REVIEW

Chicken and porcine models for training in laparoscopy and robotics

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Purpose of review
To review the most recent literature and contemporary role of the use of porcine and chicken models in laparoscopic and robotic simulation exercises, for training and skill assessment.

Recent findings
There are multiple types of the simulators which include mechanical, virtual reality, hybrid simulators and animal models. The recent literature has seen insurgence of several of such simulators, specifically the animate ones comprising porcine and chicken models. The different training models reported have evolved from generalized and simpler, to a more task dedicated and complex versions. Unlike in the past, the recent publications include analysis of these models incorporating different measures of validity assessment.

Summary
On account of the natural tissue properties inherent to these porcine and chicken models, they are proving to be instrumental in acquisition of higher surgical skills such as dissection, suturing and use of energy sources, all of which are required in real-time clinical scenarios be it laparoscopy or robotic-assisted procedures. In-vivo training in the animal model continues to be, perhaps, the most sophisticated training method before resorting to real-time surgery.

Keywords
chicken, laparoscopy, porcine, robotic, simulator

INTRODUCTION

Conventional open surgery relied on the concept of Halstedian principle – see one, do one, teach one – wherein the trainee imbibed learning by observing his mentor and replicating the same [1,2]. Laparoscopy has brought with it a set of concerns in the form of hand–eye coordination, depth perception, the fulcrum effect, working with two-dimensional system, lack of haptic feedback, physiological tremor and limited degrees of freedom. In an attempt to overcome these limitations, came the application of robotic surgical platforms. The emergence of these novel minimally invasive techniques led to the realization of the requirement of intermediaries to shorten the learning curve. These were the simulators. Simulation can be defined as a model or exercise or device that enables a trainee to reproduce under test conditions, phenomena that are likely to occur in actual performance [3].

There are multiple types of the simulator which include mechanical, virtual reality, hybrid simulators and animal models (including chicken and porcine). These could further be considered to be low or high fidelity, depending on the degree of realism they provide and achieve. Although it is a well accepted fact in surgical arena that the skills and outcomes improve with experience, nevertheless the bottom line remains that the patient suffers minimal or ideally said, no harm [4]. Herein comes the role of surgical simulators or models, whereby the trainees and novices could undergo practice sessions and adequate dedicated hours, before embarking on the real-time scenario. The realization of importance of simulators has been accepted by trainers and trainees alike [5], so much so that many authors [6–8] advocate it to be included as a part of routine urology curriculum. The recent literature has seen insurgence of several of such simulators, specifically the animate ones comprising porcine and chicken models. This article intends to review the most recent literature on the use of porcine and chicken models in present day laparoscopic and

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KEY POINTS

- The porcine and chicken models are now being increasingly used for higher skill acquisition required for complex urological procedures.
- The evaluation of these models in recent literature includes subjective as well as objective (validity) assessment.
- In-vivo training on these models continues to be perhaps the most sophisticated training method before resorting to real-time surgery.

robotic simulation exercises, for training and skill assessment. A literature search was made in *PubMed* database using the following keywords 'porcine, chicken, laparoscopy, robotic, simulator'.

REVIEW OF LITERATURE

Ever since Rassweiler *et al.* [9] showed the importance of preclinical training on pelvic trainer and animal studies before progressing to real-time laparoscopic nephrectomy in their step by step training model, there has been an increase in number of training models being utilized and reported in literature. Commonly these training models involve the use of either porcine or chicken models, be it the learning of ablative or reconstructive procedures. The early years of evolution of laparoscopy involved using basic tasks and models for learning primarily ablative techniques such as nephrectomy [9–12]. However, the gaining momentum in minimally invasive surgeries, paved way for learning complex surgical skills with multiple models being developed for partial nephrectomy, pyeloplasty, single port surgery, natural orifice transluminal endoscopic surgery, and lately orthotopic renal transplants.

PYELOPLASTY

Ever since the performance of first cases of laparoscopic pyeloplasty by Schuessler *et al.* [13] in 1993, the technique gained worldwide acceptance owing to the promising outcomes and the obvious associated benefits of laparoscopy. However, the technical complexity of suturing, meticulous tailoring of renal pelvis-ureter and antegrade stent placement culminated in a steep learning curve, thereby limiting the widespread applicability of the technique. In an attempt to address this, several training models and simulators utilizing porcine ureteropelvic junction, small intestine, ureter; and bladder and urethra were proposed by McDougall *et al.* [14], Fu *et al.* [15], Yang *et al.* [16] and Teber *et al.* [17]. respectively. Although some of the models had proven validity but concern seems to be the tissue characteristics. The most promising animate model in recent literature appears to be the chicken crop model by Ramachandran *et al.* [18▪▪], the construct validity of which was recently confirmed by Chun *et al.* [19]. This model comprising the crop and oesophagus, appears to have similar tissue characteristics with the human renal pelvis and ureter in terms of thickness, texture, appearance, as well as the presence of surrounding tissue, which needs to be dissected, so as to give a close resemblance to the real-time scenario as is required in humans. The lower segment of the oesophagus is ligated, the crop cleaned and filled with water to simulate the dilated human renal pelvis and the upper segment of oesophagus being used to simulate the human ureter. After positioning in a pelvitrainer a laparoscopic dismembered Anderson–Hynes pyeloplasty is performed. After completion of anastomosis, the integrity is checked by instillation of fluid to detect leakage.

