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URETERORENOSCOPY TRAINING ON CADAVERS EMBALMED BY THIEL'S METHOD: SIMULATION OR A FURTHER STEP TOWARDS REALITY? INTITIAL REPORT

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Abstract:

Objective: The technique of ureterorenoscopy has a significant learning curve. Cadavers embalmed by the Thiel method have been successfully used in simulation training for a number of surgical specialties, including urology. Here we present the first report to assess the plausibility of using Thiel cadavers in ureterorenoscopy simulation.

Materials and methods: The two day inaugural 'Masterclass in Flexible Ureterorenoscopy' was run with 6 participants performing semi-rigid and flexible ureterorenoscopy on three Thiel cadavers under the guidance of three experienced endourologists. A qualitative questionnaire was delivered to the participants and faculty. Three key domains were assessed, namely tissue characteristics (colour, consistency, vulnerability) of the cadaveric bladder, ureter and pelvicalyceal system, anatomical features and procedural aspects (quality of vision, irrigation, scope navigation). A five-point Likert score was used to assess responses. Data regarding the level of training and experience in endourology were also collected. Video recordings of the procedures were made.

Results: 8 questionnaires were collected (5 delegates, 3 faculty). All participants completed cadaveric ureterorenoscopy using semi-rigid and flexible ureteroscopes.75% reported the overall quality of tissue in the cadaveric bladder, ureters and pelvicalyceal system as high or excellent. 50% 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. The same number also reported that the intramural ureter was somewhat stiffer than in live patients and that ureteric anatomical narrowings were preserved in the cadavers. Overall , the tissues were reported as being paler than in live patients. Four out of eight strongly agreed with overall quality of the cadaveric model, three agreed and one respondent remained neutral. 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, thereby improving their cost-effectiveness. We have described the first use of Thiel cadavers in a designated ureterorenoscopy course, with high levels of delegate satisfaction. Further work is required to develop the role of Thiel cadavers as part of integrated, modular urology training.

Introduction:

The technique of ureterorenoscopy is at the core of the management of upper urinary tract stone disease and tumours. 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. Patient safety has been of central concern since the first successful ureterorenoscopy. Lyon taught that **'**disasters such as perforation of the ureter are a distinct possibility if care and thought are not practiced' and Perez-Castro Ellendt emphasized the need for high quality training as 'in the hands of skilled endoscopists the rate of complications should be fairly low'. [1,2]

Like elsewhere in surgery, training in Urological techniques has come under pressure from a range of sources. Much has been written about the effect of the European Working Time Directive (EWTD) on constricting the time available for 'on the job' training, with a corresponding rise in interest in developing techniques to foster the requisite skills outwith the clinical environment. 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. [3,4] 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. [5] 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 higher fidelity i.e. the ability to produce a more 'life-like' training environment. The skills learnt on simulators still require verification in clinical practice,

which can be assessed on cadavers.[7] Following that logic, cadaveric models have been described as the 'gold-standard' in technical skill development.[8]

Thiel's method on embalming has been previously described and our centre was the first in the United Kingdom to convert to this technique.[4] 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 live procedures.[4] 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. [9-11] Several advantages of the Thiel embalming technique have been reported. Application of this method allows for preservation of the colours, consistency and transparency of cadaveric tissues.[12, 13] In addition, it possesses exceptional disinfecting properties combined with virtually no risk of releasing harmful substances into the environment and consequently no risk of exposure of the end users to dangerous chemicals.[12-15]

For ureterorenoscopy, a range of virtual-reality simulators, bench models, hybrid systems and fresh cadaveric models have been described.[16-18] There have not been any published descriptions of the use of Thiel cadavers as training models for ureterorenoscopy. In this study we aimed to assess the potential role of Thiel cadavers in skill acquisition for ureterorenoscopy.

Materials and methods:

The inaugural 'Masterclass in Flexible Ureterorenoscopy' was run on the 16th and 17th of March 2015 in the Cushieri Skills Centre, University of Dundee, Scotland. Six urologists in training participated in the course, with three endourology Consultants as faculty. Day 1 of

the course consisted of core knowledge lectures and wet-lab work. Three male cadavers prepared by Thiel's method, as previously described, 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.[12-15]

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 viability. All ureters could be intubated and the pelvicalyceal system was accessed bilaterally in each cadaver. Each participant performed semi-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. 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. A sample domain of the questionnaire is included in Appendix 1. 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 mean number of years spent in urology was 10.9 (4-22 years). The mean number of semi-rigid ureterorenoscopies performed was 5.1 per week (2-10). The mean number of flexible ureterorenoscopies performed per week was 5.5 (1-10), 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 50% 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.

