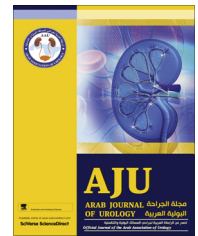




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REVIEW

Training in ureteroscopy for urolithiasis



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KEYWORDS

Lithotripsy;
Learning curve;
Training;
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Urolithiasis

ABBREVIATIONS

GRS, global rating scale;
OCEBM, Oxford Centre for Evidence-Based Medicine;
TCT, task completion time;
(f)URS, (flexible) ureteroscopy;
VR, virtual reality;
RCT, randomised controlled trial

Abstract Objectives: To provide an insight into the current status of semi-rigid and flexible ureteroscopy, following new curricula for training methods, including training with models, virtual reality and active mentoring.

Methods: We systematically reviewed previous reports, including articles in English identified using the following strategy: ('ureteroscopy'[Mesh]) or ('urolithiasis'[Mesh]) AND ('education'[Mesh]), or ('teaching'[Mesh]). Abstracts submitted at congresses were not included. Relevant articles that were identified as references in the retrieved articles were also included.

Results: The terms ('urolithiasis'[Mesh] AND 'education'[Mesh]) retrieved 106 articles, of which five were included. The terms ('urolithiasis'[Mesh] AND 'teaching'[Mesh]) retrieved six articles, of which three were included. The terms ('ureteroscopy'[Mesh] AND 'education'[Mesh]) retrieved 29 articles, of which 21 were included. The terms ('ureteroscopy'[Mesh] AND 'teaching'[Mesh]) retrieved eight articles, of which seven were included. Remaining articles were found in the reference section of retrieved articles. Finally, 43 articles were included. Four randomised controlled trials with level 1b evidence were included. Currently there is no standard teaching method for ureteroscopy and the number of cases to reach competence has not yet been defined. However, simulation-based training has been shown to be effective, cost-effective, and to increase patient safety.

Conclusions: Simulators lead to a more rapid acquisition of skills in ureteroscopy than do conventional training methods, and improve the performance of future surgeons. Flexible ureteroscopy simulators are a promising tool for training, and have

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the advantage of minimising the need for learning the procedures on patients. A didactic and clinical curriculum, including surgical videotape reviews as well as operative mentoring, enables a rapid progression in already experienced endourologists. However, there are few reports specifically addressing the skills necessary for training.

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1. Introduction

The field of ureteroscopy (URS) has increased rapidly with the advent of innovative technologies. Flexible URS (fURS) has confirmed efficacy in the diagnosis and treatment of urolithiasis. The use of URS simulators could improve procedural skills before starting to operate on patients. With an increase in the expectation of a high-quality service by the public, and with the risk of litigation, it is desirable to acquire technical competence before undertaking procedures on patients as a first attempt [1]. Therefore, there is increased interest in simulating surgical operations, with the potential to shorten the initial learning curve without compromising patient safety [2]. The rapid development of new flexible ureteroscopes has led to a demand for physicians trained in these procedures. Surveys of urologists show a significant variation in training skills. fURS is an example of an effective procedure that is underused, due to the low distribution of cost-intensive equipment and maintenance, partly caused by inadequate training [3].

Reasons hampering the broad induction of fURS include the costs associated with disposable equipment [4], and the learning curve for fURS is another barrier to this approach [5].

The slow implementation of fURS might be related to a significant learning curve and the high procedural costs due to instrument failure caused by malpractice. To date there is no recommendation on the number of

supervised fURS procedures for initial training or to maintain competency. There is currently no standard teaching method for fURS. Simulation-based training, when used for surgical and medical procedures, is effective, cost-effective, and increases patient safety.

Legal and ethical concerns about practising these procedures on a patient have become increasingly important. Therefore, a large part of the learning can be done by training on a model first, and does not require training on patients.

The objective of this review was to search for what types of ureterorenoscopic training models have been studied and how they were validated. The definitions of different forms of validity are given in Table 1 [6]. The results can be used as a guide for skills training in URS.

