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Validity of a sponge trainer as a simple training model for percutaneous renal access

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KEYWORDS

PCNL;
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Model validity

ABBREVIATIONS

PCNL, percutaneous nephrolithotomy;
PRA, percutaneous renal access;
VR, virtual reality

Abstract ***Objective:*** To evaluate the efficacy of our simply designed trainer for junior urologists to acquire the initial skills for percutaneous renal access (PRA).

Subjects and methods: Three sponge sheets ($60 \times 50 \times 10$ cm) were arranged horizontally over each other. A rectangular groove was made in the middle sheet to accommodate an inflated balloon of a Foley catheter, radio-opaque metal balls, metal rings, or a plastic tube that were sequentially placed for the four training tasks. In each session, 18 trainees were asked to pass a fluoroscopically guided puncture needle from a surface point to the placed object in middle sheet. Clinical impact of training was evaluated by an experience survey on a 5-piont Likert scale (for model usefulness, tactile and fluoroscopic-guidance feedback) and success rate in further mentored practice.

Results: There was a gradual increase in tasks' and sessions' scores over the training sessions. According to the experience survey after first clinical practice, the mean (SD) score for overall model usefulness by trainees was 3.8 (0.9) with high fluoroscopic guidance reality [3.6 (1.1)] but poor tactile realism [2.3 (0.9)]. On mentored PRA, the success rate for trainees was 78.3%.

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Conclusion: Our early evaluation showed our novel, cost-effective and reproducible sponge trainer could be an effective training model for PRA with a beneficial impact on subsequent clinical practice.

Introduction

Today, percutaneous nephrolithotomy (PCNL) represents the first option for renal stone management and is used in other procedures, e.g. endopyelotomy and the treatment of renal TCC [1,2]. The key feature of successful PCNL is to establish proper percutaneous renal access (PRA) without complications. Only 11–27% of urologists can gain proper PRA [3–5], which may be explained by the absence of well-prepared training protocols for PCNL in many residency training centres [3,6].

Moreover, the lack of a simple, cheap and appropriate model for *in vitro* PRA training is a significant training problem [4]. The available training models are animal models, virtual reality (VR) simulators, and gel models, but each one has its pros and cons. However, the common disadvantages of these models are the expense, inability to reuse and/or unavailability in most urological centres [7]. For training of such manoeuvres, a big challenge is encountered between achieving proficient intraoperative hands-on training [6] and patients' safety constraints with financial considerations [8].

According to McDougall [9], 'validity' is a term used for objective assessment of the surgical training sets. Training model validity is evaluated through the opinion of individuals either trainees (face validity), or trainers (content validity), and/or through inherited characters of the simulators; as its ability to measure levels of acquired skills and experience to trainee(s) over time (construct validity), or by predictive ability to correlate between training and operating-room performance (criterion validity). In the present study, we present the preliminary results of using our innovative sponge-training model as a simply designed PRA training aid for PCNL beginners.

Subjects and methods

This study was performed between November 2012 and November 2014 in the Urology Department, Tanta University Hospitals after reviewing and approval of the protocol by our local Institutional Review Board. The involved 18 trainees were junior urologists. The training programme was mentored by four senior urologists, who had PCNL experience.

Trainer design

Three sheets of sponge (60 cm long, 50 cm wide and 10 cm thick) were arranged horizontally over each other. The upper sheet was thinned in the midline and towards the periphery to simulate the human back. Radio-opaque cylindrical bands simulating human vertebrae and ribs were arranged within the top sheet material. A groove (12 × 8 × 4 cm) was carved just lateral to the midline of the middle sheet to simulate the renal area (Fig. 1a and b).

Training tasks

In all tasks, the trainees were asked to pass a fluoroscopically guided puncture needle (20 G) obliquely from a selected surface point on the top sheet to the object placed within the middle sheet groove (triangulation technique). The C-arm was moved between parallel (to keep mediolateral direction) and oblique (detect depth of needle) positions to the puncture needle [10].

