

Ureterorenoscopy training on cadavers embalmed by Thiel's method: simulation or a further step towards reality? Initial report

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Introduction The technique of ureterorenoscopy has a significant learning curve. Cadavers embalmed by the Thiel method have been successfully used for simulation training in a number of surgical specialties. Here we present our experience of the first use of Thiel cadavers in a formal ureteroscopy training course.

Material and methods The inaugural 'Masterclass in Flexible Ureterorenoscopy' was run with participants performing ureterorenoscopy on three Thiel cadavers under expert supervision. A qualitative questionnaire was delivered to the participants and faculty. Assessed domains were tissue characteristics of the cadaveric urinary tract, anatomical features and procedural aspects. A five-point Likert score was used to assess responses. Data regarding participant experience in endourology were also collected.

Results 8 questionnaires were collected. All participants completed cadaveric ureterorenoscopy. Three-quarters reported the overall quality of tissue in the cadaveric bladder, ureters and pelvicalyceal system as high or excellent. Half reported the cadaveric bladder as being softer than in a live patient, whilst five out of eight thought that the cadaveric ureter was softer and more prone to trauma. Seven out of eight were satisfied with the overall quality of the cadaveric model. The quality of vision and irrigation in the upper urinary tracts was reported as high.

Conclusions Thiel cadavers have been shown to have excellent tissue characteristics, as well as being durable and reusable. We have described the first use of Thiel cadavers in a designated ureteroscopy course, with high levels of delegate satisfaction. Further work is required to develop the role of Thiel cadavers as part of an integrated, modular urology training.

Key Words: ureteroscopy ↔ cadavers ↔ Thiel embalming ↔ simulation ↔ training

INTRODUCTION

Appropriate training in diagnostic and therapeutic ureterorenoscopy is essential, as the procedure requires a high degree of dexterity and endoscopic skills, as well as a comprehensive understanding of upper urinary tract anatomy. It has been recognised that complication rates should be low in the hands of experienced endoscopists, but that significant risks, including ureteric injury, remain associated with the procedure [1].

The implementation of novel technologies and techniques, the increasing demands of service provision, coupled with a reduced exposure to practical anatomy in undergraduate education lends further impetus to efforts to improve the efficiency of training and reduce the learning curve [2, 3]. These factors have promoted the development of procedure-specific training models for use in urological training, with a range of computer-based and animal model simulators described [4]. The first ureterorenoscopy

simulators incorporated x-ray imaging, detailed anatomy of upper urinary tract in order to mimic a sensation of interaction with tissue [6]. It has been demonstrated that the outcomes are superior for simulators with a higher fidelity i.e. the ability to produce a more 'life-like' training environment. Training on cadavers may complement the lack of other simulators in providing sensation and feeling of real interaction. Cadaveric models have been described as the 'gold-standard' in technical skill development, with the potential to provide the training substrate and haptic feedback which is lacking in other simulators [7, 8].

Thiel's method on embalming has been previously described [3]. Thiel cadavers have been used in a formal laparoscopic nephrectomy training course accredited by the British Association of Urological Surgeons, with participants reporting very high correlation between the cadaveric experience and the live procedures [3]. Moreover, a human cadaver embalmed by Thiel's method was described as a training model for cystoscopy and transurethral resection of the prostate, as well as other, non-urological procedures [8, 9, 10]. Application of this method allows for preservation of the color, consistency and transparency of cadaveric tissues, offering excellent disinfection whilst minimising exposure to embalming chemicals [11–14]. In this study, we aimed to assess the potential role of Thiel cadavers in skill acquisition for ureterorenoscopy.

MATERIAL AND METHODS

A two-day masterclass in flexible ureteroscopy was run at our center. Six urologists in training participated in the course, with three endourology Consultants as faculty. Three male cadavers prepared by Thiel's method, were available.

