Current status of wet lab and cadaveric simulation in urological training: A systematic review

Ahmed Al-Jabir, MSc, MBBS[1]*; Abdullatif Aydin, BSc (Hons), MBBS*[2]*; Hussain Al-Jabir, MSc, MBBS*[3]*;*
M. Shamim Khan, FRCS (Urol), FEBU[2,4]*; Prokar Dasgupta, MSc, MD, FRCS (Urol), FEBU*[2,4]*;*
Kamran Ahmed, PhD, FRCS (Urol)[2,5]

[1]GKT School of Medical Education, King's College London, London, United Kingdom; [2]MRC Centre for Transplantation, Guy's Hospital, King's College London, London, United Kingdom; [3]William Harvey Research Institute, Barts and The London School of Medicine School of Medicine and Dentistry, London, United Kingdom; [4]Department of Urology, Guy's and St. Thomas' NHS Foundation Trust, London, United Kingdom; [5]Department of Urology, King's College Hospital NHS Foundation Trust, London, United Kingdom

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Appendix available at *cuaj.ca*

Abstract

Introduction: We undertook a systematic review of the use of wet lab (animal and cadaveric) simulation models in urological training, with an aim to establishing a level of evidence (LoE) for studies and level of recommendation (LoR) for models, as well as evaluating types of validation.

Methods: Medline, EMBASE, and Cochrane databases were searched for English-language studies using search terms including a combination of "surgery," "surgical training," and "medical education." These results were combined with "wet lab," "animal model," "cadaveric," and "in-vivo." Studies were then assigned a LoE and LoR if appropriate as per the education-modified Oxford Centre for Evidence-Based Medicine classification.

Results: A total of 43 articles met the inclusion criteria. There was a mean of 23.1 (±19.2) participants per study with a median of 20. Overall, the studies were largely of low quality, with 90.7% of studies being lower than LoE 2a (n=26 for LoE 2b and n=13 for LoE 3). The majority (72.1%, n=31) of studies were in animal models and 27.9% (n=12) were in cadaveric models.

Conclusions: Simulation in urological education is becoming more prevalent in the literature, however, there is a focus on animal rather than cadaveric simulation, possibly due to cost and ethical considerations. Studies are also predominately of a low LoE; higher LoEs, especially randomized controlled studies, are needed.

Introduction

The Halsteadian model of "see one, do one, teach one" has long permeated and monopolized surgical education,[1] with surgeons learning techniques in an apprenticeship style under an experienced colleague in the operating room (OR). However, in modern medical practice, service delivery pressures have reduced training hours and so new ways must be found to enhance and be an adjunct to patient and operation exposure hours.

The solution of the aviation industry has long been to use simulation models to enhance learning[2,3] and this style of learning is also becoming more widely adopted and validated as a way to enhance performance in the OR.[4-7]

Despite the widespread use of bench-top dry lab models, the gold standard of simulation-based surgical training is still using wet lab models, consisting of animal models (both live animals and animal tissues) and cadaveric simulation models. The advantages and disadvantages of these are summarized in Table 1.

Previous systematic reviews have been published on the use of surgical simulators in specific specialities[8-12] but to date, none have comprehensively focused on the use of wet lab simulation models in urology. The aim of this study is to systematically review the literature for the use of wet lab simulator models in urological surgery, to establish a level of evidence (LoE) for studies, a level of recommendation (LoR) for models, as well as evaluating types of validation used in studies.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to optimize the transparency and detail of the review.[13]

Eligibility criteria

Included in the review are original research articles and systematic reviews, as well as posters and oral presentations from conferences that described the use of wet lab models for surgical simulation. We included validation studies or articles studying the educational value of a model.

Table 1. Advantages and disadvantages of wet lab simulation methods

Simulation method	Advantages	Disadvantages
Animal tissues	Cost-effective, real tissue	Single-use, difficulties in storage
Live animals	Good face validity, can do full procedure	Single-use, ethical issues, cost, special procedures, anatomical differences
Cadavers	Best face validity, haptic feedback, full procedure, realistic tissue, 'the gold standard'	Single-use, cost, availability, infection risk

Systematic reviews, insufficiently short abstracts, and articles not in the English language were excluded, as were those relating specifically to dental surgery.

Information sources and search processes

Studies were identified by searching MEDLINE, EMBASE, and Cochrane Library databases via Ovid from 1946 to present using the strategy in Fig. 1. Search terms included a combination of "surgery," "surgical training." and "medical education." These results were combined with "wet lab," "animal model," "cadaveric," and "in vivo" (Supplementary Table 1; available at *cuaj.ca*)

Study selection and data collection process

After the initial search, abstracts and titles were screened and duplicates removed. Articles chosen were agreed upon by all authors. Full-texts were then reviewed to exclude non-urological articles, as well as those that do not meet the inclusion criteria. Further to this, a hand search of reference lists was done for any further articles missed.