The tasks were divided according to the needle action on placed objects in the groove as follow:

- Task 1: Rupture of inflated balloon of a Foley catheter with (5, 3 and 1 cm) contrast material (Fig. 2).
- Task 2: Touch one of five metal balls of different sizes and (superficial and deep) at different planes (Fig. 3).
- Task 3: Pass through a selected one of multiple 5–10 mm metal rings arranged in different directions and planes (Fig. 4).
- Task 4: Pass an angled-tip guidewire from the Chiba needle to the lumen of a bevelled 22-F radio-opaque plastic tube after emersion in contrast material (Fig. 5).

Success of the task was defined as the needle not reaching its end without performing the task and without much needle deviation from the target (precision criteria) within the proficiency time (11, 13, 14 and 15 s for the four tasks, respectively). Precautions regarding radiation exposure (dosimetry) were taken into consideration according to radiation exposure protocol of our institution.

Training protocol

All trainees began the training tasks guided by a live demonstration by the supervisors and availability of

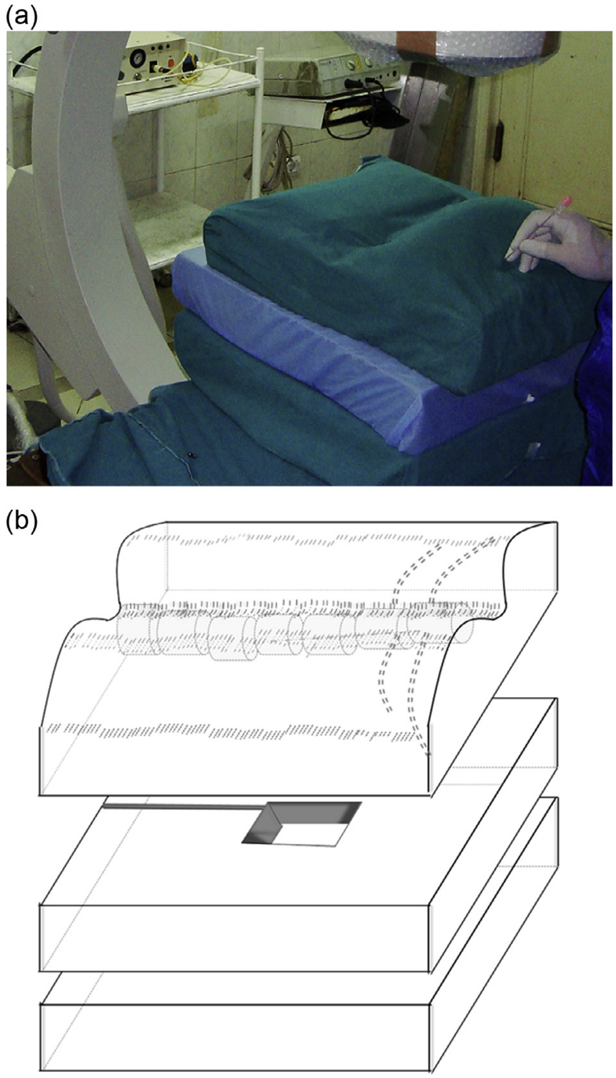

Fig. 1 (a) Model design. (b) Inner part of the model.

on-demand instructional videos during sessions for every task.

The training programme was arranged twice a week and considered as one training session. Only one task was evaluated per session, i.e. twice; at the beginning and at the end of each session for efficiency (time required to perform each task) and the precision of performance. The trainee was allowed to shift to the next task only after performing the previous one within the proficiency time and in a precise manner. The proficiency time of each task was calculated by the mean fluoroscopic exposure time needed by three PCNL experts. After successful performance of the four sessions, all trainees had a 2-week break from any PCNL training, followed by performing the four tasks in one session to test recall and retention of the acquired skills (construct validity).

