Pilot study for low-cost model validation in laparoscopic pediatric pyeloplasty simulation

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ABSTRACT

Objective. To describe the creation of an original 3D-printed liquid latex model designed for laparoscopic pyeloplasty (LP) simulation in infants, and to assess its usefulness.

Materials and methods. A 3D model of a dilated pelvis and a ureter with ureteropelvic junction obstruction (UPJO) was designed. It was covered in liquid latex, which allowed flexible models to be achieved in order to conduct pyeloplasty in a pelvitrainer. The total price of each model was 6 euros. A nearly-experimental, non-randomized, blind study was carried out, while measuring operating times and OSATS (Objective Structured Assessment of Technical Skills) scores. Following simulation completion, a survey based on Likert scale was conducted to assess overall appearance, texture, usefulness, and probability of recommending the model for regular training.

Results. 8 pediatric surgeons spent a median of 71.5 minutes (range: 50-86), and rated the model with a median 20.1/30 (range: 17-24) OSATS score. The model received a 4.25 (range: 3-5) score in terms of overall appearance, a 4.37 (range: 3-5) score in terms of texture, a 4.5 (range: 4-5) score in terms of usefulness, and a 4.6 (range: 4-5) score in terms of probability of recommending the model for regular training.

Conclusions. Our liquid latex model for laparoscopic pyeloplasty simulation is feasible, with favorable preliminary results. Its usefulness in laparoscopic pyeloplasty training is promising.

KEY WORDS: Simulation; Pyeloplasty; Surgical training; Laparoscopy; Printing; Three-dimensional.

ESTUDIO PILOTO PARA LA VALIDACIÓN DE UN MODELO DE BAJO COSTE EN LA SIMULACIÓN DE LA PIELOPLASTIA LAPAROSCÓPICA PEDIÁTRICA

RESUMEN

Objetivos. Describir la creación de un modelo original de látex líquido diseñado para la simulación de la pieloplastia laparoscópica (PL) en lactantes, construido a partir de una impresión tridimensional (3D), y valorar su utilidad.

Material y métodos. Se diseñó un modelo 3D de una pelvis dilatada y un uréter con estenosis pieloureteral (EPU), que fue recubierto por látex líquido obteniendo modelos flexibles para realizar la pieloplastia en un pelvitrainer. El precio total de cada modelo fue de 6 euros. Se realizó un estudio cuasiexperimental, ciego y no aleatorizado, midiendo el tiempo quirúrgico y la puntuación OSATS (*Objective Structured Assessment of Technical Skills*). Tras completar la simulación, se realizó una encuesta utilizando la escala de Likert, en la cual se valoró el aspecto general, la textura, la utilidad del modelo y el grado de recomendación en el entrenamiento habitual.

Resultados. 8 cirujanos pediátricos dedicaron una mediana de 71,5 minutos (R 50-86), y puntuaron una mediana de 20,1/30 (R 17-24) en la escala OSATS. El modelo obtuvo una valoración de 4,25 (R3-5) en aspecto general, 4,37 (R3-5) en textura, 4,5 (R 4-5) en utilidad y 4,6 (R 4-5) en recomendación para incorporar al entrenamiento habitual.

Conclusiones. El uso de nuestro modelo de látex líquido para la simulación de la pielopalstia laparoscópica es factible y los resultados preliminares han sido favorables. Su utilidad como herramienta en el entrenamiento de la pieloplastia laparoscópica es prometedora.

PALABRAS CLAVE: Simulación; Pieloplastia; Entrenamiento quirúrgico; Laparoscopia; Impresión; Modelo 3D.

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INTRODUCTION AND OBJECTIVE

Dismembered pyeloplasty remains the gold standard technique in the treatment of ureteropelvic junction obstruction. The laparoscopic approach allows for less postoperative pain, shorter hospital stay, quicker resumption of daily activity, and better cosmetic results[1-3]. Technical difficulty and long operating times are the main limiting factors, especially when considering these children have smaller operating fields and more delicate tissues. Smaller surgical instruments and materials as compared to adult patients also contribute to this[4].