In the study by Chun *et al.* [19], the quality of the anastomosis was assessed by an independent observer, who was blinded to the individuals who were divided into three groups depending on the experience. The analysis showed significantly short completion times (33.80 min) and significantly better quality scores (average quality score = 9.0) by the experts as compared with the other groups, thereby exhibiting good construct validity.

Another model for learning laparoscopic pyeloplasty was recently reported by Díaz-Güemes Martín-Portugués *et al.* [20]. Their study aim was to assess the most adequate surgical approach for the creation of ureteropelvic junction obstruction in animal model and to validate their model for laparoscopic pyeloplasty training among urologists. They reported clipping the swine left ureteropelvic junction to produce obstruction. A total of 36 large white pigs were used and were randomized to laparoscopic conventional surgery or single port surgery and each group being further divided into a transperitoneal or retroperitoneal approach. After a period of 10 days, all animals underwent an Anderson–Hynes pyeloplasty carried out by nine urologists, who subsequently assessed the model by means of a subjective validation questionnaire. The authors reported the total operative time as being significantly more in retroperitoneal single port group ($P = 0.001$) and tenderness being significantly more in both retroperitoneal approaches ($P = 0.0001$). The rating of their model for training had high or very high scores, all above 4 on a 1–5 point Likert scale. The model created by retroperitoneal single port approach presented the best score in the subjective evaluation, whereas, as a whole, a transabdominal laparoscopic approach was preferred.

NEPHRECTOMY AND PARTIAL NEPHRECTOMY

Chiu *et al.* [21] used 15 male pigs for performing the nephrectomy and successfully could complete the procedure in 14. However, it was soon realized that a number of refinements were required for standardization of the procedure. Rassweiler *et al.* [9,22] defined a step by step approach for nephrectomy, in terms of creating pneumoperitoneum, port and trocar placement, techniques of clip application and organ retrieval on porcine model before it could be extrapolated to human settings.

To further explore the potential application of laparoscopy in urology, McDougall *et al.* [23] performed the first feasibility study of partial nephrectomy in porcine model. The authors highlighted the key elements of the procedure being control of the renal hilum, transient parenchymal compression with a plastic cable and use of the argon beam coagulator to achieve haemostasis.

With these pioneering studies serving as a benchmark, the literature over a period of years, became bundled with a number of animal models, both live and cadaveric, being used for performing nephrectomy and partial nephrectomy. The latter in particular has sparked huge interest, owing to the technical complexities involved and it being considered as the gold standard for small renal masses and T1 tumours as well as for the testing of new approaches to the haemostatic control of the parenchyma or to the closure of collecting system [24–29].

The usual theme is utilization of either a live or a cadaveric porcine model with the kidney being perfused and the trainee practicing the necessary manoeuvre and steps as are required in a real-time clinical situation.

With the inception of robotic surgical platforms in urologic practice, there came a need for dedicated simulator and model so that the present day surgeon could keep up with this innovative technology. Although it is believed that robotic surgery may allow a urologist without extensive laparoscopic experience a shorter learning curve to perform partial nephrectomy compared with its laparoscopic counterpart [30], nevertheless, adequate training remains paramount. Partial nephrectomy remains one of the urological surgeries ideally suited for robotic approach owing to the technical complexity of its laparoscopic counterpart, as well as being associated with all the comprehensive advantages of a minimally invasive surgery.

Although a number of training models have been proposed in the past for laparoscopic partial nephrectomy, recently, a novel surgical training model for robotic-assisted partial nephrectomy utilizing porcine model was proposed and validated by Hung *et al.* [31]. The study participants were divided into three groups, depending on the number of robotic console cases completed: experts (>100), intermediates (1–100) and novices. For tumour simulation, an ex-vivo porcine kidney embedded with Styrofoam ball was used and each of the participants performed a partial nephrectomy using the da Vinci Si Surgical System (Intuitive Surgical, Sunnyvale, California, USA). Participants were anonymously judged by three expert reviewers using Global Operative Assessment of Laparoscopic Skills tool [32]. Performance between groups was compared and a poststudy questionnaire assessing training model realism and utility was used. On analysis of results, expert surgeons rated the training model as ‘very realistic’ (median visual analogue score of 7/10) establishing the face validity; and as ‘extremely useful’ training tool for residents (median score 9/10) and fellows (9/10), thereby establishing the content validity, although less so for experienced robotic surgeons (5/10). Experts outscored novices on overall performance ($P = 0.0002$) as well as individual metrics. Likewise, experts also outperformed intermediates in most metrics ($P < 0.05$).