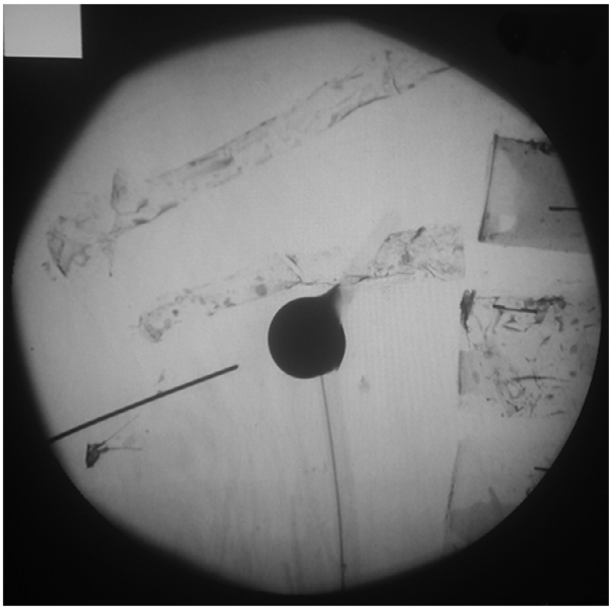

Fig. 2 Needle touching inflated balloon of Foley catheter with contrast material.

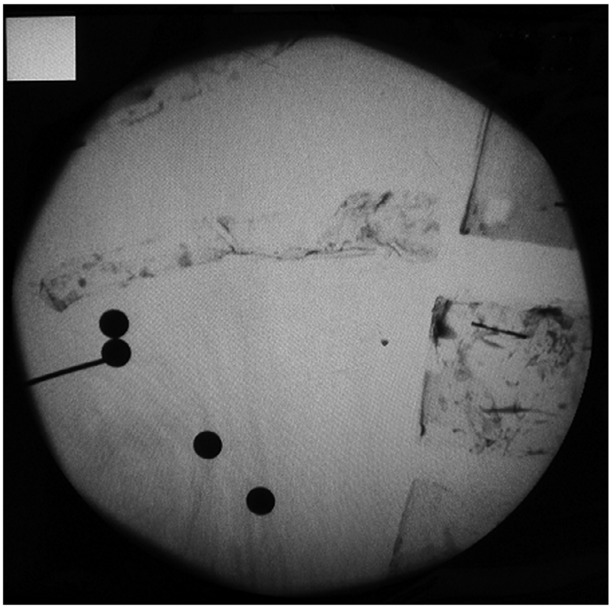

Fig. 3 Needle touching metal balls.

Over the next 4 months, all trainees were allowed to perform intraoperative PRA under close supervision by training experts, to mentor the procedure and deal with failed PRA (criterion validity). At the end of the study, trainers reported the number of performed *in vitro* and *in vivo* PRAs, and their success ratio. Also, both trainers and trainees were asked to complete the experience survey including model usefulness; tactile realism; and fluoroscopic-guidance reality of the model (content and face validity). A 5-point Likert scale was used for the evaluation. The comments 'very poor', 'poor', 'acceptable', 'good' and 'excellent' were given scores of 1, 2, 3, 4 and 5, respectively.

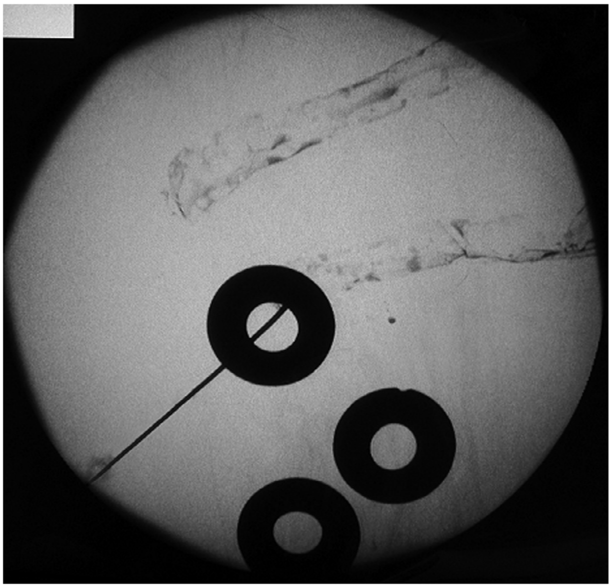

Fig. 4 Needle passing through lumen of the selected metal ring.

