European Association of Urology

Education

Chicken RAPS: Chicken Robot-assisted Pyeloplasty Simulation. Validation Study of a Novel Chicken Model for Wet Laboratory Training in Robot-assisted Pyeloplasty

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Article info

Abstract

Background: Since the introduction of minimally invasive surgery, the number of simulation models available for teaching new surgeons has continued to increase.
Objective: To evaluate and validate use of a model for teaching robot-assisted pyeloplasty.
Design, setting, and participants: Twenty simulated robot-assisted pyeloplasty procedures were performed by experienced ($n = 4$) and novice ($n = 16$) surgeons using a chicken crop model at two different training centers using third- and fourth-generation robotic systems.
Outcome measurements and statistical analysis: We evaluated the time needed to perform the procedure, and the sufficiency and patency of the anastomosis. Participants rated the efficiency, face validity, and possible acceptance of the model as part of a structured curriculum on a scale from 0 to 10. Statistical significance for comparison of results was set at $p < 0.05$.
Results and limitations: Robot-assisted pyeloplasty was successfully performed by 75% of the participants. The completion time was significantly higher in the novice group ($p = 0.016$). The model was deemed to be similar to the human ureteropelvic junction by the novice group. Both groups regarded the model as a useful simulation task as part of a standardized training curriculum, with mean scores of 6.5 versus 8.69 ($p = 0.046$) for face validity and 8 versus 9.25 for acceptance ($p = 0.053$) reported by the experienced versus novice group, respectively. Limitations of the study are the costs associated with the robotic system and the unequal number of participants in the groups.
Conclusions: The chicken crop model is a low-cost and reproducible simulation model for accomplishing both the resection and reconstructive steps during the learning phase for robot-assisted pyeloplasty.

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Patient summary: We assessed the use of chickens as a model for practicing a robot-assisted operation called pyeloplasty to fix narrowing of the ureter (the tube that drains urine from the kidney to the bladder) where it attaches to the kidney. This model can be used for simulation of robot-assisted pyeloplasty when training new robotic surgeons.

1. Introduction

Urological surgery has experienced a new era since the introduction of laparoscopy as a treatment option for various oncological and nononcological diseases [1]. Historically, surgeons had to learn and optimize their surgical skills directly on the patient. Nowadays, there are many teaching options for introducing instruments and techniques to novice surgeons, which allows structured and safe maturation of the skills necessary to perform minimally invasive surgery. Structured and methodical training has a positive effect on the learning curve of surgeons, as well as on operative outcomes for patients [2–4].

As a consequence of the relatively wide utilization of laparoscopy, there is great demand for training courses and for improvements in training options with realistic models that approximate the in vivo surgical situation as authentically as possible. Robotic surgical systems have advantages that include better vision, dexterity, and versatility in comparison to conventional laparoscopy, but they have their own specific learning curves. Accordingly, there is also a demand for robot-assisted laparoscopy-specific courses and teaching methods for equivalent surgical procedures.

When starting a training curriculum, trainees first undergo theoretical training with simulation models ("dry lab") to become familiar with the tools and the work environment. After achieving a sufficient level of technical competence, trainees proceed to use the skills they have acquired on tissue ("wet lab") for which either cadaveric models (human/animal) or sedated animals are used. Trainees are required to accomplish rather easy tasks first, mostly focusing on hand-eye coordination and dexterity, followed by more advanced tasks such as dissection and suturing [4].

To document relevant and measurable progression, there is an ever-increasing demand for suitable training models, which can be implemented even in the early phases of training. These may provide a steeper learning curve, optimize surgical skills, and can ultimately improve surgical and functional results [5].

One such model uses chicken esophagus and crop for simulation training of pyeloplasty for pyeloureteral stenosis in the upper urinary tract. As a reconstructive surgical step, pyeloplasty is associated with a higher level of difficulty than other surgical procedures. Moreover, in cases of re-stenosis, revision surgery is even more challenging. Such a surgical procedure is prone to suboptimal results in patients with already constrained renal function and may result in irreversible renal impairment.