Data items

Data extracted was as follows: author; year; type of simulation model; if animal model, which animal; if animal model, whether in-vivo or ex-vivo; procedure simulation method tested for; subjects size; validation type; brief description; LoR; LoE (if appropriate). Each study was classified for validity where appropriate using the definitions developed by McDougall,[1] Van Nortwick et al,[14] and Tay et al [15] (Supplementary Table 2; available at *cuaj.ca*).

A LoE and LoR was given to each study and model as according to the modified educational Oxford Centre for Evidence-Based Medicine classification system, as adapted by the European Association of Endoscopic Surgery[16] (Supplementary Tables 3A, 3B; available at *cuaj.ca*).

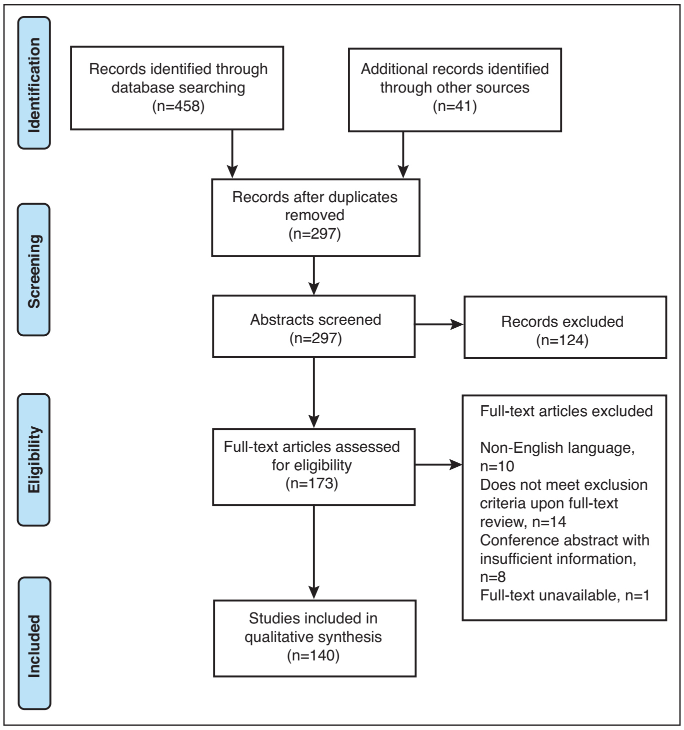

Fig. 1. PRISMA Flow diagram as per Moher et al.[13]

Synthesis of the data

Due to the heterogenous and qualitative nature of many of the studies, a quantitative meta-analysis could not be performed.

Results

Description of included studies

A total of 498 studies were identified for potential inclusion. After screening of abstracts and full-text review, 143 articles met criteria for inclusion in the study. Of the 140 articles included, 43 studies were identified as dealing with urological procedures.[17-58]

There were a far-ranging number of participants of each study, from 2–102, with a mean of 23.1 (±19.2), a median of 20 participants, and a mode of 20 participants per study. Overall, the studies were largely low-quality, with 90.7% of studies being lower than LoE 2a (n=26 for LoE 2b and n=13 for LoE 3). Subsequently, they had low LoR (58.5% LoR 3, 31.7% LoR 4). Most (72.1 %, n=31) studies were in animal models, with only 27.9 % (n=12) were in cadaveric models: 26 studies were porcine studies and four were chicken studies. Thirteen (31.7%) studies were descriptive only, with the others involving elements of evaluation (Table 2). For evaluation studies, the average number of participants was 23.6

Table 2. Characteristics of included studies (n=140)

Study profile	n (%)
Type of simulation	
Animal	31 (72.1)
Ex vivo	21
In vivo	9
Cadaveric	12 (27.9)
Animal model used	
Pig	26
Chicken	4
Rabbit	1
Validity focus	
Face	31
Content	18
Construct	17
Concurrent	2
Predictive	2
Transfer	3
Levels of evidence	
1b	1
2a	3
2b	26
3	13
Levels of recommendation	
2	4
3	24
4	13

(±20.7), with a median of 20. Eighteen studies had elements of content validity evaluation and 17 studies examined construct validity. A total of 58.3% of cadaveric studies had LoE 2b, with the rest having LoR 3. Of the animal studies, three had LoE 2a, 19 had LoE 2b, and nine were descriptive-only studies with LoR 4.

The studies described a wide variety of simulation models covering percutaneous nephrolithotomy, flexible and semi-rigid ureterenoscopy, as well as nephrectomy simulation models.