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 colour 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.

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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. Negotiating and navigating the ureters was reported as between 'neutral' and 'high' in terms of realism.

Overall satisfaction with the cadaveric training model:

Four out of eight respondents to the questionnaires strongly agreed with the statement: 'Overall, I am satisfied with the cadaveric model', three out of eight agreed and one out of eight remained neutral.

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). 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.[19,20]

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.[20] 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.[20] 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.[4] Prasad Rai *et al.* described the use of Thiel cadavers in an advanced renal laparoscopic course, with excellent tissue characteristics reported by the participants.[21] In addition, Thiel cadavers have been employed for training in cystoscopy, transurethral resection of the prostate and retrograde ureteropyelography.[4] 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.[11, 22,23]

As the first description of a formal training course in ureterorenoscopy using Thiel cadavers, 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. 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 75% 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. 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. 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. 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 benefits including reduced formaldehyde exposure and the absence of phenol, compared to traditional methods.[19]

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 procedures is relevant. The cadavers will be re-used on future courses, 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. 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.

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 the validity of the model for use in the teaching of routine endourological procedures.

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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 per week	7.2	12

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).

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 per week	7.2	12

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).

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 per week		

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).

Component of ureterorenoscopy	Mean score (±SD)
Urethral navigation	3.2 (±1.16)
Identification of ureteric orifice	4.1 (±0.99)
Entering ureter with guidewire	3.6 (±0.74)
Entering ureter without guidewire	3.5 (±0.93)
Navigating scope in ureter with guidewire	3.3 (±1.07)
Navigating scope in ureter without guidewire	3.3 (±1.16)
Navigating scope in pelvicalyceal system	3.9 (±0.99)
Quality of vision in ureter: Semi-rigid scope	4 (±1.07)
Quality of vision in uterer: Flexible scope	4 (±1.07)
Quality of irrigation in ureter: Semi-rigid scope	4(±1.31)
Quality of irrigation in ureter: Flexible scope	3.9 (±1.25)
Quality of irrigation in pelvicalyceal system: Semi-rigid scope	4.2 (±0.89)
Quality of irrigation in pelvicalyceal system: Flexible scope	4.1 (±0.83)

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

Appendix 1.

Sample from Questionnaire: Bladder.

1. The quality of cadaveric tissue of the bladder in comparison with a real-life patient is:

Poor/Low/Neutral/High/Excellent.

2. The colour of cadaveric tissue of the bladder in comparison with a real-life patient is similar:

Strongly disagree/Disagree/Neutral/Agree/Strongly Agree

3. The colour of cadaveric tissue of the bladder in comparison with a real-life patient is:

White/Pale/Grey/Pink/Red

4. The consistency of cadaveric tissue of the bladder in comparison with a real-life patient is:

Strongly disagree/Disagree/Neutral/Agree/Strongly Agree

5. The consistency of cadaveric tissue of the bladder in comparison with a real-life patient is:

Very Soft/Soft/Equal/Hard/Very Hard

6. The vulnerability (ability to traumatise) of cadaveric tissue of the bladder in comparison with a real-life patient is similar:

Strongly disagree/Disagree/Neutral/Agree/Strongly Agree

7. The vulnerability (ability to traumatise) of cadaveric tissue of the bladder in comparison with a real-life patient is:

Very Easy/Easy/ Neutral/Difficult/Very Difficult

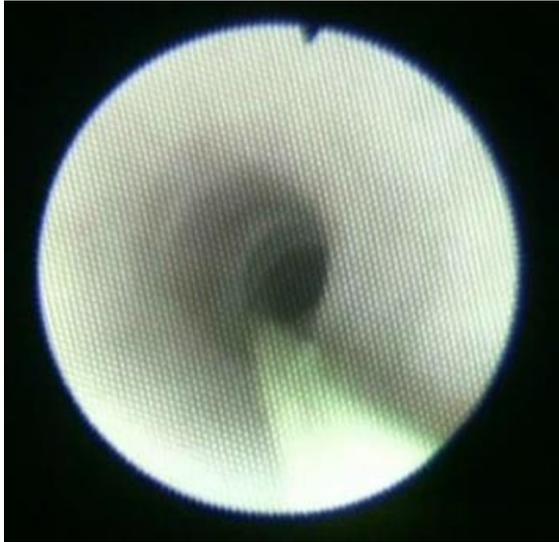Figure 1. Left ureteric orifice in cadaver with guidewire in ureter.

Figure 2. Left mid-ureter in Thiel cadaver, guidewire *in situ*.

Figure 3. Left renal pelvis from pelvic-ureteric junction.

Figure 4. Cadaveric renal pelvis.