommended that PRP simulation models be developed and validated.⁽¹⁾

There is a clear need for simulators that can enable surgeons to acquire necessary skills. It has been shown that residents who have trained on models demonstrate better surgical skills when operating on live patients.^(4,5) Animal laboratories (wet lab) and training models can be used to develop these skills; however, the literature indicates that only a few models for PRA have been established to date, and these can be categorized as virtual reality simulators (VRSs), ex - vivo (biological) models, and non - biological models.⁽⁶⁾ In the literature of the non-biological training models, it was observed

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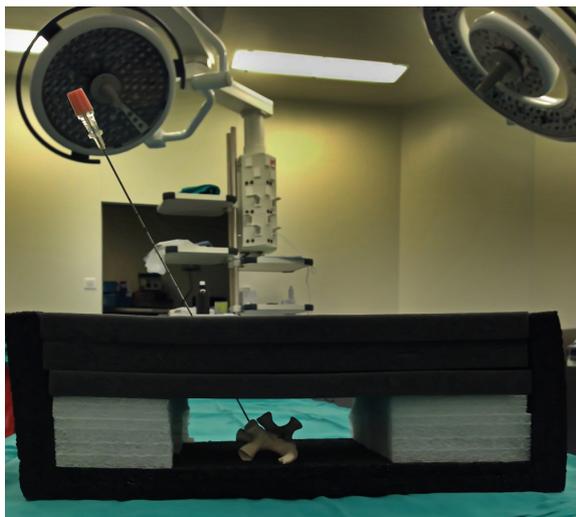


Figure 1. The percutaneous renal puncture model from one open side



Figure 2. The percutaneous renal puncture model. The view from upside (from the side of the surgeon) with C - arm fluoroscopy position on the opposite side and X - ray image.

that the most common limitations of the models were the cost and the insufficiency reusable feature of them. We designed a new and simple non-biological training model for percutaneous renal puncture (PRP). Based on success in preliminary experiments, we designed this study to assess the PRP model as a training tool for fluoroscopy-guided PRA. We also searched the literature of non-biological models to assess the model's economic feasibility for clinical use.

MATERIALS AND METHODS

Percutaneous Renal Puncture Model

The PRP model (**Figures 1 and 2**) has two components: a rectangular prism and pelvicalyceal system (PCS) maquettes / units. The prism is 25 cm wide x 31 cm deep x 12 cm high. Two sides of the prism are open, which enables the user to see inside when necessary. The prism is constructed of rubber and foam that used to simulate human tissue elasticity. The top portion of the prism consists of three layers with 2 cm thickness that can be changed to simulate different tissue thicknesses. The skin - kidney distance could be changed with this three layer design. The skin - kidney distance is minimum 6 cm, maximum 12 cm. All layers and walls except portable roof layers were fixed with hot silicone.

The second component of the model, the PCS maquette, is made by hand with using play dough by one of the authors (DU) who is a senior urologist. They are available as six separate designs (identified as PCS 1 to 6) that simulate different renal case scenarios (**Figure 3**). These designs provide different shapes, different calyx configurations (i.e., 7, 8 or 9 calyces), and different hydro - nephrosis statuses. The different configurations were identified from his patients CT images. The total cost of this PRP model is \$US 25, which includes \$US 5 for the outer portion of the structure, \$US 15 for play - dough, and \$US 5 for hot silicone for fixing layers.

Study Design

We followed the study design of the study that reported by Zang et al. in 2014.⁽⁷⁾ The investigation involved assessments by five experts who were defined as experienced at performing PCNL (i.e., individuals who had managed more than 100 clinical PCNL cases⁽¹⁾) and by 21 novices (i.e., urologists or pediatric surgeons without prior PCNL experience). Experts performed PRA once using the model, and novices performed PRA twice: initially after brief and very basic training for orientation (i.e., a pre-test), and again after two 1 - hour training sessions (i.e., a post - test). All procedures were done using an 18 G needle and C - arm fluoroscopy.

Table 1. The experts' (n = 5) questionnaire results regarding the percutaneous renal puncture model.

QUESTION NO.	MODEL CHARACTERISTIC ASSESSED	MEDIAN SCORE* (RANGE)
1	Overall appraisal	5 (4 - 5)
2	Simulation of ease/complexity	4 (3 - 5)
3	Quality of x - ray images	5 (4 - 5)
4	Training tool	5 (4 - 5)
5	Assessment tool	5 (4 - 5)

*Scale:

- 1 = Very poor
- 2 = Poor
- 3 = Good
- 4 = Very good
- 5 = Excellent

Abbreviation: n: number in group

Table 2. Objective data for the percutaneous renal puncture model: Comparison of results for the experts and novices.