Laparoscopic surgery

Eight studies were identified for the simulation of laparoscopic procedures (Supplementary Table 4; available at *cuaj.ca*).

Nephrectomy

Molinas[44] trained 10 medical students and 10 specialists in laparoscopic nephrectomy on a live rabbit model, finding a reduction in operative time, as well as significant differences between the experienced and novice groups.

Six moderately experienced laparoscopic surgeons were trained in radical nephrectomy on a live porcine model by Cruz et al.[26] They found reduced blood loss, increased depth perception, and dexterity from the initial training session showing face and content validity.

De Win et al[56] designed a model with a porcine kidney that is connected to a pulsatile pump and participants (n=22) were instructed to dissect the renal vessels, finding construct validity.

A study by Marchini et al[43] enrolled 15 urologists in a course to learn single-incision laparoscopic total nephrectomy in a live porcine model and demonstrated face and content validity.

Pyeloplasty

Ramachandran et al[59] developed a chicken-crop and esophagus model to simulate laparoscopic pyeloplasty. Following from this study, Jiang et al[17] demonstrated the construct validity of this model with 15 participants of varied experience.

Teber et al[24] describe a one-knot pyeloplasty model using a porcine bladder with five laparoscopic surgeons finding a 21% reduction in anastomotic time after training showing construct validity.

Urethrovesical anastomosis

Four studies used chickens to simulate urethrovesical anastomosis. Yang and Bellman[18] used chicken skin folded on a catheter to simulate a bladder and urethral stump (n=8), with Laguna et al[19] using the esophago-glandular-stomach junction of chicken carcasses (n=5), and Boon et al[27] using a section of pig intestine (n=12). All models demonstrated construct B validity.

Sabbagh et al[28] evaluated a model using live anesthetised pigs with a randomized controlled trial comparing the model with a foam pad bench-top model; the group trained on the simulator outperformed the control group, also demonstrating face validity.

Endourology (Supplementary Table 5; available at *cuaj.ca*)

Urethrocystoscopy

Grimsby et al[38] describe the evaluation of a boar bladder and urethra model by two residents for cystoscopy and bladder biopsy. They found an improvement after training with the model and thus demonstrated construct A validity.

Soria et al[22] describe a live porcine module for urethrocystoscopy featuring ureteral orifices cannulation and subsequent ureteroscopy

Bowling et al[55] performed a randomized controlled trial comparing use of fresh-frozen cadavers and a bench-top model for rigid urethrocystoscopy in 29 obstetric residents and demonstrated construct B validity. Additionally, rigid and flexible urethrocystoscopy were two of the modules in the BAUS cadaveric course described by Ahmed et al.[54]

Ureterorenoscopy (URS)

Twenety fully qualified urologists were trained in flexible ureteroscopy by Hu et al[23] using in vitro porcine kidneys and ureters. They found a 39% improvement in average operative time, as well as improvement on a global rating scale. Additionally, the authors found that a learning curve was established, plateauing at six training sessions.

Sixteen first-year medical students trained on a bench-top model or the UROMentor virtual reality (VR) simulator in a study by Chou et al,[57] then later independently performed URS on an ex-vivo porcine kidney/ureter model. Both groups performed equally well, proving the concurrent validity of the animal model.

Ogan et al[58] evaluated 16 medical students and 16 residents on a VR model and then followed it by a diagnostic ureteroscopy on a cadaveric model. They found close correlation between VR and cadaveric performance in students but not in residents. Cadaveric simulation showed construct B validity due to its ability to distinguish between training levels.

Mains et al[51] designed a course using Thiel-embalmed cadavers to train flexible ureterenoscopy. Five urological trainees and three faculty members demonstrated face and content validity with high level of satisfaction with the realism and quality of the tissue, however, noted the difficulties in variations of anatomy between cadavers, including tortuous ureters.

Rai et al[52] also used Thiel-embalmed cadavers and demonstrated face validity for the technique, especially with regards to anatomical and haptic resemblance. However, it was noted that endoscopic resection safety was difficult to assess fully, as there is a lack of adequate perfusion limits training in the prevention of vascular injuries.

Soria et al[42] performed a study with 40 participants comparing a bench-top model for URS with laser lithotripsy and stone removal on an ex-vivo porcine model followed by live porcine model and demonstrated face, content, and construct validity.

Huri et al[48] used both fresh-frozen and soft embalmed cadavers for training in flexible ureteroscopy in 12 inexperienced urologists, demonstrating a 50.6% improvement in mean operative time with no intraoperative injuries, as well as feasibility for re-use in further sessions.