Thiel fixation involves a water-based solution of glycol and various salts to achieve long-term cadaveric preservation whilst retaining tissue elasticity and compliance. The embalming procedure consists of vascular perfusion followed by submersion of the cadaver in embalming fluid for a period of at least 3 months. The embalming solution consists of boric acid and various salts for fixation and disinfection, low levels of 4-chloro-3-methylenphenol for mould prevention, ethylene glycol for preservation of tissue plasticity, low concentrations of formalin (0.8% in the submersion fluid) and alcohol and morpholine for preservation of tissue consistency and colour. The cadavers are preserved long-term and can be used and re-used for multiple procedures [11–14].

Cadavers were placed in the lithotomy position. Saline irrigation was run, with pressure bags providing

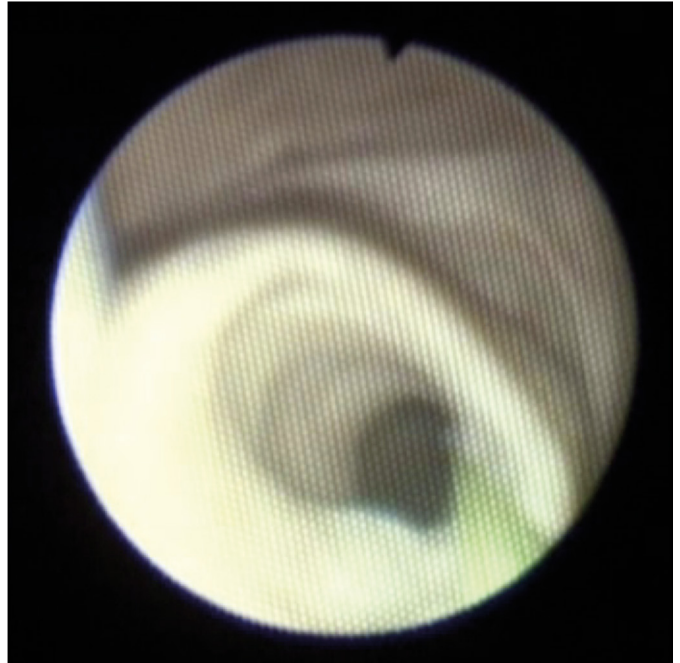


Figure 1. Cadaveric ureteric orifice following several ureteroscopies, with guidewire in place.

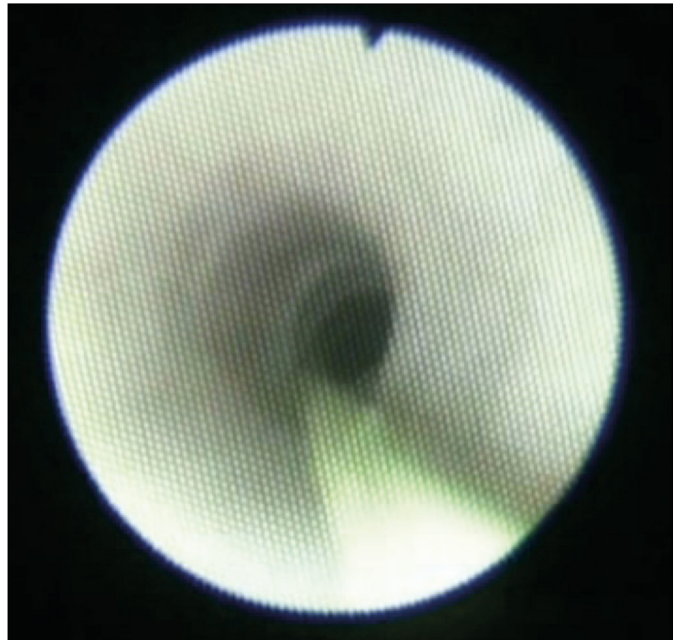


Figure 2. Cadaveric ureter with guidewire in place.

an irrigant pressure of 100 mmHg. Bilateral semi-rigid and flexible ureteroscopy had been performed by an expert (high volume ureteroscopist) on each cadaver prior to the course to ensure technical suitability. All ureters could be entered and the pelvicalyceal system was accessed bilaterally in each cadaver (Figures 1, 2, 3). Each participant performed semi-



Figure 3. Cadaveric pelvicalyceal system.

