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Chi-Fai Ng

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REVIEW

Training in percutaneous nephrolithotomy: The learning curve and options

Chi-Fai Ng *

Division of Urology, Department of Surgery, The Chinese University of Hong Kong, China

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KEYWORDS

PCNL;
Training;
Simulator training;
Work hour limitation

ABBREVIATIONS

PCNL, percutaneous nephrolithotomy

Abstract ***Objective:*** To review the current approach to training and the learning curve for percutaneous nephrolithotomy (PCNL), and to formulate a recommendation for structured PCNL training for the urologist in-training.

Methods: Publications related to PCNL training, simulator training, surgical training and working-hour restrictions on surgical training were reviewed.

Results: The key components for a successful PCNL training programme should include stages for acquiring basic knowledge related to the procedure, acquiring basic skill in various training models, and acquiring clinical experience under supervised clinical practice. Lastly, life-long continuous learning would be important to maintain the practising standard.

Conclusion: Despite being one of the main endoscopic procedures for managing stones, PCNL remains a difficult procedure with a long period of learning. Facing the challenge of working-hour restrictions on training, a more structured training programme, together with the use of models, would improve the learning curve for PCNL.

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Introduction

Since the introduction of percutaneous nephrolithotomy (PCNL) in 1970s, it has become rapidly established in the management of urinary calculi, especially for large urinary stones (>2 cm) or stones for which other less invasive therapy (such as ESWL) has failed. However, despite >30 years of development, it remains a difficult procedure to learn. Moreover, despite being a very effective procedure for removing stones, the complication

* Address: Department of Surgery, 4/F Clinical Science Building, The Prince of Wales Hospital, Shatin, Hong Kong, China. Tel.: +852 26322625; fax: +852 26377974.
E-mail address: ngcf@surgery.cuhk.edu.hk

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rate is higher than for other endoscopic procedures for managing stones, particularly in less experienced hands [1]. Therefore, there is a need to improve the training for PCNL, to maintain it as a safe and effective treatment for patients.

Learning curve for PCNL

Because it is a complicated procedure, a urologist will need to perform a certain number of PCNLs to gain the necessary experience and skills to conduct the surgery competently. Knowing the mean number of cases needed to achieve surgical competence is important for planning surgical training. There are many variables used as markers to assess surgical competence, and hence for evaluating the surgical learning curve. These variables included measures of the outcome, e.g., the stone free rate and complication rate [2], and treatment variables, e.g. the duration of surgery and fluoroscopy [3].

Taniverdi et al. [2] noted that the operative duration improved to a steady level after the surgeon had performed ≈60 cases. This was also true for the mean duration of fluoroscopy. Therefore, they suggested that it would probably need 60 cases for a surgeon to become competent in performing PCNL. Allen et al. [3] also noted that the operative duration for new surgeons reached a plateau level after 60 cases. However, they also reported that the duration of fluoroscopy and radiation dose only reached a plateau level after 115 cases. Therefore, they concluded that the competence in performing PCNL could be reached after 60 cases, and a urologist would excel in PCNL after performing 115. In another study based on the operative duration and complication rate, Ziawee et al. [4] reported that the variables reached a steady level after 45 cases. However, focusing on the stone clearance rate, it took 105 cases to reach an excellent level. In summary, a urologist probably needs 45–60 cases to achieve surgical competence in PCNL, and >100 cases to achieve excellent results after PCNL. Ideally this learning curve should be completed during the training period, so that surgeons can perform the procedure competently during their post-training career.