Percutaneous nephrolithotomy (PCNL)

Mishra et al[36] compared 24 experts performing a percutaneous renal puncture in a live porcine model under C-arm guidance and a VR PERC Mentor (Simbionix, Lod, Israel). They demonstrated construct validity by finding superior realism and usefulness ratings in the animal model.

Earp[30] produced a PERC model using an ex-vivo porcine kidney and a plastic catheter fixed to 3 cm thick foam to simulate the retroperitoneal tissue. This model was found to be useful, as well as cheap and able to be re-used; however, it was not possible to use ultrasound guidance using this model.

Hammond et al[32] used a model where a porcine kidney with an artificial stone was placed inside a chicken carcass to simulate the layers of human posterior tissue. They demonstrated face validity particularly with regards to percutaneous renal access.

Zhang et al[35] used porcine kidneys wrapped in a full-thickness skin flap with 42 urologists and assessed face validity finding 85.7% rating it "helpful" or '"very helpful."

Hacker et al[31] designed a model modified from that of Hammond[32] using a porcine kidney, a chicken carcass, and artificial stones with the addition of a layer of ultrasound gel surrounding the kidney to enable more effective ultrasound monitoring.

Strohmaier and Giese[34] developed a model using a porcine kidney embedded in silicon and filled with stone and demonstrating high ratings for haptic feedback and realism of tissue. This model was later improved in a followup study[33] by embedding the model in porcine thoracic/abdominal wall tissue to simulate retroperitoneal tissue in humans.

Jagtap[37] compared a VR PCNL model to simulation in live, anesthetised pigs and found the live porcine model to be superior in realism (4.44/5 vs 2.75) with superior usefulness as an assessment tool (4.68 vs 2.75), however, noted that the VR model enabled repeated use and was easier to set up.

Jutzi et al,[25,29] used ex-vivo porcine kidneys placed between two full-thickness skin lobes in a laparoscopic trainer with an adjustable plate enabling simulation of prone, upright or supine patient positioning. All participants rating the model useful for training PCNL.

Robot-assisted surgery

Seven studies were identified for robot-assisted procedures (Supplementary Table 6; available at *cuaj.ca*).

Nephrectomy

Hung et al[20] described a model for robot-assisted partial nephrectomy using porcine kidney and a styrofoam ball to a mimic renal tumor in the da Vinci Skills Simulator (dVSS; Intuitive Surgical, Sunnyvale, CA, U.S.), a simulator version of the most commonly used surgical robot. They established face, content, and construct validity in 46 participants, with 28% being experts. A followup study established concurrent and predictive validity in 24 participants.[21]

Renal transplantation

Khanna and Horgan[39] developed a model for robot assisted ex-vivo kidney transplantation using porcine kidneys and the dVSS focusing on the skills for venous and arterial anastomoses. The model was assessed by a single specialist robotic surgeon and showed improvement in time taken after repeated training with the dVSS, as well as reduced leak rates and increase in surgical finesse.

Tiong et al[41] used a live porcine model for robot-assisted kidney autotransplantation with a primary outcome of arterial anastomotic time for intermediate transplant surgeons with prior robotic experience, establishing face and content validity. In addition, they used intraoperative indocyanine green imaging to test perfusion of the graft.

Robot-assisted radical prostatectomy

Alemozaffar et al[40] established face, content and construct validity in 20 participants for a porcine genitourinary model for robot-assisted radical prostatectomy.

Training courses

In a study by Blaschko et al,[49] 22 residents participated in a robot-assisted surgical training course using fresh-frozen cadavers by in combination with cardiac surgery training, with face validation established.

Raison et al[50] ran a novel cadaveric training course for radical cystectomy, radical prostatectomy, extended lymph node dissection, and radical nephrectomy using fresh-frozen cadavers for 16 delegates using the dVSS finding face, content, and construct validity.

Ozcan et al[53] used cadavers as part of a surgical anatomy training course using theoretical lectures and practical dissection focussing on renal, prostatic, bladder, and penile/scrotal anatomy. Fifty urological residents undertook the course and their knowledge, as tested by a written multiple-choice examination, improved by a statistically significant 11.1%.

Open surgery (Supplementary Table 7; available at *cuaj.ca*)

Huri et al[45] introduced a uro-oncology training course for 25 participants featuring open prostatic, scrotal, and nephrectomy procedures on cadavers; on a five-point satisfaction scale, the course was rated more than 3.2/5 for all elements, theoretical and practical. The surgical anatomy sections of the course were the most highly rated.

Cabello et al[47] describe a training model for open renal transplantation using Thiel-embalmed cadavers in 28 participants. On a 10-point scale, the participants rated it 8.6/10 for utility and 8.9/10 for usefulness for daily clinical practice. However, the authors noted the lack of bleeding and the difficulties in determining the quality of vascular anastomosis.

