Introduction
1. The history of practical skills training in endoscopic urology

The last few decades have seen a considerable expansion of the use of minimally invasive surgery (MIS) as an alternative to conventional open surgery. As the term indicates, MIS is mainly characterized by being less invasive than open surgery and, consequently, leaving smaller or no operative scars. Reasons for the shift from open surgery to MIS are benefits in terms of shorter hospital stay, less postoperative pain, faster recuperation and improved cosmetics [1-8].

In urology, endoscopy is known as a MIS technique that includes a variety of endourological and laparoscopic procedures. Endourology is an intraluminal endoscopic technique in which natural urological orifices such as the urethra are used to introduce operating instruments. Examples are: ureterorenoscopy (URS), transurethral resection of a bladder tumour (TURBT) and transurethral resection of the prostate (TURP). Laparoscopic procedures (keyhole surgery) can be categorized as extraluminal endoscopic surgical procedures performed through small incisions (usually 0.5-1.5 cm). These procedures include among others: laparoscopic pyeloplasty, laparoscopic nephrectomy, laparoscopic radical prostatectomy and laparoscopic pelvic lymph node dissection.

As early as 1806 the first endoscopic treatment of a bladder tumour was described by Bozzini, “the father of Endoscopy” [9]. Experiences with endoscopic treatment of the prostate date from 1909, when Hugh Hampton Young, “the father of American Urology”, performed his first cold-cut prostatic punch operation [10]. The first laparoscopic nephrectomy was performed by Clayman in 1990 and since then, in experienced hands, laparoscopy has become the procedure of choice for several procedures such as nephrectomy, radical prostatectomy, and pelvic lymph node dissection [2;7;8;11;12].

Since the introduction of urological endoscopic techniques, the Halstedian master-apprentice type of training, characterized by the adage “See one, do one, teach one,” has been the most commonly used approach to teach these complex skills to postgraduates and urologists [13]. The common educational strategy is for trainees (postgraduate, novice, apprentice) to learn basic and procedural surgical skills by practicing directly on patients under supervision of a tutor (surgeon, supervisor). However, this seems somewhat contradictory with the Hippocratic Oath which implies “First, do no harm”. The skills needed to perform endoscopic techniques differ from those required for open surgery and are characterized by longer learning curves [14]. Furthermore, the use of endoscopic techniques requires surgeons to be more technically skilled and equipped than in the past. As a consequence, there is a real danger of incidents and complications when these complex and technically challenging endoscopic techniques are learned by performance in patients.
Figure 1. (Lint de JG. Atlas van de geschiedenis der geneeskunde. De ontleedkunde. SL van Looy - Menno Hertzberger. Amsterdam. 1925, p. 53)
Although many excellent surgeons have first learned their skills in Halstedian master-apprenticeship training programmes, it is questionable whether today this approach is still adequate for MIS procedures [15]. Moreover, it has become a topic of public debate whether it is ethically and legally acceptable to learn by performing procedures in real patients and whether the operating room (OR) can remain the ideal classroom [16]. Today's patients differ from those of earlier days: they are more knowledgeable and assertive and less willing to be recruited as 'training models' for junior doctors’ first attempts at technically challenging procedures. The training of the basics and/or parts of procedures outside the OR, in a simulated environment and/or on surgical simulators, appears to offer an attractive alternative, because it allows for structured educational programmes as well as a safe learning environment [17-20].

Simulation has been defined as “The technique of imitating the behaviour of some situation or process (whether economic, military, mechanical, et cetera) by means of a suitably analogous situation or apparatus, especially for the purpose of study or personnel training.” [21] It has been in use in many contexts, including the modelling of human systems to gain insight into their function and for real-time practising in a safe environment. Since antiquity models of clay, stone and metal have been used to demonstrate clinical features of diseases and their effects on humans. Also, for many centuries, medical practitioners have dissected human bodies to obtain knowledge about human processes and to practise surgical techniques (Figure 1) [22].

