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Article

Experience in Box Simulation Program for Pediatric Laparoscopic Inguinal Hernia Repair Using Training Model Assembled with Common Hospital Items

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Abstract

Background/Objectives: This study aims to develop and validate a reproducible training model, built using common hospital items, for laparoscopic inguinal hernia repair with an intracorporeal suturing approach, specifically focusing on iliopubic tract redress in pediatric patients. **Methods**: Pediatric surgery residents and consultants were instructed on model building and engaged in training sessions. They practiced for four weeks with the handcrafted model and completed a post-simulation survey. The time taken to conclude the training task and the modified Objective Structured Assessment of Technical Skills score were compared between the initial and last sessions at the end of the training period. Additionally, the time required by consultants to perform the laparoscopic procedure in vivo, intraoperative complications, and recurrence rates were analyzed from the time they started the training. **Results**: A feasible model was created using a colostomy dressing support, Penrose drains, Foley catheters, feeding tubes, and surgical gloves to simulate. The sample involved a total of twelve residents and five consultants with an average age of 33 years old. All participants successfully completed the task during the session. Since the consultants started their training on the model, the operative results for laparoscopic inguinal hernia repair in the theater have improved. **Conclusions**: Training experience on this model led to improve laparoscopic skills such as cutting and dissection and intracorporeal tying and knotting. This study confirms that training outside clinical practice can significantly benefit laparoscopic proficiency and safety in vivo.

Keywords: pediatric surgery; minimally invasive surgery; laparoscopy; congenital inguinal hernia; laparoscopic inguinal hernia repair; surgical training

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1. Introduction

Over the past three decades, minimally invasive surgery and endoscopic procedures have been supplanting open surgery for many indications, even in pediatric surgery. Laparoscopy is the most common minimally invasive surgical approach used for pediatric patients, but it is more technically challenging than conventional surgery and requires effective training sessions outside the clinical setting to be successful in the theater [1,2]. Simulation has emerged as a well-established pedagogical tool for the acquisition of and improvement in surgical skills in a preclinical setting, significantly enhancing performance during surgery [3]. Inguinal hernia repair is among the most frequently performed procedures in pediatric surgery, with laparoscopic approaches increasingly being recognized as viable alternatives to traditional open surgery. While laparoscopic inguinal hernia repairs (LIHRs) in children have demonstrated safety, efficacy, and reproducibility, controversy remains regarding the appropriateness of this technique for pediatric surgeons lacking extensive experience in laparoscopic methodologies [4,5]. LIHR encompasses various procedural techniques that can be categorized based on the chosen suturing method for obliterating the internal inguinal ring, either an extracorporeal or intracorporeal suturing approach, with or without the dissection of the hernial sac [6]. We developed and validated a novel laparoscopic training box model made from commonly available hospital materials to enhance surgical training. This model is designed for training in the step-by-step LIHR based on intracorporeal suturing, specifically focusing on the iliopubic tract redress technique.

2. Materials and Methods

From April 2023 to October 2024, pediatric surgery consultants and residents were enrolled in a training program designed to validate a novel box training model for training in LIHR with the iliopubic tract redress technique. All participants included in this study voluntarily took part in the simulation program in order to improve their surgical skills and signed an explicit, freely given and informed consent form for data processing. They filled out a demographic questionnaire regarding their age, gender, level of specialization, and basic laparoscopic skills. All participants were required to have previously acquired basic laparoscopic knowledge and skills. The residents needed to be capable of assisting in LIHR procedures in the operating room, whereas the consultants were required to be able to perform the procedure independently. They learned how to construct and use the model properly before starting the program. A simulation station was set up at our facility, using a monitor and a computer with software connected to a common laparoscopic box training simulator. Laparoscopic instruments with a diameter of 3 mm were used, including 2 needle holders, a Maryland dissector and scissors. All participants practiced for 4 weeks using the handcrafted training model simulating the procedure and then answered a post-simulation survey, made up of 8 multiple choice questions with 5 answers, with it being possible to only choose one. A Likert score (1–5) was obtained for each question (Figure 1). A Likert scale was employed to provide a structured assessment of participants' satisfaction with the training program, covering both the design phase and the practical implementation of the model. The evaluation addressed overall impressions, the ease of model assembly, the accessibility of the medical materials required for its construction, the realism and reproducibility of the model, and the perceived educational value of the training program.