Ahmed et al[54] developed a cadaveric simulation course with the British Association of Urological Surgeons for 81 residents and 27 faculty including core open surgery, endourology, and advanced trauma and emergency urological surgery. The procedures taught and simulated included both renal, prostate, and bladder surgery, as well as scrotal procedures such as testicular fixation and radical orchidectomy. The course demonstrated face validity, with a mean of 3/5 on a five-point Likert scale and >3/5 for content validity.

Discussion

Summary of evidence

This is the first paper to systematically review and compare the use of cadaveric tissue, animal tissue, and live animals in a wet lab simulation environment for urological surgery. Against a backdrop of restricted training time for surgical trainees in the present environment, the need for a representative, cost-effective, and realistic wet lab model is imperative,[60] and this is clearly a growing issue. It is clear from reviewing the literature that wet lab simulation is being used across a range of procedures, however, there is a clear bias towards the use of wet lab simulation for laparoscopic and endoscopic procedures. The reasons for this have not been formally elucidated, but it appears that the high level of dexterity required for successful procedures has driven innovation in training techniques, namely wet lab simulation.

Most studies are of poor quality, with only a single study demonstrating LoE 1b (a randomized controlled trial, albeit with a small size with 29 participants), and three studies demonstrated LoE 2a (randomized but not necessarily controlled, with an average of 22.7 participants per study). No study demonstrated LoR 1.

Overall, many studies were small, with a mode of 20 participants per study. This correlates with the findings of Van Nortwick et al,[14] who reviewed validity studies and found an average of 37 participants per study (median=29). A significant proportion were often descriptive-only, demonstrating no more than LoR 4. Many of the studies show potential but have not undergone comparative research.

Most studies featured face validation (72.1%), however, few demonstrated higher-level validation, with only two studies demonstrating concurrent validity and two studies on predictive validity. This is also consistent with the findings of Van Nortwick e al,[14] who found only 24% of studies they reviewed demonstrated concurrent validity and 5% predictive validity.

Most studies were in animal models, which is to be expected from the discussions of authors highlighting the superior visual and tactile realism of animal models compared to bench-top dry lab models. However, within wet lab models, the realistic anatomy and tissue feel of cadavers means that it retains its "gold standard" status in simulated training. The higher cost, poorer availability, and ethical concerns related to use of this tissue mean that it cannot be the sole method of wet lab simulation for surgical trainees. The numerous studies concerning animal models indicates the pertinence of this point.

The major point discussed in relation to cadaveric models is that animal models are cheaper and without the same ethical considerations (especially if using ex-vivo tissue models). Cadaver acquisition is beset with problems regarding culture, religion, and the necessity for organ donation, which has reduced the supply of appropriate tissue,[61] in conjunction with the increase in medical students, and subsequently, surgical trainees.

We have previously espoused a training algorithm for use in urology, suggesting trainees commence with VR models and continue onto dry-lab models, followed by animal tissue and live animal models.[54] Cadaveric samples form a later stage of training, enabling the fine-tuning of skills on the relatively scarce numbers of available cadavers. The general concordance of wet lab model usage between surgical specialties would suggest that this algorithm could be translated for use across numerous specialities, with positive effects on patient safety and learning quality.

VR models have gained traction within certain specialities over recent years, including urology. A further extension to our work could systematically review the introduction of VR models into the variety of surgical fields.

We recommend the implementation of wet lab training methods from the earliest stages of surgical training to maximize learning within the limited time frame of formal teaching. As ex-vivo animal models are relatively affordable and have some educational value, they should be introduced early on within surgical training, progressing to in-vivo models and finally to cadaveric tissue.

Limitations

The studies exhibited significant heterogeneity and could not be used to perform a quantitative pooled meta-analysis. Additionally, many studies were excluded for being based on conference abstracts with insufficient information, in addition to other grey literature potentially being excluded contributing to bias.

Conclusions

Simulation in surgical education is becoming more prevalent in the literature, with the value of wet lab simulation in early stages of training clearly demonstrated and cadaveric simulation for more advanced procedures. There is currently a focus on animal rather than cadaveric simulation, possibly due to cost and ethical considerations. However, new techniques in embalming, such as the Thiel method, are improving the utility of cadaveric simulation. Studies are also predominately of a low LoE with higher LoE, especially randomized controlled studies, needed to determine the most effective method of simulation.