Laparoscopic pyeloplasty (LP) training usually takes place in the form of surgical assistance in regular clinical

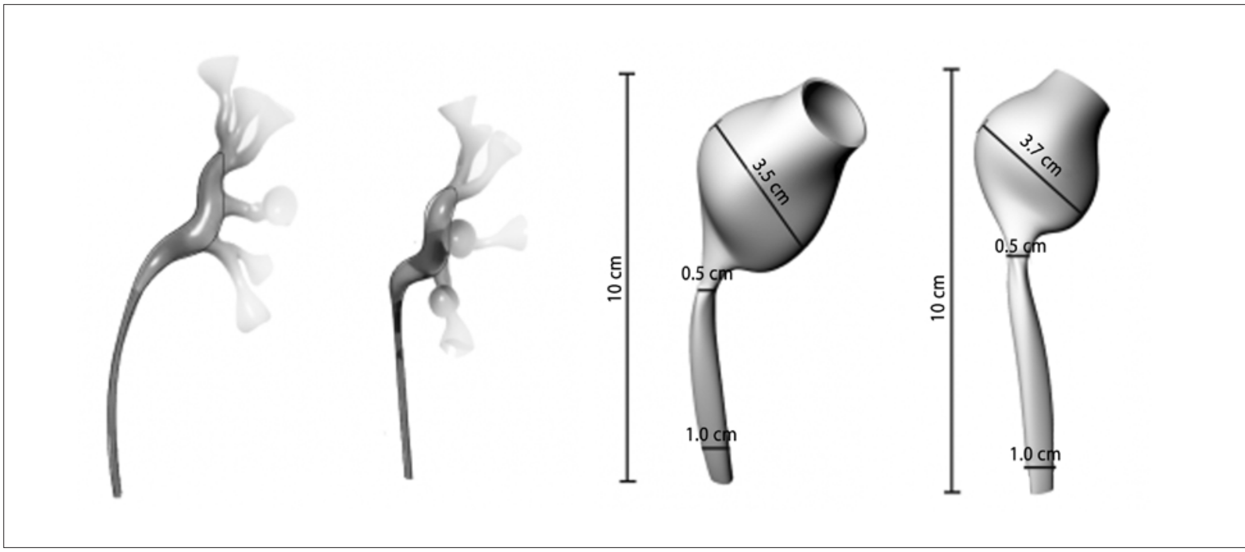

Figure 1. 3D design.

practice. Given the low incidence of UPJO, 1-5 laparoscopic pyeloplasties are carried out at each healthcare facility annually[5]. In addition, the offer of pediatric laparoscopic surgery training courses, which are mostly based on animal models and virtual simulation, is scarce and expensive. A reproducible, low-cost model that accurately simulates the key steps of the procedure and pediatric patients' texture and size will allow for easier training, shorter operating times, and better results in real patients.

3D printing allows human anatomy to be reproduced in detail and to be associated with specific pathologies prior to surgery. Its usefulness in surgical training has been demonstrated in various studies[6].

The objective of this work was to describe the creation of an original 3D printed liquid latex model for laparoscopic pyeloplasty simulation in infants, and to make an initial assessment of it in terms of usefulness.

Figura 2. 3D printing.

MATERIALS AND METHODS

Model design

A 3D design of a dilated pelvis with ureteropelvic junction obstruction and a normal-sized ureter was carried out. A normal pelvis and a normal ureter – anatomically speaking – were exported from the 3D Anatomy Learning free application. Based on the usual dimensions of dilatation in infants with UPJO, the anteroposterior diameter of the pelvis was increased to 3.5 cm, and the diameter of the ureteropelvic junction was reduced to 0.5 cm. The rest of the ureter was 1 cm in diameter, and the model's wall was initially 5 mm thick (Figures 1 and 2).