PARAMETER	EXPERTS TEST(n = 5) MEDIAN (MIN - MAX)	NOVICES PRE - TEST (n = 21) MEDIAN (MIN - MAX)	NOVICES POST - TEST(n = 21) MEDIAN(MIN - MAX)	P ^a Value	P ^b Value	P ^c Value
PROCEDURE TIME	63 s (51 - 120 s)	183 s (52 - 696 s)	45 s (25 - 93 s)	.005d	< .001 ^d	.034 ^d
X - RAY EXPOSURE TIME	30 s (25 - 60 s)	77 s (12 - 180 s)	15 s (6 - 45 s)	.034d	< .001 ^d	.028 ^d
NUMBER OF ATTEMPTS	2 (1 - 2)	4 (1 - 8)	1 (1 - 2)	.012d	< .001 ^d	> .05

^a Comparison of expert results versus novice pre - test results

^b Comparison of novice pre-test versus post - test results

^c Comparison of expert's results versus novice post - test results

^d Statistically significant ($P < .05$)

Abbreviations: n: number in group, min: minimum, max:maximum, s: second

The same unit (PCS 1 maquette) was used only during pre and post tests, not during training sessions.

The experts were invited to perform PRA using the PRP model. The objective data collected were procedure time (i.e., total time required to achieve successful puncture beginning from initiation of the first attempt), X - ray exposure time, and number of attempts required to achieve successful PRA. An observer judged the success of PRA; the criterion for this was PRP performed in the correct direction through the papilla, not the infundibulum or renal pelvis. The experts who were judged to have performed PRA successfully using the model were asked to complete a questionnaire with five questions about the PRP model (Table 1).

Each individual novices attempted PRA using the model with PCS 1, and performance of PRA was evaluated based on the above - listed objective parameters. Following this, the novices received two 1 - hour sessions of supervised training to improve their skills in standard PRA using other PCS maquettes (PCS 2, 3, 4, 5, and 6). An expert (SO, an urologist, experienced with 100 PCNL cases) did these training sessions with one day time interval between sessions for each participant. "Eye of the needle (Bull's eye)" technique was taught to novices by the senior for accessing. 24 hours later each novice performed PRA using PCS 1, the post - test objective data (listed above) were recorded. As noted, all tests was done using the same PCS maquette/unit (PCS 1) and all the attempts to puncture were towards the same (posterior - inferior) calyx while recording the

performance.

Statistical Analysis

Experts' results were compared to novices' results, and novices' pre- and post - test results were compared to assess skill acquisition. Data were analyzed using the software package SPSS v. 16.0 (SPSS Inc. Released 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.), and the Wilcoxon signed - rank test and the Mann - Whitney U test were used. $P \leq .05$ was considered to indicate statistical significance. With an alpha of 0.05 (two - sided) we will need 21 surgeon in novices group to achieve a power of .80.

RESULTS

All five experts performed PRA successfully using the PRP model, and all completed the questionnaire. Complete data sets were collected for 21 novices.

Regarding the questionnaire findings (Table 1), for overall appraisal, all five experts rated the PRP model as 4 (i.e., "very good") or 5 (median score, 5 : excellent). Scores for the model's ability to simulate ease / complexity of the real - life procedure ranged from 3 (i.e., "good") to 5 (median score, 4). Four experts rated the model's performance with respect to X - ray images as excellent (score 5) (Figure 4). Four experts rated the model as an excellent training and assessment tool (score 5 for both), and one assigned a score of 4 for these traits.

The test results for the experts and novices are sum-



Figure 3. The six maquettes that can be used with the percutaneous renal puncture model