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This paper has been peer-reviewed

References

1. McDougall EM. Validation of surgical simulators. *J Endourol* 2007;21:244-7. https://doi.org/10.1089/end.2007.9985
2. Coxon JP, Pattison SH, Parks JW, et al. Reducing human error in urology: Lessons from aviation. *BJU Int* 2003;91:1-3. https://doi.org/10.1046/j.1464-410X.2003.04003.x
3. McGreevy JM. The aviation paradigm and surgical education. *J Am Coll Surg* 2005;201:110-7. https://doi.org/10.1016/j.jamcollsurg.2005.02.024
4. Torkington J, Smith SG, Rees BI, et al. Skill transfer from virtual reality to a real laparoscopic task. *Surg Endosc* 2001;15:1076-9. https://doi.org/10.1007/s004640000233
5. Andreatta PB, Woodrum DT, Birkmeyer JD, et al. Laparoscopic skills are improved with lapmentor™ training: Results of a randomized, double-blinded study. *Ann Surg* 2006;243:854-60. https://doi.org/10.1097/01.sla.0000219641.79092.e5
6. Sedlack RE, Kolars JC. Computer simulator training enhances the competency of gastroenterology fellows at colonoscopy: Results of a pilot study. *Am J Gastroenterol* 2004;99:33-7. https://doi.org/10.1111/j.1572-0241.2004.04007.x
7. Wignall GR, Denstedt JD, Preminger GM, et al. Surgical simulation: A urological perspective. *J Urol* 2008;179:1690-9. https://doi.org/10.1016/j.juro.2008.01.014
8. Aydin A, Raison N, Khan MS, et al. Simulation-based training and assessment in urological surgery. *Nat Rev Urol* 2016;13:503-19. https://doi.org/10.1038/nrurol.2016.147
9. Aydin A, Shafi AM, Shamim Khan M, et al. Current status of simulation and training models in urological surgery: A systematic review. *J Urol* 2016;196:312-20. https://doi.org/10.1016/j.juro.2016.01.131
10. Brunckhorst O, Aydin A, Abboudi H, et al. Simulation-based ureteroscopy training: A systematic review. *J Surg Educ* 2015;72:135-43. https://doi.org/10.1016/j.jsurg.2014.07.003
11. Morgan M, Aydin A, Salih A, et al. Current status of simulation-based training tools in orthopedic surgery: A systematic review. *J Surg Educ* 2017;74:698-716. https://doi.org/10.1016/j.jsurg.2017.01.005
12. Musbahi O, Aydin A, Al Omran Y, et al. Current status of simulation in otolaryngology: A systematic review. *J Surg Educ* 2017;74:203-15. https://doi.org/10.1016/j.jsurg.2016.09.007
13. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med* 2009;6:e1000097. https://doi.org/10.1371/journal.pmed.1000097
14. Van Nortwick SS, Lendvay TS, Jensen AR, et al. Methodologies for establishing validity in surgical simulation studies. *Surgery* 2010;147:622-30. https://doi.org/10.1016/j.surg.2009.10.068
15. Tay C, Khajuria A, Gupte C. Simulation training: A systematic review of simulation in arthroscopy and proposal of a new competency-based training framework. *Int J Surg* 2014;12:626-33. https://doi.org/10.1016/j.ijsu.2014.04.005
16. Carter FJ, Schijven MP, Aggarwal R, et al. Consensus guidelines for validation of virtual reality surgical simulators. *Surg Endosc* 2005;19:1523-32. https://doi.org/10.1007/s00464-005-0384-2
17. Jiang C, Liu M, Chen J, et al. Construct validity of the chicken crop model in the simulation of laparoscopic pyeloplasty. *J Endourol* 2013;27:1032-6. https://doi.org/10.1089/end.2013.0085
18. Yang RM, Bellman GC. Laparoscopic urethrovesical anastomosis: A model to assess surgical competency. *J Endourol* 2006;20:679-82. https://doi.org/10.1089/end.2006.20.679
19. Laguna MP, Arce-Alcazar A, Mochtar CA, et al. Construct validity of the chicken model in the simulation of laparoscopic radical prostatectomy suture. *J Endourol* 2006;20:69-73. https://doi.org/10.1089/end.2006.20.69