rigid (7.5F Karl Storz GmbH, Tuttlingen, Germany) and flexible (Flex X2 Karl Storz GmbH, Tuttlingen, Germany) ureterorenoscopy on the cadaver under the guidance of the expert faculty. Two cadavers had had guide-wires inserted into unilateral upper urinary tract (one each) prior the wet-lab work to ensure easy access to the ureter. One cadaver was noted to have a difficult intramural ureteric segment whilst another had a tortuous ureter. None of the cadavers had significant urethral or bladder neck obstruction. Participants were advised to use Roadrunner® (Cook; Bloomington, Indiana, USA) guide-wires to negotiate ureteroscopes and to minimise trauma to the ureters. Ureteral access sheaths were not used in the cadavers. All procedures were video-recorded for feedback and analysis.

All participants and faculty were asked to evaluate the cadavers following completion of the exercise. A questionnaire was designed specifically for the study and was delivered to the participants and faculty to assess three primary domains: tissue characteristics, organ characteristics and procedure characteristics. Responses were recorded using five-point scales. Responses were collected according to the following headings for the bladder, ureters and pelvicalyceal system: tissue quality, colour, consistency and vulnerability to trauma. Aspects of the procedure were also assessed with participants asked to compare the models with their experience in patients according to the following parameters: identification of anatomical landmarks, navigation of the scope,

quality of vision and quality of irrigation. A global satisfaction score with the cadaveric models was also recorded, with responses rated on a five-point Likert scale.

RESULTS

Eight completed questionnaires were collected (5 participants and 3 faculty). The sixth trainee was unable to complete a questionnaire, having had to leave the course somewhat early. The mean number of years spent in urology was 10.9 (4–22 years). The mean number of semi-rigid ureterorenoscopies performed by participants was 5.2 per week (2–8). The mean number of flexible ureterorenoscopies performed by participants per week was 2.4 (0–5), with two participants not performing regular flexible ureterorenoscopy.

Bladder

Delegate and faculty responses were collected and are outlined in Table 1. Five out of eight questionnaires rated the overall quality of the cadaveric bladder as high, one out of eight as excellent, in comparison with operative experience with living tissue. Of the remainder, one out of eight rated it as of ‘low’ quality and one out of eight remained neutral. Respondents generally found the cadaveric bladder to have a pale appearance compared to real-life patients (6/8) with 4/8 reporting it as soft in consistency. Two out of eight rated the bladder consistency as equal. In terms of susceptibility to trauma, four out of eight rated the cadaveric bladder as more vulnerable to procedural trauma with three out of eight rating it as equivalent.

Table 1. Delegate vs. Expert reported experience of the cadaveric bladder. Mean scores according to a Likert scale: 1. Strongly disagree; 2. Disagree; 3. Neutral; 4. Agree; 5. Strongly agree. Score for overall quality 1 (poor) to 5 (excellent)

Bladder	Delegates (n = 5)	Experts (n = 3)
‘The colour of cadaveric tissue of the bladder in comparison with a real life patient is similar’	3.2	3.3
‘The consistency of cadaveric tissue of the bladder in comparison with a real life patient is similar’	2.6	3.7
‘The ability to traumatise the cadaveric tissue of the bladder in comparison with a real life patient is similar’	1.8	2.7
Overall quality of Thiel cadaveric bladder	3.8	3.7
Mean number of ureteroscopic procedures (semi-rigid and flexible) per week	7.6	12

Ureter

Delegate and faculty responses were collected and are outlined in Table 2. Two out of eight questionnaires rated the overall quality of ureteric tissue as excellent with four out of eight rating it as of high quality. Two out of eight remained neutral. As with the bladder, respondents found the ureters to have a pale (6/8) or white/grey appearance (2/8). Four out of eight participants of the study agreed that the color of ureteric tissue was similar to real-life patients. Five out of eight reported that the ureters felt soft or very soft in comparison with real-life experience, with five out of eight also reporting that the cadaveric ureters were more prone to trauma during the procedure. Five out of eight respondents reported that anatomical ureteric narrowings were preserved in the cadavers, one out of eight thought they were more pronounced and two out of eight thought they were less pronounced. Five out of eight surveyed felt that the tissue compliance of the intramural ureters was less than in real-life, rendering them somewhat stiffer in the cadaveric models.