Methods

We systematically reviewed previous reports, identifying published articles in English using the following strategy: ('ureteroscopy'[Mesh]) or ('urolithiasis'[Mesh]) AND '(education'[Mesh]) or (teaching [Mesh]). Abstracts submitted at congresses were not included. Relevant articles found as references in retrieved articles were also included. Both authors reached a consensus about the inclusion and exclusion of articles. Abstracts submitted at congresses were not included.

Table 1 The definition of validity [6].

Type of validity	Definition
Construct	Ability to distinguish the experienced from the inexperienced surgeon (between groups) or for one surgeon over time.
Content	A judgement of the appropriateness of the simulator as a teaching method by experts. This addresses the question of whether the simulator realistically teaches what it is supposed to teach.
Criterion	Compares the evaluation results from the new simulator with those of the old technique or evaluation, to assess the degree of correlation.
	Concurrent
	Comparing a new with an old model by an objective structured assessment of technical skill
Predictive	Comparing model performance with operating room performance, using an objective structured assessment of technical skill
Face	Assessed informally by non-experts and relates to the realism of the simulator, i.e., does the simulator represent what it is supposed to represent?

Results

All abstracts were evaluated by both authors. The following Mesh terms were used: ('urolithiasis'[Mesh] AND 'education'[Mesh]) retrieved 106 articles, of which five were included; ('urolithiasis'[Mesh] AND 'teaching'[Mesh]) retrieved six articles, of which three were included; ('ureteroscopy'[Mesh] AND 'education'[Mesh]) retrieved 29 articles, of which 21 were included; and ('ureteroscopy'[Mesh] AND 'teaching'[Mesh]) retrieved eight articles, of which seven were included. Remaining articles were found in the reference section of retrieved articles. Finally, 43 articles were included. Studies focusing on different aspects of endourology training were excluded. The most commonly described URS models were the high-fidelity Uro-Scopic trainer (Limbs & Things, Bristol, UK), giving the opportunity to train with instruments as used in the operating room [7–12], and the Uro Mentor (Simbionix, Lod, Israel), a computer-based virtual reality (VR) model with the possibility of training with semi-rigid and flexible ureterorenoscopy models [8,9,12–17].

The training concepts identified were new curriculum training methods, training with bench models (high-fidelity and low-fidelity), VR, active mentoring, and conventional training on patients. Their effect on the outcome was assessed by a global rating scale (GRS), the task completion time (TCT) and the learning curve. Validation studies were found in 14 articles (Table 2) [7–32].

Validation studies

Randomised controlled trials (RCTs) were reported in four articles [10,14,21,33]. Matsumoto et al. [10] investigated the effect of bench-model fidelity, whereas Wilhelm et al. [14] and Watterson et al. [33] investigated the acquisition of skills using a computer-based VR endourological simulator.

Validation studies were rated on the basis of the Oxford Centre for Evidence-Based Medicine (OCEBM) levels of evidence. These RCTs had the highest OCEBM score of 1b [34]. Fourteen studies were validation studies, of which nine investigated construct validity, four criterion validity, four content validity and three face validity (Table 2). The ability to transfer skills from the model to the patient (predictive criterion validity) was found in three studies [17,18,25].

For simulators from Limbs & Things, Mediskills and the URO Mentor, an ability to distinguish the experienced from the inexperienced surgeons (between groups) or for one surgeon over time was reported (construct validity) [11,14,17–19,23,25,33,35].

The pitfalls

Urologists and residents reported on the possible pitfalls with URS [36], and therefore, a list of pitfalls for each

Table 2 Studies assessing the level of validation.