20. Hung AJ, Ng CK, Patil MB, et al. Validation of a novel robotic-assisted partial nephrectomy surgical training model. *BJU Int* 2012;110:870-4. https://doi.org/10.1111/j.1464-410X.2012.10953.x
21. Hung AJ, Patil MB, Zehnder P, et al. Concurrent and predictive validation of a novel robotic surgery simulator: A prospective, randomized study. *J Urol* 2012;187:630-7. https://doi.org/10.1016/j.juro.2011.09.154
22. Soria F, Morcillo E, Serrano A, et al. Development and validation of a novel skills training model for retrograde intrarenal surgery. *J Endourol* 2015;29:1276-81. https://doi.org/10.1089/end.2015.0421
23. Hu D, Liu T, Wang X. Flexible ureteroscopy training for surgeons using isolated porcine kidneys in vitro. *BMC Urol* 2015;15:23. https://doi.org/10.1186/s12894-015-0067-9
24. Teber D, Guven S, Yaycioglu O, et al. Single-knot running suture anastomosis (one-knot pyeloplasty) for laparoscopic dismembered pyeloplasty: Training model on a porcine bladder and clinical results. *Int Urol Nephrol* 2010;42:609-14. https://doi.org/10.1007/s11255-009-9668-0
25. Jutzi S, Imkamp F, Kuczyk MA, et al. 656 improved porcine ex-vivo organ model for percutaneous renal surgery (sandwich-model) using a laparoscopy-training-box (situs box). *Eur Urol Suppl* 2013;12:e656. https://doi.org/10.1016/S1569-9056(13)61138-0
26. Cruz JA, Passerotti CC, Frati RM, et al. Surgical performance during laparoscopic radical nephrectomy is improved with training in a porcine model. *J Endourol* 2012;26:278-82. https://doi.org/10.1089/end.2011.0367
27. Boon JR, Salas N, Avila D, et al. Construct validity of the pig intestine model in the simulation of laparoscopic urethrovesical anastomosis: Tools for objective evaluation. *J Endourol* 2008;22:2713-6. https://doi.org/10.1089/end.2008.0058
28. Sabbagh R, Chatterjee S, Chawla A, et al. Transfer of laparoscopic radical prostatectomy skills from bench model to animal model: A prospective, single-blind, randomized, controlled study. *J Urol* 2012;187:1861-6. https://doi.org/10.1016/j.juro.2011.12.050
29. Jutzi S, Imkamp F, Kuczyk MA, et al. New ex vivo organ model for percutaneous renal surgery using a laparoendoscopic training box: The sandwich model. *World J Urol* 2014;32:783-9. https://doi.org/10.1007/s00345-013-1151-y
30. Earp PP. Percutaneous renal surgery: New model for learning and training. *Int Braz J Urol* 2003;29:151-4. https://doi.org/10.1590/S1677-55382003000200011
31. Hacker A, Wendt-Nordahl G, Honeck P, et al. A biological model to teach percutaneous nephrolithotomy technique with ultrasound- and fluoroscopy-guided access. *J Endourol* 2007;21:545-50. https://doi.org/10.1089/end.2006.0327
32. Hammond L, Ketchum J, Schwartz BF. A new approach to urology training: A laboratory model for percutaneous nephrolithotomy. *J Urol* 2004;172:1950-2. https://doi.org/10.1097/01.ju.0000140279.15186.20
33. Strohmaier WL, Giese A. Improved ex vivo training model for percutaneous renal surgery. *Urol Res* 2009;37:107-10. https://doi.org/10.1007/s00240-009-0180-x
34. Strohmaier WL, Giese A. Ex vivo training model for percutaneous renal surgery. *Urol Res* 2005;33:191-3. https://doi.org/10.1007/s00240-005-0478-2
35. Zhang Y, Ou TW, Jia JG, et al. Novel biologic model for percutaneous renal surgery learning and training in the laboratory. *Urology* 2008;72:513-6. https://doi.org/10.1016/j.urology.2008.05.016
36. Mishra S, Kurien A, Ganpule A, et al. Surgical skills lab for percutaneous renal access training: Content validation comparison between live porcine and simulation model. *J Endourol* 2009;23:A212.
37. Jagtap J. Surgical skills lab for percutaneous renal access training: Content validation comparison between live porcine and VR simulation model. *J Urol* 2010;183:e515. https://doi.org/10.1016/j.juro.2010.02.939
38. Grimsby GM, Andrews PE, Castle EP, et al. Urologic surgical simulation: An endoscopic bladder model. *Simul Healthc* 2011;6:352-5. https://doi.org/10.1097/SIH.0b013e3182211096
39. Khanna A, Horgan S. A laboratory training and evaluation technique for robot assisted ex vivo kidney transplantation. *Int J Med Robot* 2011;7:118-22. https://doi.org/10.1002/rcs.379
40. Alemozaffar M, Narayanan R, Percy AA, et al. Validation of a novel, tissue-based simulator for robot-assisted radical prostatectomy. *J Endourol* 2014;28:995-1000. https://doi.org/10.1089/end.2014.0041