Pelvicalyceal system

Delegate and faculty responses were collected and are outlined in Table 3. Six out of eight questionnaires rated the overall tissue quality of the pelvicalyceal system as high or excellent, two out of eight responded as neutral. The pelvicalyceal system appeared paler than encountered in live patients to all responders. Four out of eight respondents to the survey thought the pelvicalyceal system of the cadavers felt softer than in live patients whilst three out of eight felt it was equal. Three out of eight reported the cadaveric pelvicalyceal system to be more susceptible to trauma, with four out of eight remaining neutral on the question.

Procedural components of ureterorenoscopy on the Thiel cadaver

Every course participant successfully performed a complete semi-rigid and flexible ureterorenoscopy on the Thiel cadaver, with and without a guidewire. They were asked to assess each component of the procedure in terms of realism and the results are presented in Table 4. The quality of vision and irrigation in the upper urinary tracts of the Thiel cadavers using both a flexible and semi-rigid ureteroscopes was reported as high. Identifying the ureteric orifice in the cadavers, a procedural component which junior trainees may find challenging, was felt to correspond well with the procedure in a live patient.

Table 2. Delegate vs. Expert reported experience of the cadaveric ureter. Mean scores according to a Likert scale: 1. Strongly disagree; 2. Disagree; 3. Neutral; 4. Agree; 5. Strongly agree. Score for overall quality 1 (poor) to 5 (excellent)

Ureter	Delegates (n = 5)	Experts (n = 3)
'The colour of cadaveric tissue of the ureter in comparison with a real life patient is similar'	3.2	3
'The consistency of cadaveric tissue of the ureter in comparison with a real life patient is similar'	2.2	2.3
'The ability to traumatise the cadaveric tissue of the ureter in comparison with a real life patient is similar'	2.4	2.7
'The compliance of the cadaveric intramural ureter in comparison with a real-life patient is similar'	2.4	2.3
'The compliance of the cadaveric ureter in comparison with a real-life patient is similar'	2.4	2
Overall quality of Thiel cadaveric ureter	4.2	3.3
Mean number of ureteroscopic procedures (semi-rigid and flexible) per week	7.2	12

Table 3. Delegate vs. Expert reported experience of the cadaveric pelvicalyceal system. Mean scores according to a Likert scale: 1. Strongly disagree; 2. Disagree; 3. Neutral; 4. Agree; 5. Strongly agree. Score for overall quality 1 (poor) to 5 (excellent)

Pelvicalyceal system	Delegates (n = 5)	Experts (n = 3)
'The colour of cadaveric tissue of the pelvicalyceal system in comparison with a real life patient is similar'	3.2	3
'The consistency of cadaveric tissue of the pelvicalyceal system in comparison with a real life patient is similar'	2.6	4
'The ability to traumatise the cadaveric tissue of the pelvicalyceal system in comparison with a real life patient is similar'	2.2	2.3
'The cadaveric pelvicalyceal system anatomy is similar to a real-life patient'	4.6	4
Overall quality of Thiel cadaver pelvicalyceal system tissue	4.2	4
Mean number of ureteroscopic procedures (semi-rigid and flexible) per week	7.6	12

Negotiating and navigating the ureters was reported as between 'neutral' and 'high' in terms of realism. There were no reported ureteric perforations nor mucosal tears.

Overall satisfaction with the cadaveric training model

Four out of eight respondents to the questionnaires strongly agreed with the statement: 'Overall,

Table 4. Procedural aspects of the cadaveric models; 5-point Likert score: 1: unrealistic/poor; 5 realistic/excellent