Statistics

The performance of each trainee for each task was illustrated by a progression curve. Data were collected, organised and tabulated using the Statistical Package for Social Sciences for Windows (SPSS®, Chicago, IL, USA). For all data, the range and mean (± SD) values were calculated. The paired Student's *t*-test was used to compare the means of the four sessions' scores.

Results

All the included trainees completed the course successfully. At the start of each task some difficulties were recorded but marked improvement was noted by the end of the training session. The proficiency time was achieved by most of the trainees in each task. For example, trainees number three and nine exceeded the proficiency training time in the first and third task respectively, whilst both trainees number 13 and 18 exceeded the 15 s needed as the proficiency time for the fourth task. Other trainees performed the targeted tasks earlier than the designated proficiency times. For example, trainee number six in the second task, and number four in the third task, and number 10 in the fourth task achieved the trained skill before the end of its required proficiency time.

Within 4 months of mentored practice, 106 PRA trials were done by the 18 participants (range 4–6 trials/-trainee) with an overall success rate of 78.3% (83/106), as judged by the mentors. After clinical practice, the overall model usefulness was described as 'excellent' by four participants, 'good' by seven, 'acceptable' by six, and 'poor' by one participant. The mean (SD; median) score of overall usefulness was 3.8 (0.9; 4) points. The model was considered 'poor' for tactile reality, with a

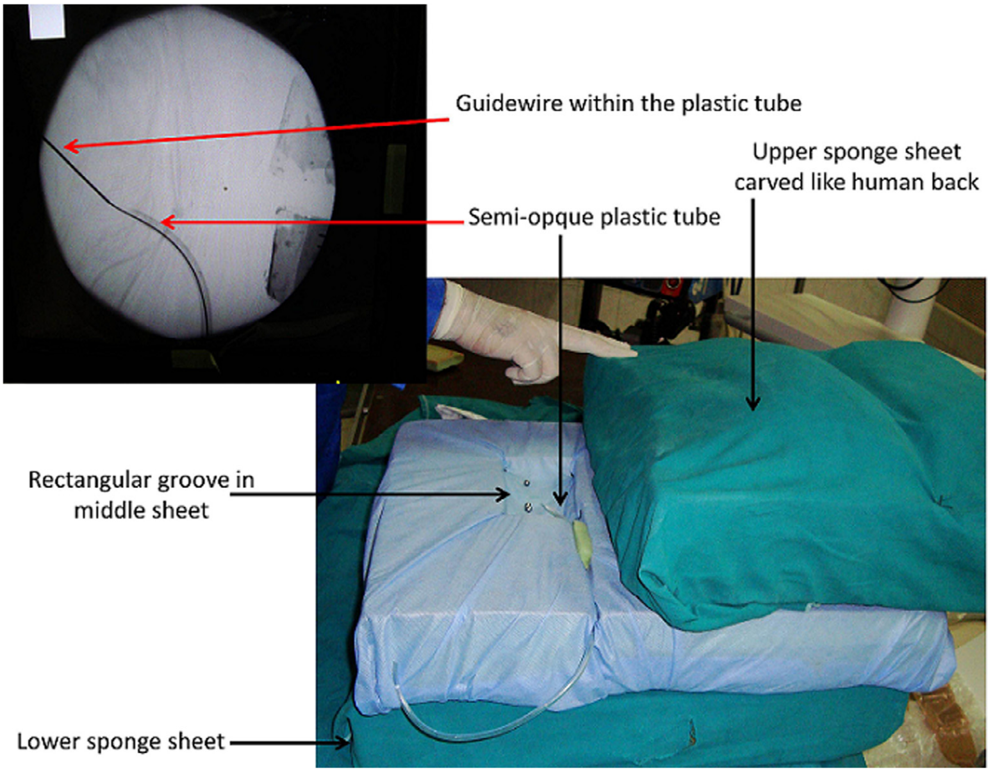

Fig. 5 Guidewire passing from the Chiba needle to the lumen of the plastic tube.

mean (SD; median) score of only 2.3 (0.9; 2) points, whilst realism of fluoroscopic guidance had a mean (SD; median) score of 3.6 (1.1; 4) points (Fig. 6).