The mold was printed using a fused deposition modeling 3D printer. From the rigid mold, liquid latex models were created. They were made of Pébéo Gédé, which consists of 1.4 cis-polyisoprene and natural elastic hydrocarbon from the *Hevea brasiliensis* tree. This product allows for the creation of flexible products which are elastic following stretching, not deformed by heat, not broken by cold, and not sticky. The mold was covered in vaseline and left to dry for 36 hours. The plastic mold was carefully removed from the inside, and the simulation model was obtained. A plasticine renal model was subsequently built. The renal pelvis model was anchored to it for laparoscopic pyeloplasty simulation purposes (Fig. 3).

The price of 3D printing was 5 euros per model, while the price of 250 ml of liquid latex was 8.75 euros. Approximately 15 ml per model were used.

Figure 3. Final design of the liquid latex model

Laparoscopic pyeloplasty simulation

8 voluntary pediatric surgeons with various training levels participated in dismembered LP simulation according to Anderson Hynes' technique. Before that, they had responded to a survey in order to determine laparoscopic surgery training levels.

The hands-on session was carried out using 5mm surgical instruments – dissector, scissors, grasper, needle holder, and contra-needle holder. A 5/0 non-absorbable monofilament suture, as well as a vessel loop to simulate double J stent placement at the anastomotic level, were used. In each training, operating time (minutes), knotting safety (Likert scale), anastomotic patency (Likert scale), absence of loops or kinks (Likert scale), and OSATS score – which rates 6 areas from 1 to 5, including respect for the tissues, time and movement, instrument control, instrument handling, surgery fluency, and surgery understanding, for a maximum 30-point score – were assessed.

Model and simulation assessment

Following the hands-on session, each participant responded to an anonymous survey to assess general impression, texture, image sharpness, usefulness, and probability of recommending this simulation to other pediatric surgeons. Responses were given according to Likert scale.

RESULTS

Median pediatric surgical training of study participants (n=8) was 7 years (range: 3-13). Participants conducted a mean of 3-8 (range: 1-15) laparoscopic surgeries annually. 5 participants had previously witnessed laparoscopic pyeloplasty, and only 1 had performed laparoscopic pyeloplasty as the principal surgeon. Median hours of laparoscopic training were 16 hours (range: 10-70). Of the 8 participants, half of them felt capable of conducting laparoscopic pyeloplasty in real patients.

All participants completed the simulation, with a mean operating time of 71.5 minutes (range: 50-86). Mean in terms of knotting was 3.6/5 (range: 3-5), mean in terms of anastomotic patency was 3.1/5 (range: 2-5), and mean in terms of absence of anastomotic loops or kinks was 3.5/5 (range: 2-4). Mean OSATS score was 20.1/30 (range: 17-24). In particular, mean in terms of respect for the tissue was 2.6/5 (range: 1-4), mean in terms of time and movements was 2.6/5 (range: 2-4), mean in terms of instrument handling was 3/5, mean in terms of instrument control was 5/5, mean in terms of surgery fluency was 2.5/5 (range: 2-4), and mean in terms of surgery understanding was 4/5 (range: 4-5). Simulation results are featured in Table 1.

Participants rated general impression with a mean of 4.25 (range: 3-5), texture with a mean of 4.37 (range: 3-5), image sharpness with a mean of 1.5 (range: 1-3), usefulness with a mean of 4.5 (range: 4-5), and probability of recommending the model with a mean of 4.6 (range:

Table I. Laparoscopic skills of study participants (pre-simulation survey).

	Years of pediatric surgical training	*Monthly laparoscopic surgeries*	*Laparoscopic pyeloplasties as the principal surgeon*	*Laparoscopic pyeloplasties as an assistant surgeon*	*Laparoscopic training hours*	*Capable of conducting laparoscopic pyeloplasty*
P1	7	1 - 5	0	4	16	Yes
P2	7	1 - 5	0	5	25	Yes
P3	5	1 - 5	0	0	10	No
P4	9	5 - 10	1	2	10	Yes
P5	6	1 - 5	0	1	10	No
P6	10	5 - 10	0	0	25	No
P7	13	10 - 15	0	0	70	Yes
P8	3	5 - 10	0	4	16	No

Table II. Simulation results.