Recently, in an interesting study by Hung *et al.* [33■■], the authors made a comparative assessment of three standardized validated robotic surgery training methods: structured inanimate tasks, virtual reality exercises on the da Vinci Skills Simulator and *in vivo* live porcine model. In the latter, the objective of the task was to suture a loop of bowel to the peritoneum overlying the kidney secured by a square knot, performance of which was independently evaluated by expert robotic surgeons using the six metrics of global evaluative assessment of robotic skills [34■■]. Each of the three training methods were assessed for their construct validity and a novel concept of cross-method validity, where the relative performance of each method is compared, was evaluated.

Robotic surgical skills were prospectively assessed in 49 participating surgeons who were grouped as novice/trainee – previous experience less than 30 cases ($n = 38$) and experts with previous experience at least 30 cases ($n = 11$). On analysis it was found that experts consistently outperformed residents with all three methods ($P < 0.001$), thereby confirming the construct validity. In terms of cross-method validity, the overall performance of inanimate tasks significantly correlated with virtual reality robotic performance ($r = -0.7$, $P < 0.001$) and in-vivo robotic performance based on global evaluative assessment of robotic skills ($r = -0.8$, $P < 0.0001$). Virtual reality performance and in-vivo tissue performance were also found to be strongly correlated ($r = 0.6$, $P < 0.001$). Finally, the authors concluded that the novel concept of cross-method validity, may provide a method of evaluating the relative value of various forms of skills education and assessment.

LAPAROENDOSCOPIC SINGLE-SITE SURGERY

Of late, there has been an enthusiasm in laparoendoscopic single-site surgery (LESS) owing to the single port entry and limiting the access through the umbilicus, thereby being even less invasive than conventional multiport laparoscopy. However, there are concerns regarding the issue of frequent clashing of instruments, loss of triangulation and uncomfortable working angle of instruments. One of the means of reducing these is by limiting the number of instruments inserted through the port site. In an attempt to do the same magnetic technology has been studied and applied as magnetic anchoring and guidance system (MAGS) devices, comprising magnetic instruments or camera. These are inserted intraperitoneally through a single incision and moved by means of an external handheld magnet. These have been successfully used in both experimental and clinical scenarios and have demonstrated safety as well [35–37]. Woong *et al.* [38] recently published first of its kind, a comparative study between MAGS–LESS nephrectomy and conventional LESS nephrectomy in a porcine model in terms of surgeon-assessed ergonomic and workload demands. The authors concluded that use of the MAGS camera during LESS nephrectomy lowers the task workload for both the surgeon and camera driver when compared with conventional laparoscope use.

RENAL TRANSPLANT

As of present, laparoscopic nephrectomy has become a standard of care for live renal donors at most of the centres [39]. The past decade has seen extending the indications of laparoscopy and robot-assisted surgeries to renal transplant in heterotopic location that is the iliac fossa. However, He *et al.* [40] recently reported the first study of laparoscopic renal orthotopic transplant in pig model. Ten live female pigs were used as study models. Renal artery was anastomosed end to end to the renal artery stump and the renal vein was anastomosed end to end to the renal vein stump by 6/0 Prolene (Polypropylene Suture, Ethicon Inc., USA) sutures. The authors reported graft warm ischemia time as between 3–5 min and cold ischemia time as between 1.5–2 h. The time for renal artery anastomosis was from 25 to 35 min, whereas the time for renal vein anastomosis was from 25 to 30 min. The laparoscopic kidney transplant was successful in seven of 10 pigs, with failure of venous anastomosis in one and arterial anastomotic failure in two. The authors concluded that this training model could be used by surgeons who wish to perform human laparoscopic kidney transplant.

LAPROSCOPIC RADICAL PROSTATECTOMY

Laguna *et al.* [41] in their study utilized the chicken crop and assessed the feasibility of this model. After partial emptying of the corporal cavity of dead chickens, an 18F catheter was placed through the oesophagus to the stomach. In the pelvic trainer, a laparoscopic section of the oesophago-glandular-stomach junction and a suture between the two edges were performed in the same fashion as for a urethrovesical suture in laparoscopic radical prostatectomy [41].

Similarly, Boon *et al.* [42] in their study assessed the utility of using pigs intestine for training in urethrovesical anastomosis. They also concluded that this model has the ability to differentiate between experienced and nonexperienced operators. Further, they add that this model helps in providing an objective measure of the quality of the anastomosis [42].

CONCLUSION

In-vivo training in the animal model continues to be, perhaps, the most sophisticated training method before intraoperative clinical training. The different training models reported in literature have evolved from generalized and simpler to a more task dedicated and complex versions. Unlike in the past, the recent publications include analysis of these models incorporating different measures of validity assessment. There are authors who have highlighted the need for a consensus regarding validation methodologies [41].

On account of the natural tissue properties inherent to these porcine and chicken models, they are proving to be instrumental in acquisition of higher surgical skills such as dissection, suturing and use of energy sources, all of which are required in real-time clinical scenarios be it laparoscopy or robotic-assisted procedures.

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Conflicts of interest

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■■ of outstanding interest

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