Discussion

According to clinical guidelines, PCNL represents the cornerstone for the management of renal stones in many situations [1,2]. The most important issue amongst surgeons concerning PCNL is its learning curve [4,11].

The first step of PCNL is PRA, which is probably the steepest part of the learning curve in PCNL [10,12]. The coordination between fluoroscopic guidance and spatial direction of the needle from the puncture skin point to a selected calyx is the key to successful PRA [10,12,13]. Lee et al. [3,14] suggested that performing ≥24 PRA procedures during residency may increase proficiency level later on. Due to the long learning curve and inadequate case volume to maintain skills; many urologists still consider PRA as a job for the radiologist [3,14].

According to Marcovich and Smith [15], performance of PRA by a urologist has many advantages, particularly the complete control of the procedure from start to finish, with better optimisation of the interventional plans. To encourage urologists to perform their own PRA, availability of a training model for PRA is mandatory to teach this technique regularly for junior urologists [4,16,17].

Although animal models are very realistic their use is limited due to high cost, ethical issues, animal licenses, and lack of pathological conditions [18]. Inability for task repetition and long set-up times make this model infeasible in most urological centres.

The use of VR simulation models to enhance and monitor skills of trainees has become more important, with emphasis on competency-based assessment. In a study by Papatsoris et al. [19], they reported significantly improved skills of trainees for PRA after training on a mentored VR simulator. These simulators allow for repetitive skills training in a risk-free environment, improved hand-eye coordination with C-arm manipulation, processing two-dimensional fluoroscopic images into three-dimensional mind images, and reducing unnecessary X-ray exposure for patients as trainees attain experience during the training. That study recommended attending short workshops for improving PRA skills, so as to reduce the risks and complications associated with the early stages of the learning curve on patients. VR simulators have a drawback, as they do not provide the requisite tactile feedback or fluoroscopic guidance realism. Also, VR simulation is associated with high costs for purchase and maintenance, which may hinder their wide use. Other training models (e.g. gel model) still have limited capacity for re-use [7].

Compared with the mixed advantages of the previously mentioned models, our sponge trainer was simple to setup, allowing multiple task repetition to improve the required psychomotor skills of trainees, whilst being extremely cost-effective. In our present study, we tried to implement a newly designed set with a comprehensive training course.

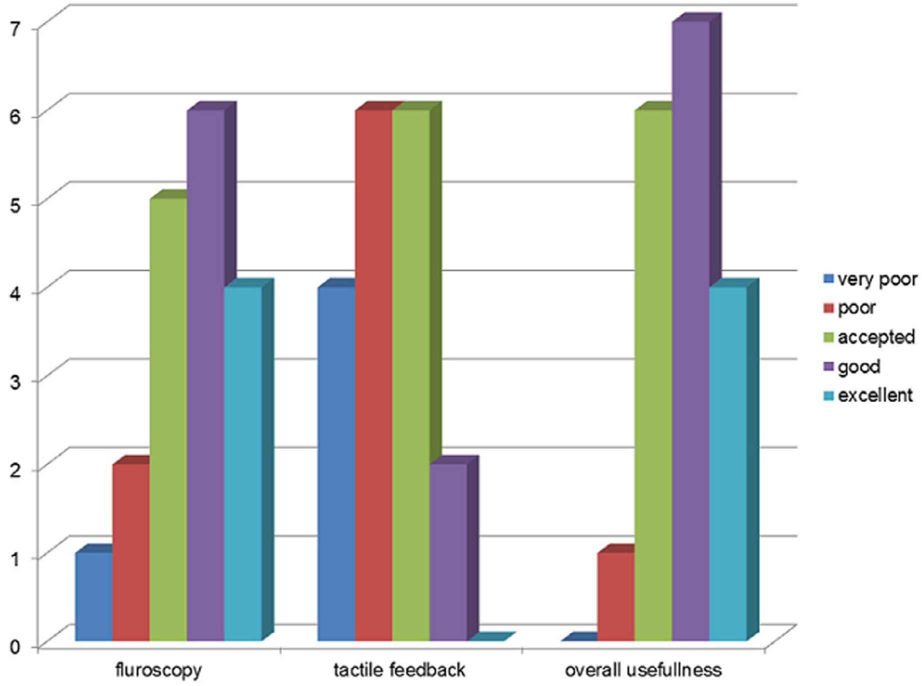

Fig. 6 Results of post-training evaluation survey of the model.