All these factors have prompted the development of new accurate and effective training models. Many of these models have been used for teaching and training standard laparoscopic pyeloplasty [1,6–8]. The resection part of the procedure (from the start of the operation until resection of the stricture in the ureteropelvic junction) has been evaluated in a porcine model [9], whereas the reconstructive steps (spatulation of the ureter and renal pelvis area, anastomosis via sutures and pigtail placement) have been evaluated in various chicken models [1,8,10,11]. However, none of these training models has been evaluated for robot-assisted pyeloplasty to date.

The aim of this study was to evaluate and validate the chicken crop model for teaching robot-assisted pyeloplasty. We evaluated the acceptability of the proposed model as reported by experts and novices. We tested whether the model is appropriate for use in simulations that can effectively improve trainees' surgical skills for specific steps in robot-assisted pyeloplasty via further training, as well as perception of the model as a key part of a structured curriculum in robot-assisted surgery.

2. Materials and methods

2.1. Study groups

The overall study cohort consisted of 20 robotic surgeons consisting of two groups that differed in their level of experience. Group A (experienced) comprised four robotic surgeons with experience ranging from 120–4500 previous robotic cases. Group B (novice) comprised 16 urologists with no or minimal previous exposure to the robotic console (but varying experience in open surgery) and no previous robotic pyeloplasty cases. The participants in group B had previous exposure to the appropriate robotic simulator, providing evidence of successfully accomplishment of various tasks. Before the study, all participants in group B were able to perform tasks within the framework of multiple dry-lab training sessions. All participants provided consent to take part in this study.

The simulation study took place in two different training centers with third- and fourth-generation robotic systems (da Vinci Si, X and Xi systems; Intuitive Surgical, Sunnyvale, CA, USA).

2.2. Model

We used 20 adult hens (*Gallus gallus*) that were sacrificed and plucked before delivery to the study centers [1,11]. The simulation models were large enough and appropriate for the study (adult hens weighing >1.5 kg after sacrifice and plucking, with a stretched length of >60 cm from the head to the bottom of the feet and an esophagus of >10 cm in length). The model was prepared on the same day as the simulation for each participant. Selection of the tissue models and completion of the study were performed in accordance with the bioethical standards for animal experimentation established by the Declaration of Helsinki [12].

2.3. Model preparation

Our model preparation followed the basic principles previously published by Valero et al [1], with a few modifications. After delivery of the sacrificed and plucked hens, we dissected the neck and visualized the esophagus, crop, and trachea. After excising the trachea, the crop was carefully dissected from the surrounding tissue and the esophagus was left attached on the connecting tissue to the cervical vertebrae.

Following placement of a 12F Foley catheter into the esophagus and flushing of residual material from the crop with saline solution, we fixed the cervical vertebrae to a designated plate to immobilize the model. Owing to the delicate nature of the structures, we refrained from ligating the junction between the esophagus and the crop to avoid any malformation of the model. The chicken model was placed on a dedicated table. Because the fulcrum effect is negligible in robot-assisted surgery, we did not place the model into a pelvic trainer.

2.4. Surgical technique

The robotic set-up consisted of the main camera port (8 mm or 12 mm, depending on the robotic system) and two accessory ports for the instruments needed (8 mm), namely robotic monopolar scissors, a robotic large needle driver, and a robotic bipolar dissector. The model was arranged to imitate a left-sided transperitoneal robot-assisted pyeloplasty. One of the investigators acted as assistant for the surgeon.

The participants proceeded to the surgical field to perform an Anderson-Hynes dismembered pyeloplasty. The instruments initially used for dissection were the scissors and the dissector. The simulation (and time count) began with first incision in the area of the esophageal-crop junction, assuming the presence of an imitated stenosis of the left ureteropelvic junction (Fig. 1A). After excision of the presumed stenotic region, the surgeon proceeded to spatulation of the proximal part of the esophagus (the ureter; Fig. 1B). Following spatulation, the assistant changed the right robotic instrument to a needle driver. Two 4/0 HR17 monofilament sutures, each with a length of ∼15 cm, were handed to the surgeon. Placing the first stitch with the first suture in the lower part of the crop and thus imitating the first stitch between the ureter and the renal pelvis (Fig. 1C, D), the surgeon then proceeded to reconstruction of the dorsal part of the anastomosis in the direction from the caudal to the cranial side. The surgeon then performed ventral anastomosis using the second suture, and the anastomotic procedure was completed by tying the two separate sutures. Finally, the assistant cut the excessive suture and extracted the needles, marking the endpoint for time measurement.