	Operating time (min)	*Knotting (Likert)*	*Anastomotic patency (Likert)*	*Absence of loops or kinks*	*OSATS score*
P1	86	3	2	4	19/30
P2	50	4	3	4	21/30
P3	77	3	2	3	17/30
P4	84	4	4	4	21/30
P5	77	3	3	3	18/30
P6	75	3	3	4	24/30
P7	53	5	5	4	21/30
P8	67	4	3	2	20/30

Table III. Liquid latex model usefulness results.

	General impression (Likert)	*Texture (Likert)*	*Image sharpness (Likert)*	*Usefulness (Likert)*	*Recommendation (Likert)*
P1	3	3	1	4	4
P2	4	5	1	4	4
P3	4	5	1	4	5
P4	5	4	3	5	4
P5	4	4	3	5	5
P6	4	4	3	4	5
P7	5	5	1	5	5
P8	5	5	2	5	5

4-5). Satisfaction rates regarding the use of the model are featured in Table 2.

DISCUSSION

The model vas positively rated by a group of young, enthusiastic pediatric surgeons interested in learning and improving minimally invasive surgical techniques. Texture and general impression were rated as highly adequate, and the hands-on session was regarded as very useful and highly recommendable for other pediatric surgeons.

3D printing allows the anatomical structure of infrequent pathologies to be accurately reproduced. Thanks to liquid latex (1.4 cis-polyisoprene), surgical training models with a texture similar to that of real tissue can be created. Direct printing on "flexible" material was ruled out, since the options available in flexible 3D printing today (silicone or rubber) are more rigid and expensive, and they require to be over 5 mm thick to be successfully reproduced by the printer, with longer printing times.

This model is significantly cheaper than the other three models described in the literature and in the simulation market. Indeed, the approximate price per model is below 10 euros, which means it is 6 times cheaper than the model developed by the University of Minnesota[7], 11 times cheaper than the model developed by Toronto's Hospital for Sick Children[4], and 60 times cheaper than the model marketed by SimuLap.

Contrarily to Toronto's model, ours does not feature peritoneal simulation. However, peritoneal division does not take long, nor does it impact surgical results in real patients. In addition, placing a double J stent to ensure anastomotic patency is key in pyeloplasty, and our model is the only one that assesses this aspect of the technique. The model developed by the University of Minnesota allows for a more objective anastomotic assessment, since it features black light to evaluate anastomotic orientation. However, it feels more rigid and features no renal tissue simulation.

According to the pre-simulation survey, minimally invasive surgical training – and particularly that related to laparoscopic pyeloplasty – was scarce for all participants. The low incidence of ureteropelvic junction obstruction and the fact only ideal cases are selected for laparoscopic repair make simulation-based training essential for pediatric surgeons[8-10]. Sporadically helping in this procedure does not provide physicians with sufficient training to safely conduct laparoscopic pyeloplasty as the principal surgeon.

Simulation assessment is key in surgery to acquire new skills and achieve better surgical results. The OSATS score analyzes surgical success in detail[11.12]. In this project, the final anastomotic result is also evaluated, and anastomotic patency, knotting tension, and absence of loops or kinks are checked for. Results from the various participants were similar, but the most experienced surgeon – the participant with more hours of minimally invasive surgical training and more monthly laparoscopic procedures – had the best result of all. All participants had room for improvement in all surgical aspects, namely in terms of tissue handling and surgical movement agility. Therefore, repeated simulation using this model would help develop an adequate learning curve to provide our patients with increased safety levels and better results.

The type of model developed in this study can be used in other pediatric pathologies associated with complex, infrequent surgical techniques. Using the same 3D design principles and a replica of a liquid latex mold, hollow organ models applicable to digestive and oncological pathologies could also be created.

CONCLUSIONS

Our liquid latex model for laparoscopic pyeloplasty simulation is feasible, with favorable preliminary results. Its usefulness in laparoscopic pyeloplasty training is promising. It could also be useful in shortening the learning curve by repeatedly conducting simulation, and it could be used in other pediatric pathologies associated with complex, infrequent surgical techniques.

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