Refs.	Year	Validation
[18]	2002	Construct
[19]	2005	Construct
[8]	2006	Criterion
[20]	2009	Face/content
[21]	2012	Content
[22]	2005	–
[15]	2006	–
[23]	2004	Construct
[24]	2013	Construct
[25]	2005	Construct/criterion
[26]	2001	–
[9]	2002	–
[10]	2002	Criterion
[11]	2001	Construct
[16]	2006	Construct
[13]	2002	Face/content
[27]	2004	–
[17]	2004	Construct/criterion
[28]	2013	–
[29]	2010	–
[30]	2001	–
[31]	2001	–
[12]	2007	–
[32]	2010	Face/content/construct
[7]	2008	–
[14]	2002	Construct

The only studies that scored 1b on the OCEBM levels of evidence were [10], [12] and [33].

The Uro Mentor, Limbs & Things and Mediskills bench models were able to discriminate between different skill levels (construct validity) [10,11,14,16,18,19,23,25].

procedure was established based on the results of a pilot study. According to Schout et al. [36] the study indicated that planning, the anticipation of new situations and the handling of instruments were the predominant pitfalls in transurethral procedures. This suggests that developers of training models should pay particular attention to these factors. With the recognition and awareness of common pitfalls, teaching can be raised to a higher level of quality and efficiency.

Bench model fidelity

An advantage of training models is that original instruments are used to practise with, whereas in VR simulators, VR instruments are often used. Matsumoto et al. [10] randomised 40 medical students into a group trained in didactic sessions, and groups trained using a low-fidelity or a high-fidelity bench model for practising. Testing involved stone extraction using a ureteroscopic basket. The results were obtained by examiners unaware of the group, using a GRS, pass rating and TCT. There was a significant effect of hands-on training on endourological performance ($P < 0.01$). The bench models were more effective than in the didactic group ($P < 0.05$). However, there was no significant

difference between the high- and low-fidelity groups ($P < 0.05$). The cost of the self-produced low-fidelity model was \$20, compared to \$3700 for the high-fidelity model. When choosing bench models the key constructs should be incorporated into the models, increasing the value for surgical skills training. This study by Matsumoto et al. showed that hands-on training is better than didactic teaching only, and that a self-produced, low-fidelity URS model is as effective as an expensive high-fidelity bench model.

A high-fidelity adult URS and renoscopy simulator

White et al. [32] assessed the face (opinion of non-experts about the simulator), content (opinion of experts about the simulator) and construct validity (the ability to distinguish between different levels of experience) of a high-fidelity ureterorenoscopy trainer. Data from a patient's CT were processed and an exact replica of the collecting system was created and embedded into a silicone model. A total of 46 participants assessed the face and content validity of the simulator using a standard questionnaire. Ten urologists experienced in URS, with >30 procedures per year, and 10 novice urologists with no previous experience, were assessed on their ability to perform fURS, and intrarenal basket extraction of a lower-pole calculus, using the adult URS trainer (Ideal Anatomic Modelling, Holt, Michigan, USA). All participants rated the trainer as realistic and a good training tool, and 96% would recommend it to urology trainees. All participants recommended it for use in residency programmes, and 96% would recommend it during residency. A third of experienced and all novice ureteroscopists would use it to practise. On the trainer, the experienced participants scored significantly higher on the GRS (1.3 vs. 15.0; $P < 0.001$) and checklist (4.1 vs. 2.4; $P < 0.004$), and completed the task more quickly (141 s vs. 447 s, $P < 0.01$) [32].

VR

Since the first VR URS simulator was described by Preminger et al. in 1996 [37] the bench models have become popular [7]. Dolmans et al. [20] examined the educational value of the Uro Mentor, a VR simulator for endourological procedures, by establishing its face and content validity. Eighty-nine urologists and residents in urology performed a cystoscopy and a ureterorenoscopy, with manipulation of a distal ureteric stone, using the Uro Mentor. The overall rating of the Uro Mentor was 7.3 on a 10-point scale. Of all participants, 82% rated the usefulness for education as 3.5 on a five-point scale. They concluded that the Uro Mentor appeared to be a realistic and useful training model for endourological procedures.