2.5. Evaluation

Each surgeon had one model for a single trial. The time needed to finish the task (complete anastomosis of the simulated ureteropelvic junction) was unlimited. We evaluated the sufficiency of the anastomosis, the patency of the lumen, and the total simulation time.

The sufficiency and patency of the anastomosis were evaluated by placing a 12F Foley catheter and filling the simulated renal pelvis with 12 ml of saline. Any extravasation of saline was considered as an anastomosis leakage, otherwise the result was deemed sufficient.

The patency of the anastomosis was assessed by placing the model in an upright position after removing the catheter. This position allows saline solution to flow through the anastomosis and into an appropriate receptacle. This does not rely on a hermetic anastomosis during retrograde filling but emulates antegrade ureteral urine flow at physiological pressure. Modified flowmetry was performed by measuring the time needed for complete drainage after placing the model in the upright position.
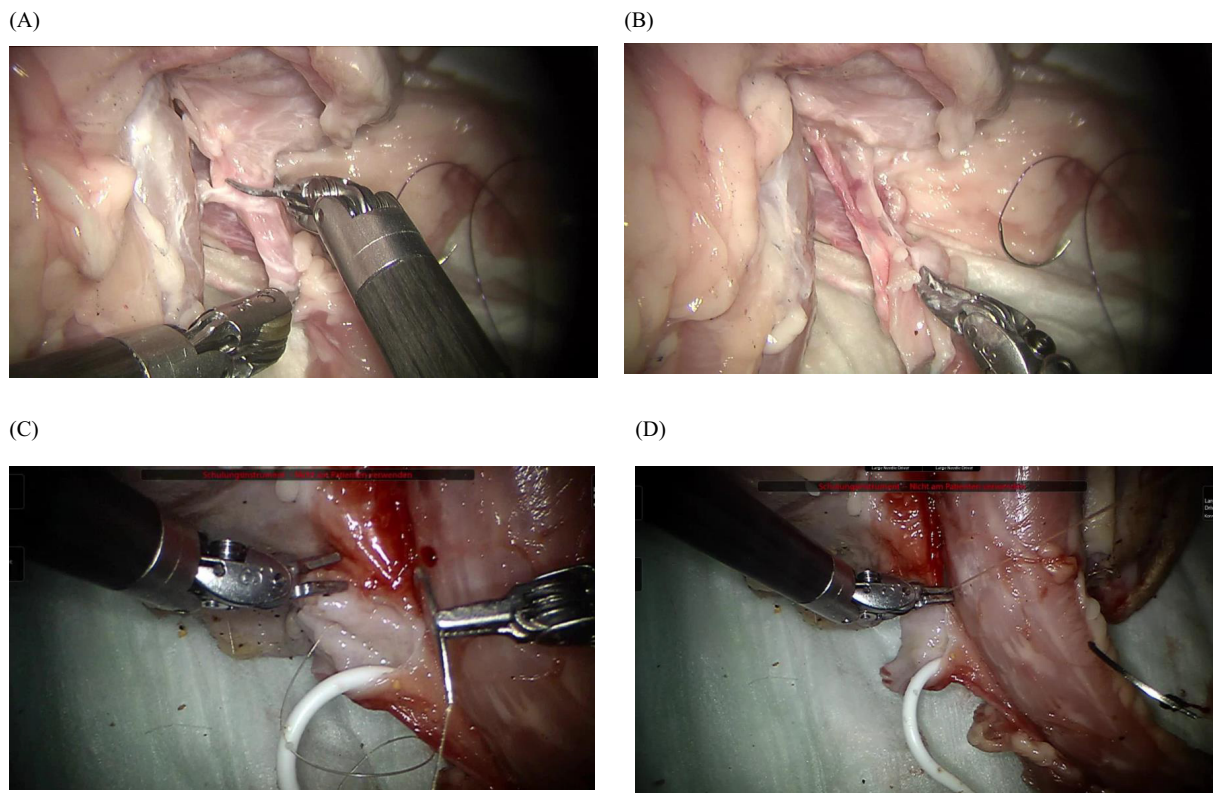
(A)

(B)

(C)

(D)

Fig. 1 – Images demonstrating the technique. (A) Incision of the area around the esophageal-crop junction, imitating a stenosis of the left-sided ureteropelvic junction. (B) Spatulation of the lateral side of the proximal part of the esophagus, imitating the left ureter. (C, D) Placement of the first suture to approximate the esophagus and the crop, imitating the left ureter and left renal pelvis, respectively.