41. Tiong HY, Goh B, Tan L, et al. Robotic assisted kidney auto-transplantation in a porcine skill training model. *Eur Urol Suppl* 2017;16:e2053. https://doi.org/10.1016/S1569-9056(17)31230-7
42. Soria F, Morcillo E, Sanz JL, et al. Description and validation of realistic and structured endourology training model. *Am J Clin Exp Urol* 2014;2:258-65.
43. Marchini GS, Fioravanti ID, Jr., Horta LV, et al. Specific training for less surgery results from a prospective study in the animal model. *Int Braz J Urol* 2016;42:90-5. https://doi.org/10.1590/S1677-5538.IBJU.2014.0658
44. Molinas CR. The rabbit nephrectomy model for training in laparoscopic surgery. *Hum Reprod* 2004;19:185-90. https://doi.org/10.1093/humrep/deh025
45. Huri E, Acar C, Binbay M, et al. Cadaveric urooncologic anatomic dissection course: A novel training method in surgical practice. *J Endourol* 2010;24:A63.
46. Page T. The use of fresh frozen cadavers for the teaching of holmium laser enucleation of prostate, thulium prostate resection and high power KTP laser vaporisation. *BJU Int* 2015;115:16-76.
47. Cabello R, Gonzalez C, Quicios C, et al. An experimental model for training in renal transplantation surgery with human cadavers preserved using W. Thiel's embalming technique. *J Surg Educ* 2015;72:192-7. https://doi.org/10.1016/j.jsurg.2014.10.002
48. Huri E, Skolarikos A, Tatar I, et al. Simulation of RIRS in soft cadavers: A novel training model by the Cadaveric Research on Endourology Training (CRET) study group. *World J Urol* 2016;34:741-6. https://doi.org/10.1007/s00345-015-1676-3
49. Blaschko SD, Brooks HM, Dhuy SM, et al. Coordinated multiple cadaver use for minimally invasive surgical training. *J Soc Laparoendoscop Surg* 2007;11:403-7.
50. Raison N, Ahmed K, Aydin A, et al. Novel cadaveric robotic training programme. *J Endourol* 2015;29:A74.
51. Mains E, Tang B, Golabek T, et al. Ureterorenoscopy training on cadavers embalmed by thiel's method: Simulation or a further step towards reality? Initial report. *Cent European J Urol* 2017;70:81-7.
52. Rai BP, Tang B, Healy S, et al. Face validity study of cadavers using Thiel method of embalming for endoscopic surgery in urology. *Urology* 2014;84:S137.
53. Ozcan S, Huri E, Tatar I, et al. Impact of cadaveric surgical anatomy training on urology residents' knowledge: A preliminary study. *Turk J Urol* 2015;41:83-7. https://doi.org/10.5152/tud.2015.87422
54. Ahmed K, Aydin A, Dasgupta P, et al. A novel cadaveric simulation program in urology. *J Surg Educ* 2015;72:556-65. https://doi.org/10.1016/j.jsurg.2015.01.005
55. Bowling CB, Greer WJ, Bryant SA, et al. Testing and validation of a low-cost cystoscopy teaching model: A randomized controlled trial. *Obstet Gynecol* 2010;116:85-91. https://doi.org/10.1097/AOG.0b013e3181e45a52
56. De Win G, Van Bruwaene S, Allen C, et al. Design and implementation of a proficiency-based, structured endoscopy course for medical students applying for a surgical specialty. *Adv Med Educ Pract* 2013;4:103-15. https://doi.org/10.2147/AMEP.S41681
57. Chou DS, Abdelshehid C, Clayman RV, et al. Comparison of results of virtual-reality simulator and training model for basic ureteroscopy training. *J Endourol* 2006;20:266-71. https://doi.org/10.1089/end.2006.20.266
58. Ogan K, Jacomides L, Shulman MJ, et al. Virtual ureteroscopy predicts ureteroscopic proficiency of medical students on a cadaver. *J Urol* 2004;172:667-71. https://doi.org/10.1097/01.ju.0000131631.60022.d9
59. Ramachandran A, Kurien A, Patil P, et al. A novel training model for laparoscopic pyeloplasty using chicken crop. *J Endourol* 2008;22:725-8. https://doi.org/10.1089/end.2007.0380
60. Khan R, Aydin A, Khan MS, et al. Simulation-based training for prostate surgery. *BJU Int* 2015;116:665-74. https://doi.org/10.1111/bju.12721
61. Krahenbuhl SM, Cvancara P, Stieglitz T, et al. Return of the cadaver: Key role of anatomic dissection for plastic surgery resident training. *Medicine (Baltimore)* 2017;96:e7528. https://doi.org/10.1097/MD.0000000000007528

Correspondence: Dr. Abdullatif Aydin, MRC Centre for Transplantation, Guy's Hospital, King's College London, London, United Kingdom; abdullatif.aydin@kcl.ac.uk