The progress for each participant was established by comparing the Objective Structured Assessment of Technical Skills (OSATS) [7] and the simulation time of the first training session to the last one, 4 weeks later. The OSATS is a useful assessment and teaching tool concerning laparoscopic intracorporeal suturing and knot-tying skills that includes a Procedure-Specific Checklist (PSC) and Global Rating Scale (GRS). The PSC assesses procedure-specific abilities by breaking down the steps of the procedure into individual tasks, which are evaluated as "yes" or "no" based on whether the task was successfully completed. A score of 1 point is assigned only when a task or a subtask is achieved. The original PSC schedule included four tasks: needle delivery/load, suturing, knot tying, and suture cut and removal. For this study, the PSC was modified. For LIHR with iliopubic tract redress, two layers of suturing are required: a deeper one involving the transverse abdominal muscle and the iliopubic tract and a more superficial one involving

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the peritoneum. Consequently, the PSC was expanded to include 7 tasks, adding the opening and dissection of the peritoneum and repeating the suturing and knot tying tasks twice, for the deeper layer and the superficial one. The modified PSC had a total score of 30 points. The GRS evaluates general technical skills across four categories: depth perception, bimanual dexterity, tissue handling, and autonomy. Participants were scored on a Likert scale from 1 to 5, with a maximum total score of 20 points based on performance (Figure 2). Therefore, the final OSATS score as structured could be as high as 50 points.

		1	2	3	4	5
1	**General impression about the model**	very unsatisfied	unsatisfied	neutral	satisfied	very satisfied
2	**Ease of access to the medical items**	very difficult	difficult	neutral	easy	very easy
3	**Ease of assembling the model**	very difficult	difficult	neutral	easy	very easy
4	**Reproducibility of the model**	very difficult	difficult	neutral	easy	very easy
5	**Realism: the model accurately simulated essential components of LIHR**	not at all realistic	not so realistic	somewhat realistic	very realistic	extremely realistic
6	**Quality of user manual**	not at all helpful	not so helpful	somewhat helpful	very helpful	extremely helpful
7	**Value in training programs**	strongly disagree	disagree	neither agree or disagree	agree	strongly agree
8	**Value in learning basic laparoscopic skills**	strongly disagree	disagree	neither agree or disagree	agree	strongly agree

Figure 1. Post-simulation survey based on Likert scale from 1 to 5.

PROCEDURE SPECIFIC COMPONENTS (PSC) modified for LIHR with iliopubic tract redress

A. Peritoneal/Glove Opening and Dissection

1. Correct side peritoneal opening
2. Dissection and exposure of iliopubic tract and the transverse abdominal muscle, using needle-holder/dissector and scissors. Safety mobilization of vas deferent and vessels

B. Needle Delivery/Load:

3. Load needle perpendicular/internal or external rotation to needle holder beak
4. Choke needle (1/2 to 2/3 from needle tip)

C. Suturing Deeper Layer

5. Place needle at 90- degree angle to tissue
6. Drive needle with supination
7. Pull suture through to establish short free end
8. Suture placed accurately, on iliopubic tract and transverse abdominal muscle target

D. Knot Tying Deeper layer

9. First throw: Surgeon's knot
    a. Knot under tension laid flat without air knots
10. Second throw: opposite direction from prior throw
    a. Knot under tension laid flat without air knots
11. Third throw: opposite direction from prior throw
    a. Knot under tension laid flat without air knots
12. Short tail end maintained
13. Appropriate tissue re-approximation without strangulation

E. Suturing Peritoneal layer

14. Place needle at 90-degree angle to tissue
15. Drive needle with supination
16. Pull suture through to establish short free end
17. Suture placed accurately on peritoneal target

F. Knot Tying Peritoneal layer

18. First throw: Surgeon's knot
    a. Knot under tension laid flat without air knots

Figure 2. *Cont.*

19. Second throw: opposite direction from prior throw
    a. Knot under tension laid flat without air knots
20. Third throw: opposite direction from prior throw
    a. Knot under tension laid flat without air knots
21. Short tail end maintained
22. Appropriate tissue re-approximation without strangulation

G. Suture cut and removal

23. Needle cut from suture under direct visualization
24. Needle safely removed under direct visualization

Completed Task: (circle one) YES NO
Start Time: End Time: Total time
Total score: _________/30

GLOBAL COMPONENT: Global Rating Checklist

Tissue and Instrument Handling				
1 Rough movements; awkward handling of instruments and tissue (or model)	2	3 Careful handling of instruments and tissue (or model) overall, with occasional awkward movements	4	5 Consistently appropriate and careful handling of instruments and tissue (or model)
Depth Perception/Accuracy				
1 Constantly misses target, slow to correct	2	3 Sometimes misses target, quick to correct	4	5 Accurately directs instrument to target
Dexterity/Efficiency				
1 Uncertain, inefficient movements without progress	2	3 Efficient movements overall with some unnecessary moves	4	5 Fluid, efficient movements without wasted time or motion
Autonomy/Proficiency				
1 Unable to complete entire task at this time	2	3 Able to perform task with some instruction	4	5 Able to perform task safely & independently, without instruction

Total Score: ______/ 20 points

Figure 2. The Objective Structured Assessment of Technical Skills (OSATS) modified for LIHR with the iliopubic tract redress procedure.