The translation of VR into clinical practice

Ogan et al. [17] prospectively studied the transfer from a male cadaver simulator to the patient (criterion validity). Criterion validity for a VR URS simulator was established by evaluating 32 trained subjects (16 medical students and 16 residents) [17]. Trainees were evaluated at baseline on a VR URS simulator (Uro Mentor), performing a simple diagnostic URS. The students then underwent 5 h of supervised simulator training. Two weeks later all participants were re-evaluated on the simulator. Each participant was then assessed on the performance of a similar diagnostic URS in a male cadaver. For the medical students the re-evaluation and cadaver performances correlated closely for the TCT and overall GRS score. By contrast, there was little correlation in the performance between residents. Despite VR training the medical students were unable to perform URS in a cadaver comparably with the residents. They concluded that performance on the simulator might be useful for educating the trainees, but VR training is unable to override the effect of clinical training, although it might help to shorten the early period of learning.

Active mentoring in fURS training

Ganesamoni et al. [21] evaluated the outcome of fURS training in 36 urologists and residents who were not experienced in fURS and who underwent mentor training with a high-fidelity model (Uro-Scopic trainer) or a VR simulator (Uro Mentor). Trainees practised with a flexible ureteroscope, using several techniques. The trainees were randomised into two groups, one under a mentor and the other without. The two groups completed the training for 2 h. A GRS was used to assess the performance of fURS, standardised for fURS and measured by an expert unaware of the grouping at the beginning and end of the training. A specific TCT for introducing the flexible ureteroscope into the ureteric orifice without previous guidewire placement, and visualising the kidney and the stone placed in the lower calyx, were noted at the end of the training. The GRS score by the expert at the end of the training was significantly higher in the mentor group. A self-assessed GRS score by trainee did not correlate with the skills acquired. The TCT was significantly lower in the mentor group and correlated well with the GRS score measured by the expert rather than the trainee. They concluded that mentorship during fURS training resulted in a higher GRS score and lower TCT at the end of the training.

Implementing the curriculum

Ruiz et al. [28] implemented a focused curriculum to accelerate the acquisition of skills. The curriculum was based on the concept of a 'mini-fellowship' with a didactic and a technical focus. As the nursing staff are an

integral part of the surgical team, also influencing the integrity of the ureteroscope, they were included [3]. A 5-day curriculum, including lectures, and unedited surgical videos with fundamental and advanced surgical manoeuvres, was introduced. Fundamental techniques consisted of the use of a safety wire, stone repositioning from a lower calyx, laser lithotripsy (including the 'dusting' technique) and stone extraction. Advanced techniques were stone management in an ectopic unit and calyceal diverticular calculi, and laser incision of an infundibular stenosis. This was followed by live surgical experience, initially as a demonstration and then as a mentored procedure using fURS and laser lithotripsy [28]. The authors found that a didactic and clinical curriculum accelerated the progression to an effective clinical practice, and simplified the introduction of laser fURS in the first 12 months, with no complications or instrument failure after another 12 months of follow-up.

Centralised simulation training

Simulators are effective during the initial phase of training [38]. Although studies have validated both bench and VR simulators, they have never been assessed for their effectiveness in a centralised, simulation-based training programme [24]. Khan et al. [38,39] designed a study to establish the feasibility, acceptability and construct validity of simulators (Uro Mentor and Perc-mentor; Symbionix), bench-top models, and a European wet-laboratory training facility, as well as non-technical skills/crisis resource management using SimMan (Laerdal Medical Ltd., Orpington, UK) to teach teamwork, decision-making and communication skills. Kahn et al. devised their simulation programme to combine aspects of both technical and non-technical skills training. They found a significant construct validity between junior trainees and registrars. Of the study population, 90% rated the training models as being realistic and easy to use, 95% recommended the use of simulation during surgical training, and 60% would like to have easy access to a simulation facility to allow further practise and improve their skills.