The time needed to complete the simulated task was measured using a stopwatch, starting at incision of the junction and ending with removal of the last excess suture by the assistant.

The participants evaluated the simulation model using a 10-point numeric rating scale (where 0 denotes total disagreement and 10 denotes total agreement) for efficiency, face validity, and possible acceptability of the model as a part of a structured curriculum.

2.6. Statistical analysis

Data were collected by the investigator. Statistical analysis was performed using SPSS version 27 (IBM, Armonk, NY, USA). We calculated the average procedure time, the average saline flow rate, and the average scores for the groups as continuous variables. Results were compared using Fisher's t test. A difference was considered significant at $p < 0.05$.

3. Results

The mean time to complete the task was twice as long in the novice group in comparison to the experienced group (31:07 vs 15:28 min; $p = 0.033$). This clear difference in surgical experience between the groups proves the construct validity of our model. Intragroup variability for the time needed to complete the task also greatly differed between the group. The completion time ranged from 11:38 to 52:30 min in the novice group, and from 05:47 to 21:03 min in the experienced group.

Sufficiency analyses revealed that three-quarters (75%) of the anastomoses were watertight. By group, 13/16 (81.25%) of the novice and two out of four (50%) of the experienced surgeons achieved a sufficient anastomosis ($p = 0.102$). Appropriate patency of the anastomosis was achieved by 90% of the participants overall (Table 1). There were no clinically relevant or statistically significant differences in patency-related total flow volume (10.31 vs 9.75 ml; $p = 0.4$) and flow rate (2.5 vs 2.25 ml/s; $p = 0.4$) between the novice and experienced groups.

Participants' evaluation scores for the simulation model differed between the groups for the three metrics, with greater favorability generally reported by the novice surgeons. Specifically, the mean score for efficiency was 8.75 (range 7–10) for the novice group versus 6.75 (range 4–8) for the experienced group ($p = 0.004$). For face validity, the mean score was 8.69 (range 7–10, interquartile range [IQR] 8–9.25) versus 6.5 (range 3–8, IQR 6–8) for the experienced group ($p = 0.046$).

The mean score for acceptance, which indicates approval of the model, was 9.25 (range 7–10, IQR 9–10) for the novice group versus 8 (range 5–10, IQR 7.25–9.25) for the experienced group, but the difference was not statistically signif-

Table 2 – Mean participant scores for the simulation task by group[a]

Parameter	Experienced group	Novice group	p value
Efficiency score (range) {IQR}	6.75 (4–8) {6.25–8}	8.75 (7–10) {8–9.25}	0.004
Face validity score (range) {IQR}	6.5 (3–8) {6–8}	8.69 (7–10) {8–9.25}	0.046
Acceptance score (range) {IQR}[b]	8 (5–10) {7.25–9.25}	9.25 (7–10) {9–10}	0.053

IQR = interquartile range.
[a] Each parameter was rated by participants on a scale from 0 to 10, where 0 denotes total disagreement and 10 denotes total agreement.
[b] For the overall cohort, the median acceptance score is 9, with a mean score of 9, a range of 5–10, and an IQR of 8.75–10.

icant ($p = 0.053$; Table 2). The median acceptance score for the overall cohort was 9 (mean 9, range 5–10, IQR 8.75–10).

4. Discussion

Since the first description of laparoscopic pyeloplasty [13], there has been an increasing trend to offer patients the minimally invasive approach if there are no contraindications. However, among minimally invasive procedures in urology, those with reconstructive surgical steps are considered to be particularly technically challenging. A possible explanation is the specific technique for laparoscopic suturing, which can be quite demanding. Reconstructive procedures are associated with a non-negligible risk of intraoperative and postoperative complications and ultimately recurrence, so prolonged learning and an aptitude to achieve surgical efficiency are required [14].