An expert supervised the participants during the training sessions in the 4-week training period and later completed OSATS evaluation forms by reviewing the recorded videos of the first and last sessions for each participant. The expert was unaware of the demographic details and surgical skills of the participants, allowing for an unbiased assessment. The training program on the model began with an initial 4-week period, followed by periodic sessions thereafter. Since its implementation, monolateral LIHR performances in vivo have been analyzed with respect to consultants, focusing on operating times (including laparoscopic setup), monitoring intraoperative complications, and assessing recurrences during the 6-month follow-up. The operating times were compared with the surgical times of the pre-simulation program performances. These evaluations aimed to track their progress in the operating room. A statistical analysis was performed using a paired T-test to compare OSATS scores and simulation times before and after the training program. The model was made with common hospital items: a colostomy dressing support with a bag, Penrose drains of sizes 8 and 12 Fr, surgical gloves, a 6 Fr feeding tube and a urinary Foley catheter of size 8–10 Ch. The Penrose drains, the Foley catheters and the feeding tube were stapled to the colostomy dressing support to simulate, respectively, the transverse abdominal muscle and the iliopubic tract and the femoral vessels and the spermatic cord. It is possible to personalize the setups for males or females and right or left inguinal hernia. The colostomy dressing support should be attached to a compressed cardboard piece, 12 × 12 cm, with a central hole and diameter of 2 cm. It was secured to another similar item, not drilled, and to two small sticks, forming a wedge. The base of the simulator can be fixed with double-sided adhesive tape to the floor of any laparoscopic video box trainer. The inclination and rotation of the operative site can be personalized during training to simulate the multiple anatomical sets involving the internal inguinal ring in vivo. In the end, a surgical glove was introduced and fixed into the enlarged silicone hole of the colostomy support, simulating the peritoneum (Figure 3). The model allows one to practice basic laparoscopic skills such as cutting and dissection, suturing and knot tying, typical surgical steps of LIHR based on the intracorporeal suturing technique, with or without the dissection of the hernial sac (Video S1).

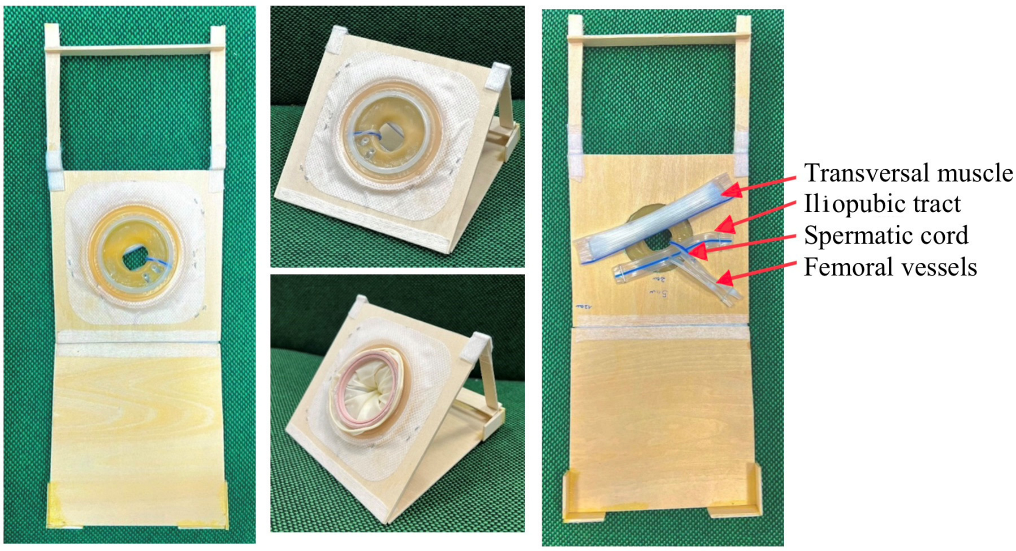

Figure 3. Laparoscopic training box model intended for step-by-step training in LIHR with iliopubic tract redress, assembled with commonly available hospital items.

3. Results

A total of 17 participants were enrolled in the training program, including 12 pediatric surgery residents (70.5%) and 5 consultants (29.5%). The cohort comprised 13 females (76.5%) and 4 males (23.5%), with a mean age of 33 years (range 26–64). The results of the post-simulation survey are presented in Table 1.