Effect of work hour restriction on surgical training

The introduction of restricted working hours in many countries has challenged the traditional model of surgical training, and could lead to a potential crisis in surgical quality [5–6]. The aim of the policy for restricting working hours was to allow enough rest time for the clinicians, so that they could maintain a good functional status, both physically and psychologically. In turn, it would be translated into improvements in the care of and the outcomes for their patients. However, in surgical training, experience was gained by practising the procedures repeatedly under supervision by trainers, in the form of an apprenticeship, during the learning phase. With the gradual increase in 'hands-on' experience, the trainee would eventually complete the learning curve and could perform the procedures competently. Therefore, the restriction of working hours could lead to a decrease in the exposure of surgeons in training to operations, and they might not then be able to master more complicated procedures, including PCNL, during their training period. They might still be in their learning phase after their residency programme, and thus be practising the procedures with no proper guidance and supervision. Ultimately, the safety of patients might paradoxically be jeopardised because of the restriction of working hours.

Many approaches have been suggested to maintain the quality of surgical training under these restrictions [5]. Developing new training methods, including more structured programmes, and the use of training models in a 'skills laboratory' are some of the ways to facilitate gaining experience in surgical procedures. Hopefully, such structured training and skills-laboratory training will help to shorten the learning curve for surgical procedures.

Training for PCNL

Being a complicated procedure with many steps [7] a good training approach is needed for PCNL to achieve surgical competence. This includes a study of the basic knowledge required for the procedure (acquiring knowledge), practice of the procedure in training models (acquiring skills) and real-life practice of the procedure in patients, and continuous advances in the skills for PCNL (acquiring experience):

- Knowledge acquisition.
  - Anatomical knowledge;
  - Procedural knowledge (both imaging and surgical procedures);
- Skill acquisition.
  - Skills laboratory training.
- Experience acquisition.
  - Basic skills practice; residency/fellowship programme.
  - Advanced skills practice; advanced training courses and workshops.

Acquiring knowledge

To perform PCNL competently a urologist needs to have a good basic knowledge of many aspects. The understanding of the surgical anatomy of the kidney is crucial. For example, it is important to understand the orientation of kidney, to help in differentiating upper pole and lower pole punctures, knowing the structure of the renal vasculature helps to appreciate the impor-

tance of end-on puncture of calyces, and understanding the relationship of the kidney to the surrounding organs is important to avoid injury to other organs during PCNL. Moreover, as imaging is heavily relied upon for the diagnosis of the stone(s) and the planning of PCNL tracks, knowledge in interpreting the imaging, including IVU, ultrasonography and CT, is also very important.

There must also be a good understanding of the procedural steps and instruments involved before starting skills training. During PCNL, the key steps include calyceal puncture, track dilatation, endoscopic manipulation, lithotripsy, and nephrostomy or stent placement. The trainee needs to understand the principles of these steps by observing the procedure. The instruments involved include fluoroscopy and ultrasonography for the renal puncture, various track dilatation devices, endoscopy (both rigid and flexible) and various intracorporeal lithotripters. Trainees should understand not only the principles and uses, but also the safety information for each instrument, including radiation, to protect their patients, staff and other surgeons from risk.

Although the basic knowledge could be acquired through self-study, it is better to learn the material in a structured training programme or in workshops. For example, in a 1-day workshop, the basic anatomy, surgical steps, and principles of the instruments could be introduced by didactic lectures, followed by case demonstrations, such as the use of unedited video-recorded cases, of the steps in PCNL. A hands-on trial of some of the instruments can also be undertaken at the same session. These workshops could be more effective in providing the necessary knowledge for trainees before beginning their practice. If possible, an assessment of the trainee's proficiency in their knowledge before the hands-on skills training would be ideal. This would ensure that they have an adequate understanding of the procedure and would minimise any potential harm that could result from any lack of knowledge.

Acquiring skills

Because of the working-hour restriction and increased awareness of the potential risks to patients during the learning phase of surgeons, there is a need to shorten the learning curve for surgical procedures. The use of various training models had been introduced to facilitate the acquisition of skills for some procedures, and hopefully trainees can already acquire some basic skills before they undertake the procedure in patients. There are many models developed for PCNL training, and each of them has advantages and disadvantages (Table 1).