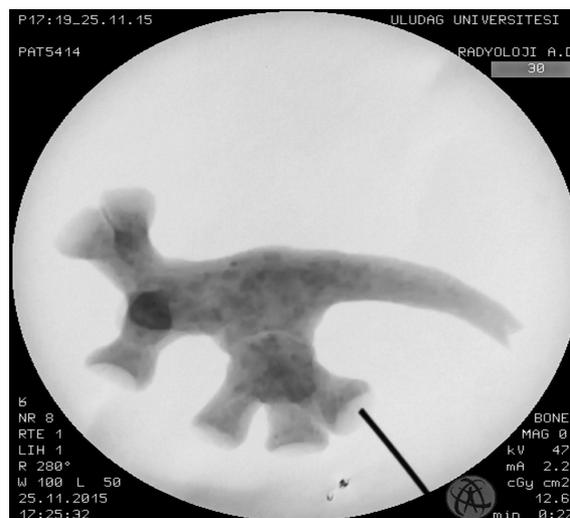


Figure 4. The X - ray image of the PCS maquette 1

marized in **Table 2**. For each objective parameter, the experts' results were significantly better than the novices' pre - test results ($P = .005$, $P = .034$, and $P = .012$ for procedure time, X - ray exposure time, and number of attempts, respectively). Comparisons of the novices' pre - and post - test results revealed statistically better post - test results for all three parameters ($P < .001$ for all). The experts' procedure time and X - ray exposure time were significantly longer than the novices' post - test results ($P = .034$ and $P = .028$, respectively). There was no significant difference between these two groups with respect to number of attempts.

DISCUSSION

The advent of simulation models in medical education has offered safe ways to improve learners' surgical skills in settings outside the operating room.^(8,9)

The literature describes a small number of non - biological training models for PRA.

A 2014 study by Zang et al. described validation of another non - biological bench model for training in PRA.⁽⁷⁾ It is constructed of silicone and has three parts: a kidney, a ureteral stump, and non - transparent perirenal tissue. The cost of this model is \$US550.⁽⁷⁾ Apart from cost, the main disadvantage of this model is that the trainee is limited to practicing on one PCS, which means that she/he tends to memorize the anatomy. Also, only a maximum of six trainees can practice PRA on one unit prior to dilation.

In a model described by Turney et al.⁽¹⁰⁾, the collecting systems from routine computed tomography urograms are extracted and reformatted using specialized software and these images are printed via a 3D printer to create bio models. Each of these models costs approximately £8072/€9584/\$US12919. The long and demanding preparation period (2-3 days), the need for high technology, and price (even though the authors state that cost is low) are the drawbacks of this tool.

In 2008, Bruyere et al. published a rapid-prototyping non-biological model for PRA that was based on abdominal computed tomography images of a patient scheduled to undergo PCNL.⁽¹¹⁾ The cost was €2,500 /\$US3,690. Its disadvantages are high cost, the need of high technology, the long time required for construction, and the fact that each model can tolerate only six practices.

In the present study, all five experts performed PRA successfully using our PRP model. The top of the model is a convertible three - layer structure, which allows the user to change the tissue thickness. The experts' answers to the questionnaire on model performance revealed a rating of excellent (median score, 5) for overall appraisal, X - ray imaging, value as an assessment tool, and value as a training tool. A rating of very good (median score, 4) was assigned for the model's ability to simulate ease/complexity of real - life PRA.

Our comparisons of pre - and post - test data revealed significant improvement ($P < .001$) in novices' skills at performing PRA using the model. After 2 hours of supervised training, procedure time and X - ray exposure time were shorter (both $P < .001$), which means less X - ray exposure for patients in the operating theatre. The training also enabled the novices to achieve successful PRA with fewer puncture attempts ($P < .001$).

Selecting the correct direction and side of puncture (i.e., successful puncture) decreases the procedure time

and associated costs.⁽¹²⁾ The trainee can learn how to perform the optimal direction of puncture through the papilla and infundibulum, to use C-arm fluoroscopy, to accurately interpret the fluoroscopic images, and to convert the 2D images into 3D in her or his mind. Once a puncture attempt is made, the trainee can view the results inside the model from both sides, understand the reasons for an unsuccessful puncture in detail, and compare the directly visible results to what is apparent on the fluoroscopy images. As well, this model improves hand - eye coordination and reduces unnecessary X-ray exposure for patients.

We observed that trainees tend to learn the positions of the calyces and anatomy of a PCS as a result of practice, and that learning on only one PCS yields a false sense of skill acquisition / success with PRA, which is misleading. It is important to switch PCS maquettes / units after a few successful punctures, and to ensure that the trainee practices with different scenarios and to reform and reduce the ease of the model. Our model also allows the supervisor / trainer to remove the PCS maquette from one side of the model and insert the new one without any additional movement.