Our results confirm the feasibility of this model as a simulation tool for robot-assisted pyeloplasty, whereby trainees can simulate the most crucial steps of the procedure. Our model offers future surgeons an opportunity to dissect, spatulate, and reconstruct animal tissue with an acceptably realistic sensation, so they can optimize their robotic skills before their first pyeloplasty in human patients. By demonstrating surgical competency in terms of sufficiency, patency, and flow dynamics, trainees obtain immediate feedback on functional outcomes. Moreover, this is an economical simulation model, as the cost is less than $10 per model.

Regarding sufficiency, patency and flow rate, the results for the two groups are as expected given their differing experience. The proportion of participants achieving patency was high in both groups (experienced 100% vs novice 87.5%; overall 90%), although only half of the experienced surgeons achieved sufficiency (two out of four, 50%). This is an unexpected finding in a group with experience in robot-assisted surgery. The differences in mean patency and mean flow rate were statistically nonsignificant ($p = 0.4$ for both), and the mean completion time was noticeably lower in the experienced group. The latter is highly conceivable and in line with the hypothesis that an experienced surgeon will complete the task in a shorter time.

Regarding the views of the participants on use of the model as part of the training process, its wide acceptance in the novice group is reflected by high scores for efficiency, face validity, and acceptance. Conversely, the experienced group rated the model significantly less favorably in terms

Table 1 – Results for the simulated task by group

Parameter	Experienced group	Novice group	p value
Sufficiency, n/N (%)	2/4 (50)	13/16 (81.25)	0.102
Patency, n/N (%)	4/4 (100)	14/16 (87.5)	0.045
Mean patency, ml (range)	9.75 (6–12)	0.31 (0–12)	0.4
Mean flow rate, ml/s (range)	2.5 (1–4)	2.25 (0–4)	0.4
Mean completion time, min (range)	15:28 (5:47–21:03)	31:07 (11:38–52:30)	0.036

of efficiency (p = 0.004) and face validity (p = 0.046). In the study by Valero et al, there was a reduction in the time needed to perform the task the longer the study participants were exposed to the model [1]. However, as this study included only experienced laparoscopic surgeons, we cannot compare our results because of obvious differences such as the surgical technique and the mixed level of experience of our participants. We presume that the lower rates of efficiency, face validity, and acceptance for our experienced group are because of the experience of these surgeons, as they had already performed numerous pyeloplasty procedures in their careers and they were expecting a more human-like/reality-like model. This phenomenon has already been described in previous studies [15].

Limitations of the model are personnel expenses (da Vinci surgeon), the need for a da Vinci system for training purposes, and the costs associated with maintaining a dedicated training system, materials, and instruments for the robotic system. These components are essential for the educational process. Moreover, the number of participants was not equal between the groups.

Our model does not replace conventional learning-by-doing, which remains essential in a surgeon's education. Nevertheless, outdated teaching models for learning surgical procedures in a human "in vivo" approach, as opposed to prior exposure in dry or wet lab training, are likely to be less common in the future. It is already widely accepted in the surgical community that acquirement of minimally invasive surgery skills should occur not only during the actual procedure but also in advance [1,10,16]. Moreover, the education of new surgeons should optimally follow a standardized training method to facilitate comparison and monitoring between surgeons [4]. This need to implement standardized training tasks in laparoscopy and robotics has led to the development of simulation models imitating both basic and advanced surgical techniques [6,10,17,18,20,21].

Following simple tasks to establish appropriate knowledge of how to use the instruments, trainees will proceed to more demanding tasks in sacrificed animals and then sedated models, including both resection and reconstructive steps. These simulation models can also be constructed from synthetic materials and three-dimensional printed models [19]. This option offers a possibly more ethical yet currently more expensive educational approach, avoiding confinement to animal-based models.

5. Conclusions

The use of simulation models in robot-assisted surgery before initiation of on-patient surgery improves the learning curve and has a positive impact on operative outcomes. In this study, we validated the chicken crop model for simulation of robot-assisted pyeloplasty. The model can be implemented in training programs for new robotic surgeons to achieve a superior level of training in preparation for real surgery.

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