The first endourological training models to be described in the literature were cadaver and animal organs [23-28]. In 1965, Habib et al. used a cow’s udder to teach transurethral operative techniques [25] and in 1981 Trindade et al. described a canine model for endoscopic procedures [28]. Training on human cadaver bladders was described by Narwani et al., Fiddian et al. and Cervantes et al. in 1960, 1967 and 1969, respectively [23;24;26]. What they all did was attach a bladder to a metal plate, to lead the current away, and practise transurethral resection by introducing real-time endoscopic instruments. In 1977 Pirkmajer et al. described the use of an apple placed inside a metal container to create a simulator for transurethral resection of the prostate [27]. Between 1980 and 1999 the number of published articles on urological skills training was small [28-30], but it has been on the rise ever since. Apart from the kinds of models we described above a relatively new type of training model has made its appearance: the virtual reality simulator.

In the Netherlands, urological endoscopic skills training has found a platform in the Dutch Foundation of Endourology Netherlands (“Stichting Werkgroep Endourologie Nederland”, SWEN), an official working group of the Dutch Association of Urology (“Nederlandse Vereniging voor Urologie”). Founded in 1989, SWEN has promoted endoscopic urology by organising practical skills courses, developing guidelines for endoscopic procedures, and coordinating endoscopic research projects. Since 2003, the year of its foundation, the Urological Training Centre (“Urologisch Opleidings Instituut”, UOII) has been collaborating with SWEN in coordinating and developing skills training.
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Courses. These courses offer (live) demonstrations as well as hands-on training sessions. The organizers strive to use validated training models whenever possible. Today, with the growing realisation that a one-day course may not suffice to provide adequate training, SWEN also focuses on the development of extended educational programmes.

Since the publication of several studies on the incidence of medical errors,[16,31-35] hospital directors, the government, programme developers, junior and senior doctors, consultants and patients have become increasingly convinced of the urgency of incorporating training methods and models outside the OR in medical curricula [36,37]. This has resulted in the establishment of skills laboratories and the purchase of high-cost simulators for use in these training environments. However, on a critical note, it should be pointed out that “It is not to say that skills facilities can in any way replace clinical experience as the key mode of learning. Rather, skills centres should be viewed as providing a foundation in clinical skills, which students will use as a springboard from which to achieve the best possible learning from subsequent clinical experience, having overcome the initial difficulties with the preliminary acquisition of skills.”[38]. Furthermore, in order to guarantee high quality skill training, training techniques and skills laboratory programmes should be subject to critical review and underpinned by findings from research by multidisciplinary teams of doctors (teachers), postgraduate trainees (learners), educationalists (teaching the teachers) and industrial designers (providing teaching facilities).

2. An educational perspective on the learning of practical skills

Thirty years ago Iseri et al. described educational objectives for postgraduate medical education [39]. Since that time the principle that postgraduate training should be organized along the lines of certain regulations/competencies has become increasingly accepted. The core competencies of physicians and surgeons were documented by the Royal College of Physicians and Surgeons of Canada (RCPSC) in the CanMEDS (Canadian Medical Educational Directives for Specialists) roles in 1993 [40]. In order to act as a competent professional in each of these roles, a doctor has to be competent as a communicator, collaborator, manager, health advocate, scholar, professional, and, obviously, as a medical expert [40]. The CanMEDS roles have been integrated into the curriculum of various specialist training programmes in the Netherlands, including urology training [41,42]. The current “Project on Training in Urology” focuses on the central competency of urological expertise, with special attention to practical endoscopic urological skills.

Once it has been defined which competencies are to be included in a training programme, the next question is: how are they to be learned and trained? In 1990 Miller described a framework of increasingly complex levels of skill performance and assessment [43]. This framework seems equally applicable to the phases of the
acquisition of practical skills (Figure 2). Miller recognized that knowledge lies at the basis of clinical skills, but at the same time argued that this did not justify the use of knowledge assessment as the predominant method in examination programmes [43]. Trainees should also be required to show that they had progressed to the levels of “knows how, shows how and does”.

Figure 2. Miller’s pyramid [43]

![Miller’s pyramid](image)

Evidently, reaching the “does” level of Miller’s pyramid in respect of MIS requires specific motor skills as well as cognitive skills and knowledge. Although some of the required knowledge and skills can be learned without formal teaching, gaining sufficient mastery also requires formal education and training. While some skills are best learned in a clinical environment, a skills laboratory is probably the best learning environment for other skills. As Dankelman et al. pointed out: “Surgery and car driving are comparable in several aspects, e.g. the ability to determine the way to reach a certain location, and to anticipate on unknown situations. Some of these skills can only be acquired in a very realistic situation, while others, like using surgical instruments and changing gears, can easily be taught outside the realistic environment” [44].