Bench models made of synthetic materials provide a relatively cheap, easily accessible, repeatedly useable approach for training of the whole PCNL procedure. However, the poor tactile feedback is the main drawback of these models. Virtual reality stimulators (e.g. the PERC Mentor™, Simbionix, Cleveland, Ohio, USA) provide scenario-based training with a full computer record of the results of various assessment endpoints, and a training log for the trainees. The computer system can provide an environment mimicking the real-life situation, including breathing movements, and rib collision, etc. However, it can only provide training on the renal puncture procedure, and so other steps, like track dilatation and endoscope manipulation, are not included in the training [8].

Besides the 'dry-laboratory' training there are also training models that include the use of live animals or parts of animals ('wet' laboratory training). There are reports of the use of porcine kidneys for training, either as truncated parts of pigs [9], or embedded in silicon [10]. The use of anaesthetised pigs for PCNL training is also feasible [11]. The main advantages of these animal models are their similarity to human renal anatomy, and the provision of tactile feeling during training. However, the preparation of these models (including the manpower for anaesthesia) and also potential ethical concerns, affect their availability for training compared to dry-laboratory training.

While studies had shown that the use of models or simulator training could improve the performance of trainees in surgery [12] there are no studies assessing the effect of model training on the learning curve of any particular surgical procedure. However, with the current working hour restrictions, model/simulator training will probably be increasingly used in the future training of surgical trainees.

Acquiring experience

After acquiring the necessary knowledge and skills for PCNL, trainees will start to perform the procedure under supervision by a mentor or trainer. This will usually be done during the residency programme or in an endourology fellowship programme. Typically, the trainee will start by assisting with the procedure, then gradually take over the procedure, and then perform PCNL under supervision and eventually independently. As every kidney and its stones are different, even when the surgeon is competent there can still be challenging cases for which the mentor might need to provide further input and support. Nevertheless, through this apprenticeship, trainees will acquire the skills, experience and confidence in performing the procedure.

Just like other surgical procedures, the technique of PCNL is also continually developing. New skills and modifications of procedural steps might help to improve the surgical outcomes of the procedure. Desai et al. [13] reported their experience in the continuous development of PCNL, leading to improvements in the outcome in a

Table 1 A comparison of various models and stimulator training systems.

Factor	Type of model			
	Dry laboratory		Wet laboratory	
	Bench	Virtual reality stimulators	Part of animal kidney	Whole animal
Cost	Cheapest	Expensive	Cheaper	Expensive (including man-power)
Repeat usage	Yes	Yes	No	No
Tactile feedback	No	Yes	Yes	Yes
Imaging facility required	Yes	No	Yes	Yes
Available for regular practice	Yes	Yes (provided the system is installed in the workplace)	No	No
Additional advantages		Scenario-based training modules; computerised assessment and record of trainee performance		
Main limitations	Lack of tactile feedback	Cost of installment; only allow training in renal puncture	Time consuming to prepare	Potential animal ethical issues

centre of expertise. Therefore, even after the trainee is competent in PCNL, he or she might still needs to continue learning new skills, e.g., alternative radiological approaches for the renal puncture, mini-PCNL, etc. These techniques could be learned by attending a master-class or workshop on new techniques, or a short-term attachment or observer programme in centres experienced in the new skills. This emphasises the importance of continuous medical education in medicine, and the continuous effort to perfect the practice.

Conclusion

PCNL is an effective but complicated procedure, with a difficult learning curve. To perform the procedure with competence, a urologist must have a good understanding of the surgical anatomy and the principles of the instruments, through a structured programme, workshops and master classes. Facing the challenge of restricted working hours during surgical training, a new training approach is needed to maintain the standard of surgical skills training. While the traditional apprenticeship approach is still the key for establishing experience in the procedure, the use of various models and stimulators can help to shorten the learning curve for PCNL. Continuous medical education and training will also be essential to practising urologists, to improve the standard of their practice.

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Conflict of interest

None.

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