Component of ureterorenoscopy	Delegate mean score (n = 5)	Expert mean score (n = 3)
Urethral navigation	3.2	3.3
Identification of ureteric orifice	4	4.3
Entering ureter with guidewire	3.8	3.3
Entering ureter without guidewire	3.6	3.3
Navigating scope in ureter with guidewire	3.8	3.7
Navigating scope in ureter without guidewire	3.4	3.7
Navigating scope in pelvicalyceal system	3.8	4
Quality of vision in ureter: Semi-rigid scope	4.2	3.7
Quality of vision in ureter: Flexible scope	4.2	3.7
Quality of irrigation in ureter: Semi-rigid scope	4.2	3.7
Quality of irrigation in ureter: Flexible scope	4	3.7
Quality of irrigation in pelvicalyceal system: Semi-rigid scope	4.4	4
Quality of irrigation in pelvicalyceal system: Flexible scope	4.2	4

I am satisfied with the cadaveric model'. Three out of eight agreed and one out of eight remained neutral with regard to the statement.

DISCUSSION

Ureterorenoscopy is a technically demanding procedure with a significant learning curve. Technical competence is a requirement prior to performing such procedures on patients due to the potential for ureteric injury and other complications. Once acquired, these skills require maintenance, especially for those surgeons who perform ureteroscopy as an occasional activity rather than a core area of practice. As with other areas of Urological training, a variety of means have been employed to develop this level of competence in trainees, with a range of simulators described in the literature. These include virtual reality (VR) and bench-top simulators, as well as the use of fresh frozen cadavers (FFC). The low-fidelity 'K-Box' model has recently been described as a useful adjunct to both ureteroscopy training and assessment [15]. In addition, the use of animal models, such as the porcine model, have been described in use on a number of courses [16, 17, 18]. The educational value and cost implications of these models remains to be established [5]. High-fidelity (very lifelike) models tend to be more expensive but the importance of fidelity in skill acquisition is thought to be more

significant in more senior trainees, suggesting that when starting on the learning curve, it is concept of the procedure which is more important than the physical substrate [19].

Cadaveric-based simulation has been shown to offer a superior training experience, allowing trainees to complete full operative procedures. The British Association of Urological Surgeons (BAUS) human cadaver training programme uses FFC and it is the first modular cadaveric programme in urology [17]. Module 2 of the programme includes semi-rigid and flexible ureteroscopy in FFC. Cadavers remain an expensive resource with a limited supply, although Ahmed et al. have recently demonstrated that incorporating endourological procedures into a modular training programme using cadavers is both effective and helps to mitigate the financial cost [19]. Embalming confers benefits including improved durability, reduced exposure to pathogens and the ability to re-use a cadaver for multiple training events. Thiel cadavers have shown much promise to date in the development of realistic training models for urological procedures [3]. Prasad Rai et al. described the use of Thiel cadavers in an advanced renal laparoscopic course, with excellent tissue characteristics reported by the participants [1]. In addition, Thiel cadavers have been employed for training in cystoscopy, trans-urethral resection of the prostate and retrograde ureteropyelography [3]. The use of Thiel cadavers has also been described in a wide range of procedures including colonic, vascular, bariatric, hernia, thyroid and plastic surgery, as well as regional anaesthetic training [10, 20–23].

As the first description of the use of Thiel cadavers in a formal ureteroscopy training course, we have demonstrated that the procedure is technically feasible, using semi-rigid and flexible ureteroscopes to access the ureter and the pelvicalyceal system in an identical stepwise manner as during ureterorenoscopy on a live patient. Since this study was performed, Bele and Kelc have reported their experience in using Thiel cadavers for ureteroscopy performed by expert endourologists [24]. The resemblance of tissue to the real-life situation is an important component in the assessment of training models. The overall quality of the cadaveric urinary tract tissue was reported as high or excellent by 6 out of 8 of respondents, whilst the anatomy of the upper urinary tracts was well preserved. The tissue was generally noted to have a paler appearance than *in vivo*, an expected finding in embalmed tissue. It is possible that changes to the embalming process could ameliorate this difference, with vascular infusion techniques using red latex being described [22]. These techniques could improve the visibility of the