A general characteristic of learning is that it is not directly observable and can only be investigated by comparing performance at different trials or points in time [45]. Numerous theories on (motor) learning have been described in the literature [46]. For those who develop training programmes and thus have to decide which skills are to be learned, how they are to be learned (in a self-directed manner or through teaching and training) and in which learning environment (skills laboratory or patient), some insight into theories of the learning of practical and motor skills is indispensable [47]. One of the prevailing educational theories on motor learning described in the motor skills and surgical literature is the three-stage theory of Fitts and Postner [48,49]. (Table 1) This model is based on the principle that learning is a sequential three-stage process. The
first phase is the cognitive phase focusing on understanding and imagining a task. This phase is followed by the integration phase, in which the previous mental process is put into practice and skills are trained; in the third phase, skill performance becomes a non-conscious automatic process. This phase is called the automation phase.

Table 1. The Fitts-Postner Three-Stage Theory of Motor Skills Acquisition

<table>
<thead>
<tr>
<th>Stage</th>
<th>Goal</th>
<th>Activity</th>
<th>Performance</th>
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</thead>
<tbody>
<tr>
<td>Cognition</td>
<td>Understand the task</td>
<td>Explanation, demonstration</td>
<td>Erratic, distinct steps</td>
</tr>
<tr>
<td>Integration</td>
<td>Comprehend and perform mechanics</td>
<td>Deliberate practice, feedback</td>
<td>More fluid, fewer interruptions</td>
</tr>
<tr>
<td>Automation</td>
<td>Perform the task with speed, efficiency and precision</td>
<td>Automated performance requiring little cognitive input, focus on refining performance</td>
<td>Continuous, fluid, adaptive</td>
</tr>
</tbody>
</table>


Learning is generally conceptualized as a continuous process in which trainees construct their knowledge on the basis of previous experiences (experiential learning) [45,50,51]. A frequently used model of experiential learning is “Kolb’s cycle”, which was inspired by Lewin’s work (Figure 3) [52,53]. In this model four phases are distinguished. Phase one is concerned with concrete experience in which learners actively experience an activity or event, either by observation, for example of an expert who is performing an operation, or by experience, for example by personally performing a skill. Learners reflect on these experiences during the second phase, the reflective observation phase, and, in the third phase, the abstract conceptualisation phase, learners use their reflections to derive learning needs and theories that may improve future practice in a particular area or skill. The fourth phase is concerned with active experimentation in which learners take concrete steps to improve their practice. This phase constitutes a new concrete experience, which can initiate a new cycle.
A skills laboratory seems the ideal setting for (parts of) the four phases of Kolb’s learning cycle and the three phases of the Fitts-Postner theory. An overview of the characteristics of training in a skills laboratory and on simulators compared to training in the clinical setting is shown in Table 2. A skills laboratory is conducive to a learner-centred approach to education in contrast to the OR, where, by necessity, the approach is patient centred. Simulation gives trainees opportunities to learn by and from mistakes, because in a simulated environment patients cannot be harmed, unlike in real-time clinical practice where mistakes would be considered unethical [17;19;20]. Learning from mistakes is an important element of training [50] that is promoted by skills laboratory settings. Skills laboratories also support another important element of training, namely the principle of deliberate practice. This was described by Ericsson [54] who argued that learning is enhanced by repeated performance of the same tasks in a standardized manner and followed by feedback. Simulators offer the additional advantage
that they can be used as an assessment tool [55-57], because tasks can be standardized and performed repeatedly [18].