Discussion

In the USA, urologists who had recently finished their residency training performed URS more often than urologists who had been in practice for more than a decade (52% vs. 38%) [40]. A Medicare sample from the USA similarly showed that urologists completing their training more recently were more likely to perform URS for treating stones [41]. This might be explained by the greater use of urology training programmes. One of the well-characterised barriers to the distribution of fURS is the learning curve associated with the procedure [42].

Learning basic surgical skills on the patient is questionable. Simulator models significantly improve the

skills required for URS [17,21,25]. Adequate training before operating on the patient has the potential to improve the outcome while reducing complications. Also, training reduces the high costs of maintaining these flexible instruments [3]. Ganesamoni et al. [21] showed that variations in both the GRS score and TCT were lower in a group with a mentor than in a group without. However, mentoring has an additional potential, especially in the beginning, as mistakes can be corrected which might be overseen when evaluating only time as the criterion. Whether the presence of an expert is needed throughout the training period is still not clear.

A training centre allows the supervising mentor to focus on the trainee instead of the patient, as attention on the trainee is limited during surgery on a patient. In addition to feedback, practising in a preferably unedited video environment has the potential to improve endoscopic skills [10].

In surgical simulation there is no clear consensus on the exact definition of the terms face, content, construct and criterion validity [6,12]. In most of the studies of construct and criterion validity, time was the only objective variable investigated. Although time is easy to measure, is time the main objective? Most experiments (for construct and criterion validity) involved VR models. This seems attractive, because the use of those models is simple and objective variables can be measured. Using a simulator has the advantage of standardising cases for all subjects, which would be difficult in the clinical setting. Bench, animal or human models can also yield objective assessments, using skill-scoring lists [43], including the handling of equipment and knowledge of procedures, all being probably more relevant than just time. In summary, the use of a simulator can improve skills compared with the non-simulation training methods using patients. Simulators reduce the number of patients necessary to achieve and maintain competence, reducing patient risk during the learning process.

Almost all URS training programmes are built on a teaching model, using experience gained on patients. For each trainee, learning a procedure is different according to a variety of rotations and mentors. Using simulators, the process of acquiring skill can be standardised and trainees can be provided with objective measures of performance. Training in potentially harmful manoeuvres can be done first, without putting patients at risk. Simulators create a virtual environment, encouraging trainees to collaborate, and compelling them to make decisions. Simulations have the potential to accelerate the learning curve. However, there is a lack of data on the learning curve for URS.

Limitations

One limitation of the randomised studies assessed here is that they included few participants. It is unclear how skills

obtained in a mentor- and model-based training system are transferred into real-life surgical procedures. However, additional randomised studies with future validation are needed to determine whether practice and performance on a simulator lead to improved clinical performance.

Conclusion

As URS, including fURS and retrograde intrarenal surgery with laser lithotripsy, continues to be increasingly widespread, it is important to develop an effective and reproducible way to disseminate surgical techniques to trainees. Protocols for teaching URS procedures in an evidence-based way are necessary as these technologies continue to expand. Simulators lead to a more rapid acquisition of skills in URS than do conventional training methods, and improve the performance of future surgeons. fURS simulators are a promising tool for training, and have the advantage of minimising the need to learn procedures on patients. A didactic and clinical curriculum, with an emphasis on the review of surgical videos, and mentored surgical experience enables a rapid progression in already experienced endourologists. Further ongoing research is necessary in how to teach surgical skills to guide proper and effective training for improving patient outcomes.

Key points

- At present, there is no standard teaching method for URS.
- The number of cases to reach competence has not yet been defined.
- Simulation-based training is effective, economic and improves patient safety.
- Part of the learning curve for procedures can be learned on a model first and does not require practising on patients.
- Simulators accelerate the acquisition of skills, improve the performance and minimise the burden of procedural learning on patients.
- It is important to develop an effective and reproducible training for URS. Improvements in training should be measurable.
- The unedited review of URS procedures enables rapid further progression in already experienced endourologists.

Conflict of interest

No conflict of interest to declare.

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