vascular milieu within the urinary mucosa. Around half of respondents felt that the tissue was generally softer and more prone to trauma in the cadaver. This may actually encourage a level of caution in trainees, which will serve them well when transferring their skills to the clinical environment. Anatomical landmarks, in the form of ureteric orifices and ureteric narrowings, were generally thought to be well preserved in the cadavers. Regarding the procedure, all respondents completed ureterorenoscopy using both the semi-rigid and flexible ureteroscopes, with and without a guidewire. Their overall impression of the procedure was positive, reflected by high satisfaction rates. The vision and irrigation within the upper urinary tracts of the cadavers was reported as generally good. Whilst this assessment of vision and irrigation is necessarily subjective, the fact that the trainees had a reasonable level of experience of 'real-life' ureteroscopy prior to attending the course should improve their ability to accurately compare the cadaveric technical components with that of live patients. However, an objective assessment of irrigation and vision could be incorporated into the ongoing evaluation of the Thiel cadaver.

This study demonstrates that Thiel cadavers offer a plausible, high-fidelity training environment for endourological procedures. All cadavers will differ from living patients and it is important that these differences are appreciated when using them in training models. These differences will include an absence of bleeding following traumatic instrumentation, as well as an absence of peristalsis. Whilst the participant number included in this study is small, further data will be collected as the course becomes established. In addition, as our experience in using Thiel cadavers for ureterorenoscopy improves, we will develop a more detailed picture of the baseline changes engendered by death and the embalming process on the upper urinary tract.

Thiel cadavers take around 3 months for tissue fixation and have correspondingly high processing costs. However, their durability allows re-use across a range of procedures and specialties, thereby increasing their cost-effectiveness. The Thiel embalming method has other benefits including reduced formaldehyde exposure and the absence of phenol, compared to traditional methods [19]. A potential downside of this durability is the requirements for adequate storage facilities for the cadavers.

In this study, the upper urinary tract could be accessed bilaterally in each cadaver. In addition, each cadaver was used several times, without significant degradation being reported. As it is the durability of Thiel cadavers which makes them cost-effective, the ability to re-use these cadavers for repeated pro-

cedures is relevant. The cadavers will be re-used on future courses in urology and other specialties, having been re-assessed beforehand. This will provide valuable information regarding their sustained durability and fidelity fatigue.

The small number of responses represents a limitation of this study. This will be addressed as the course is run on an annual or biannual basis.

The participants on the course had a range of experience in performing ureteroscopy and reported performing an average of 5.2 rigid ureteroscopic procedures per week. Despite this experience, they had self-selected to attend the course and therefore had identified their own need for further training, reflecting their comparatively lower level of experience in flexible ureteroscopy. As the assessment of the Thiel upper tracts relies on a subjective comparison with live patients, this previous experience amongst the participants of performing ureteroscopy in such patients has brought benefit to the study. Our questionnaire has not been validated, reflecting the novel nature of this training medium. This will be an area of future work as the role of cadaveric and other simulation models is further assessed.

In addition, as the expert raters were also faculty members, this may introduce the possibility of bias. However, collecting data from experienced endourologists regarding the fidelity of the Thiel experience is invaluable. As the dataset expands, we will develop a more detailed picture of the effect of experience on interpretation of face and content validity. Further work will include the incorporation of basic ureteroscopic skill tasks to the Masterclass, such as time taken to reach the pelvicalyceal system, identification of calyces, ureteric stent deployment and stone management. This would allow the further evaluation of the cadavers in terms of construct validity by comparing outcomes across the experience levels. In addition, a direct comparison of fresh-frozen and Thiel-embalmed cadavers may be beneficial to assess their face and content validity amongst experienced endourologists.

CONCLUSIONS

Learning semi-rigid and flexible ureterorenoscopy on cadavers embalmed by the Thiel's method is highly appreciated by trainees and tutors as it is felt to offer a high-fidelity training environment with good haptic feedback, compared with the live procedure. The tissue respect required to prevent injury of the Thiel cadaver serves as good training, potentially translating into a safer approach to the real-life patient. We have shown that ureterorenoscopic procedures are technically feasible on Thiel cadavers,

lending further evidence to support their integration into modular urological training programmes. We aim to complete prospective data collection from further courses to assess the validity of the model for use in the teaching of routine endourological procedures.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ETHICAL STANDARDS

The use of cadavers within this study was subject to standard ethical assessment as per the policy of our Centre.

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