With the present design, we were also interested in gradually increasing the skills' difficulty with continuous evaluation of the trainees. Also, we tried to apply both model training and mentored practice, as both methods of training are available, to diminish mental and physical exhaustion similar to improved long-term skills retention shown by Reznick et al. [18] and Kapadia et al. [20]. Moreover, the chosen tasks aimed to adapt the trainee to the two-dimensional image of the C-arm and monitor the improvement in manual dexterity and coordination. Continuous evaluation of task performance and progression of skills was recorded for successful shifting of the trainees between the different tasks.

As for animal- and gel-trainer models, radiation exposure was also a problem in our present model, which we tried to reduce through spacing the sessions (twice weekly to reduce trainee hazard), changing the supervisor PCNL expert (protect the expert), and limiting fluoroscopic time for each task trial.

The task time was decided upon based on mentors' experience aiming to limit radiation exposure, and to allow performing maximum number of trials within a maximum fluoroscopic exposure time of $\leq$4 min; as the mean 'live' PCNL exposure time is $\sim$4.5 min [21].

During tasks design, attention was paid to provide the trainees with spatial orientation and basic psychomotor skills to accurately direct the puncture needle under fluoroscopic guidance in human [22,23]. During training, some difficulties were reported by trainees in the early performance of tasks, which was overcome, reflected by the marked performance improvement in the later tasks.

The fluoroscopic-guidance technique for PRA is also of interest. The present study was designed to employ the triangulated PRA method, which is more technically applicable as compared to the simpler 'bull's eye' PRA technique. Also, we applied two parameters to evaluate training impact on clinical practice (criterion validity), with the experience survey and success rate in further clinical practice.

On analysis of the trainees' learning curve, improvement in the time and quality of tasks performance was seen over sessions. So, patience and more training time was required in the early on-model PRA to improve mental and manual dexterity. Thereafter, performance of the tasks was done in an automatic manner with a significant reduction in the time taken in the later ones (construct validity).

The main limitations of our present study were trainee sample size and the model disadvantages of: (i) poor tactile reality (as for the VR simulator), which could be overcome in future by changing the material density of the upper sheet; and (ii) the model concentrated on one step of PCNL (i.e. PRA) and renal access by X-ray only (not ultrasonography).

Before the end of on-model training, we asked the trainees to perform tasks after 2 weeks from the last training sessions, to observe their ability to recall the retained memorised skills after a period of no practice. This supports the intimate relation between the retention of acquired skills and importance of continuous training programmes to retain and improve the acquired practical skills (construct validity).

Finally, we tried to ascertain the impact of on-model training on the surgical performance of real-life PCNL surgery. This impact is well documented after VR simulator training [17]. The feedback about our model usefulness on clinical practice was encouraging. Also, it was found that top scoring trainees were more likely to pass the first live trials successfully. Such outcomes may be partially attributed to the realism of the fluoroscopic guidance, despite the model's poor tactile feedback (face validity). Although there are few reports for clinical success rate of mentored PRA trials for junior staff, the clinical outcome in the present study seems to be favourable after model training.

Conclusion

The sponge trainer was found to be a reproducible and low-cost simulator to help junior urologists to perform PRA and achieved face, construct, and criterion validity. The present training course allowed the trainee to have successful mentored PRA during early clinical practice. The present model had a high impact for fluoroscopic-guidance simulation but with poor tactile feedback. Reproduction of the present results on more trainees with improvements in the material characteristics is warranted to consolidate our early findings.

Conflict of interest

None.

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