Table 2. Characteristics of skills laboratory and clinical settings

<table>
<thead>
<tr>
<th>Skills laboratory setting</th>
<th>Clinical setting</th>
</tr>
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<tbody>
<tr>
<td>Learner centred</td>
<td>Patient centred</td>
</tr>
<tr>
<td>Repeated practice (deliberate practice)</td>
<td>One case at a time</td>
</tr>
<tr>
<td>Mistakes are allowed</td>
<td>Mistakes are unacceptable</td>
</tr>
<tr>
<td>Safe environment for learner</td>
<td>Less safe environment for learner</td>
</tr>
<tr>
<td>24-hour availability of learning facilities</td>
<td>Learning opportunities dependent on patient care</td>
</tr>
<tr>
<td>Variation of cases and exercises</td>
<td>Cases dependent on patient care</td>
</tr>
<tr>
<td>Possibility for peer teaching (learning from colleagues in the same learning phase)</td>
<td>No possibility for peer teaching</td>
</tr>
<tr>
<td>Standardized assessment</td>
<td>Assessment dependent on patient case</td>
</tr>
</tbody>
</table>

All these considerations emphasize the potential benefits of implementing simulation of endoscopic urological techniques in postgraduate training. However, educational innovations, including these training models, should not be adopted without sound evidence of their efficacy. One of the potential drawbacks of simulators for example is the inherent risk that learners become expert at performance on a simulator but unable to transfer these skills to real clinical contexts [58]. It is therefore important to obtain scientific evidence of the value of simulators as an educational tool by validity research that is performed before simulators are included in a training programme or purchased for usage in a skills laboratory [38].

3. Evaluation and validation of surgical training models

A new simulator should preferably meet multiple aspects of validity to prove its value as a skills trainer and predictor of performance. The validation process of training models requires subjective (face and content validity) and objective studies (construct and criterion validity) [59-62]. Because in the literature different types of validity have been defined in different ways [59-62], we will describe the definitions of validity we used in this thesis (Table 3).

3.1 Subjective approaches to determine validity

Face and content validity are generally deemed the basic level of validity [59,60,62]. They need to be established before it is appropriate to proceed to higher levels of validity. Face validity is defined as the “judgement of novices regarding realism and usefulness of
the simulator.” For content validity we used McDougall’s definition: “judgment of experts regarding realism and usefulness (appropriateness) of the simulator” [62].

3.2 Objective approaches to determine validity

Validity includes the ability to differentiate between different levels of skills mastery (construct validity). Two types of construct validity are distinguished. First, novices’ objectively measured performances on a simulator should show improvement after training compared to their performances before training (Construct A). Second, objective parameters of the simulator should discriminate between performance by experts (e.g. urologists) and novices (e.g. postgraduates) (construct B).

Criterion validity studies compare skills performance on the model under study with a “gold standard”. This may be an older training model or method (criterion A) or a real-time patient (criterion B).

Table 3. Definitions of validity
Different definitions of validity, based on definitions by McDougall et al. [62]

<table>
<thead>
<tr>
<th>Kind of validity</th>
<th>Subcategory</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face validity</td>
<td></td>
<td>Opinion of non-experts about the simulator</td>
</tr>
<tr>
<td>Content validity</td>
<td></td>
<td>Opinion of experts about the simulator (and its appropriateness for postgraduate training)</td>
</tr>
<tr>
<td>Construct validity</td>
<td>A: Within trainees</td>
<td>Ability of simulator to distinguish between different levels of experience, measured within</td>
</tr>
<tr>
<td></td>
<td>B: Between groups</td>
<td>Ability of simulator to distinguish between different levels of experience, measured between groups with different levels of experience</td>
</tr>
<tr>
<td>Criterion validity</td>
<td>A: Concurrent validity</td>
<td>Comparison of new model with old</td>
</tr>
<tr>
<td></td>
<td>B: Predictive validity</td>
<td>Correlation of trainees’ performance on the model with operating room performance measured by OSATS</td>
</tr>
</tbody>
</table>
1. Introduction

“I never teach my pupils; I only attempt to provide the conditions in which they can learn”.

Albert Einstein (1879-1955)

4. General problem definition

This thesis focuses on the current “conditions” (facilities) for urological training. The studies that together constitute this thesis were performed with the intention to contribute to the development, evaluation and validation of urological training models and the transfer of skills learned on a simulator to performance in patients.

The general research question of this thesis is:
To what extent and in what manner are training models currently integrated in endoscopic urological educational programmes; what is the status of their validity; and how can skills be transferred from the training model to performance in patients?