Surgical education mainly depends on hands - on practice to improve technical skills, and percutaneous renal endoscopic surgery requires advanced surgical skills. The literature indicates that, to become proficient in PCNL, a resident must perform approximately 24 of these procedures during training.⁽¹⁾ Competence at PCNL (i.e., expert level) is considered to be reached after 60 PCNL cases, and excellence is acquired at greater than 100 cases.⁽¹⁾ It is difficult to reach these numbers during the training period.⁽¹³⁾ The learning curve for PCNL is long, and surgical disasters can occur during the training period.⁽³⁾ It has been shown that residents who have trained on models demonstrate better surgical skills when operating on live patients.^(4,5)

Training on simulators of PCNL has recently become recommended practice for percutaneous renal surgery; however, time and costs tend to limit the use of these tools. Our PRP model is highly re - useable; in total, 113 puncture attempts were performed on the model during the novices' pre - tests and post - tests, and the number of additional attempts made during training sections were not recorded. In addition to being re - useable, one key advantage of our PRP model is its low cost. The total cost of our PRP model is \$US25. To our knowledge, this PRP model is the most inexpensive model of its type to have been subjected to an assessment study. As with other training models, the current version of this model has some limitations. In this model there is no perirenal and renal cortical tissue and no rib, it cannot simulate the exact tactile feeling and movement while breath. Other limitations of this model are that it could not exercise the trainee about accessing though avascular Brodel's line and accessing under ultrasound guidance or direct visualized endoscopic guidance. The complexity of the model had been tried to improve with different PCS units. In our study, the criteria for an expert (individual who had performed more than 100 PCNL) limited the number of expert group. The surgeons from four different hospitals were included the study. The number of experts among these surgeons were only five. The study performed in four different centers using four different C-armed fluoroscopy and because of technical features of machines, the radiation

dose, used during tests or training, could not be documented. It is a pilot study, we plan to validate the model with increased population size and for the next step of education we plan to design a new model for simulation of all steps of PCNL procedure.

CONCLUSIONS

PRP is one of the most important attempt for adult and pediatric urology. Our findings demonstrate that this PRP model is effective as a training tool and is economical for clinical use. This low-cost, re-useable, portable and effective model permits rapid acquisition of PRP skills, and can be used as the first step in a surgeon's learning curve for achieving successful PRA.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

1. Rosette JJMCH, Laguna MP, Rassweiler JJ, Conort P. Training in Percutaneous Nephrolithotomy—A Critical Review. *EAU* 2008;54:994–1001.
2. Watterson JD, Soon S, Jana K. Access related complications during percutaneous nephrolithotomy: urology versus radiology at a single academic institution. *J Urol*. 2006 Jul;176(1):142-5.
3. Schilling D, Gakis G, Walcher U, Stenzl A, Nagele U. The learning curve in minimally invasive percutaneous nephrolitholapaxy: a 1-year retrospective evaluation of a novice and an expert. *World J Urol* 2011;29:749–53.
4. Palter VN. Comprehensive training curricula for minimally invasive surgery. *J Grad Med Educ* 2011;3:293-8.
5. Stern J, Zeltser IS, Pearle MS. Percutaneous renal access simulators. *J Endourol* 2007;21:270-3. Review.
6. Mishra S, Jagtap J, Sabnis RB, et al. Training in percutaneous nephrolithotomy. *Current Opinion Urolithiasis* 2013; 23(2):147–51.
7. Zang Y, Yu CF, Jin SH, Li NC, Na YQ. Validation of a novel non biological bench model for the training of percutaneous renal access. *Int Braz J Urol* 2014;40:87-92.
8. Scott DJ, Cendan JC, Pugh CM, Minter RM, Dunnington GL and Kozar RA. The changing face of surgical education: simulation as the new paradigm. *J Surg Res* 2008;147:189-93.
9. Wignall GR, Denstedt JD, Preminger GM, et al. Surgical simulation: a urological perspective. *Urol* 2008;179:1690-9.
10. Turney BW. A new model with an anatomically accurate human renal collecting system for training in fluoroscopy-guided percutaneous nephrolithotomy access. *J Endourol* 2014;28:360-3.
11. Bruyère F, Leroux C, Brunereau L, Lermusiaux P. Rapid prototyping model for percutaneous nephrolithotomy training. *J Endourol* 2008;22:91-6.
12. Radecka E, Brehmer M, Holmgren K, Palm G, Magnusson P, Magnusson A. Pelvicaliceal biomodeling as an aid to achieving optimal access in percutaneous nephrolithotripsy. *J Endourol* 2006;20:92-101.
13. Gill JD, Stewart LF, George NJR, Eardley I. Operative experience of urological trainees in the UK. *BJU Int* 2012;109:1296-301.