To address the general research question, more specific sub-questions have been formulated:
1. What types of endourological training models are described in the literature and to what extent have they been validated?
2. How do directors of urological specialist training programmes view the possible shortcomings of endoscopic training and the curriculum design of urology training in the Netherlands?
3. What is involved in the development of a low-cost, easy to use training model for diagnostic and therapeutic procedures in bladder pathology
4. To what degree does UCS (Urethrocystoscopy) and URS (Ureterorenoscopy) simulation on URO Mentor resemble real-time UCS and URS procedures according to urologists and postgraduate trainees in urology?
5. Do novices significantly improve their cystoscopy performances with respect to time, trauma, inspected areas and GRS (global ratings scale) scores by training on the URO Mentor VR simulator?
6. Is it possible to discriminate between experts’ and novices’ levels of performance by using the VR simulator the URO Mentor?
7. Do trainees’ urethrocystoscopy performances in real patients improve by training on the URO Mentor VR simulator?
8. Does Uro Trainer have sufficient face and content validity to justify conducting experimental studies to investigate its construct and criterion validity?

9. What pitfalls do novices encounter when learning TURBT, TURP and URS procedures on patients and what lessons can we learn from that for the development of simulator-based training programmes?
Chapter 2 offers answers to sub-question 1. An overview is given of training models and their validity based on a qualitative systematic review of studies describing one or more training models and/or examining the validity of training models, retrieved by searches of PubMed, the Cochrane Library, and Web of Science between January 1980 and April 2008.

Sub-question 2 is addressed in Chapters 3 and 4, which report on a nationwide survey of directors of surgical specialist training programmes in the Netherlands regarding their views on current endoscopic training initiatives and any shortcomings of these initiatives. In Chapter 3 the opinions of the directors of training programmes in general surgery, urology, gynaecology and orthopaedic surgery are compared and Chapter 4 gives a detailed description of the opinions of the urology programme directors.

We believe that it is important for potential users of training models to be informed of the existence of new training models that have been tested in practice in order to prevent hospitals and universities from wasting time and energy in developing models that are already available. This consideration gave rise to sub-question 3, which is addressed in Chapter 5, in which we describe a newly developed low-cost, easy to use training model for diagnostic and therapeutic procedures in bladder pathology with real-time haptics.

The validation process of the URO Mentor (UM) virtual reality simulator is described in Chapters 6, 7 and 8. As described in the introduction, validation comprises the determination of face, content, construct and criterion validity. Chapter 6 deals with sub-question 4 and describes a study seeking the opinions of 33 novices and 56 experts regarding UM’s realism and usefulness. In order to examine whether UM can discriminate between different levels of expertise and whether novices’ performances improve after training on UM (construct validity), a prospective trial was conducted. Sub-questions 5 and 6 are addressed in Chapter 7, which describes the results of a trial in which 50 novices and 30 experts underwent a 7-task training programme. One of the key questions in the validation process “Do trainees’ urethroscopy performances in real patients improve by training on UM?” (sub-question 7, criterion validity) is addressed in Chapter 8. Criterion validity was investigated in a randomized single-blinded multicentre study in which 100 interns were randomized to perform urethrocystoscopy in a patient 1) after training on UM (=UM-trained) or 2) without training on UM (=controls).

Chapter 9 shows the results of a study to assess the face and content validity of Uro Trainer, a simulator designed for transurethral resection of bladder tumours (TURBT) and prostate (TURP) procedures. This chapter addresses sub-question 8. It turned out that measured against criteria from other validation studies, Uro Trainer’s face and content validity were unsatisfactory. The lack of general guidelines for
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establishing face and content validity which we discovered when searching the literature for this study has convinced us of the need for consensus on appropriate methods for evaluating the validity of simulators.

In our studies to establish the validity of simulators, we progressively came to realize that it is important to analyze learners’ training needs and identify any pitfalls novices may encounter in performing a procedure in a patient so that these can be incorporated into simulator training. This gave rise to sub-question 9 “What pitfalls do novices encounter when learning TURBT, TURP and URS procedures in patients and what lessons can we learn from that for the development of simulator-based training programmes? Chapter 10 describes the pitfalls of endourological procedures identified by observational research of 37 TURBT procedures, 22 TURP and 21 URS procedures.

Chapter 11 describes a critical overview of the prevailing validation methods based on a literature review. In addition, recommendations for future research and the development of training programmes are made.

The findings of the preceding chapters are discussed and summarized in Chapter 12.

Acknowledgement statement

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