All survey questions received an average Likert score exceeding 4.3 (4.3–4.6). Overall impressions were highly satisfactory among all participants. The accessibility of the necessary medical items and the assembly of the model were evaluated positively, with participants describing the model as realistic and reproducible. Furthermore, training using the model was deemed beneficial for enhancing the quality of the user manual and for improving basic laparoscopic skills, leading participants to consider it a valuable component for the training. The OSATS score results and simulation times for each participant are detailed in Table 2. All participants successfully completed the exercise during the evaluated sessions. Every participant demonstrated an improvement in the time required

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to simulate the task following training. The average time taken by the registrars to complete the task before and after the program was 45 m 57 s and 39 m 25 s, respectively. The average time for the consultants to complete the task before and after the program was 27 m 10 s and 20 m 43 s, respectively. The registrars required more time than consultants to complete the task, both prior to and following the training program. The OSATS scores for the session conducted four weeks after the training showed a significant improvement compared to the initial scores for all participants. Specifically, the average score before and after the training period was higher for the consultants, recorded at 38 (37–40) and 44 (41–47), respectively, compared to the residents, whose scores were 25 (22–30) and 30 (28–35). A paired-samples *t*-test showed a significant improvement in OSATS scores following simulation training (mean increase 5.29 ± 1.40; $t(16) = 15.52$, $p < 0.001$). Procedure time significantly decreased (mean reduction 6.54 ± 2.30 min; $t(16) = 11.72$, $p < 0.001$).

Table 1. Post-simulation survey 5-point Likert scale results.

Question	1	2	3	4	5	6	7	8
Consultant 1	5	5	4	5	4	4	5	4
Consultant 2	4	4	4	5	5	5	4	5
Consultant 3	4	5	5	5	4	5	5	5
Consultant 4	5	5	5	4	5	5	4	5
Consultant 5	5	4	5	4	5	5	5	5
Registrar 1	4	4	4	4	4	4	5	4
Registrar 2	5	5	4	4	5	3	4	5
Registrar 3	5	5	5	4	5	5	4	5
Registrar 4	4	4	5	5	5	4	4	4
Registrar 5	5	4	3	4	5	5	5	4
Registrar 6	3	5	5	4	4	4	4	5
Registrar 7	4	4	5	5	4	5	4	5
Registrar 8	4	5	4	5	5	3	5	4
Registrar 9	4	5	5	4	5	5	4	4
Registrar 10	5	5	4	4	4	4	5	5
Registrar 11	4	5	3	4	5	5	5	4
Registrar 12	5	5	4	4	4	5	5	5
Average Likert score	4.4	4.6	4.3	4.3	4.5	4.5	4.5	4.5

Table 2. Summarized pre- and post-training program OSATS score and simulation time results.

	OSATS PRE	TIME PRE (Minute)	OSATS POST	TIME POST (Minute)
Consultant 1	39	22.16	47	19.24
Consultant 2	35	25.34	41	20.53
Consultant 3	37	31.26	42	24.12
Consultant 4	40	29.57	46	21.14
Consultant 5	39	26.42	44	17.55
Registrar 1	25	44.36	31	37.28
Registrar 2	22	48.19	29	44.43
Registrar 3	29	39.58	35	34.14
Registrar 4	30	33.22	34	29.41
Registrar 5	28	40.35	33	35.17
Registrar 6	23	57.12	29	52.59
Registrar 7	26	41.00	31	32.46
Registrar 8	24	39.37	28	32.10
Registrar 9	25	43.57	29	38.46
Registrar 10	23	48.10	30	39.55
Registrar 11	24	62.34	27	51.14
Registrar 12	27	52.14	30	43.59

The consultants continued the training experience on the model with periodic sessions. Since the consultants started their training on the model, the operative times for LIHR in vivo have improved (Table 3). These results are likely attributable to the in vitro training, although other factors, such as the experience gained in the operating room, may also have contributed. Among the 63 cases of unilateral laparoscopic inguinal hernia repair performed in vivo (mean age 5.8 years, range 1–10; 40 males [63%] and 23 females [37%]), 9 minor complications (14%) were reported: 4 conversions to open surgery, 1 retroperitoneal hematoma managed conservatively, and 3 cases of minor bleeding. No recurrences were observed at the six-month follow-up.

Table 3. Average time in minutes required by consultants to perform LIHR in vivo analyzed before and after they started training.

LIHR In Vivo	Before	After
Consultant 1	71 (85–65)	58 (75–50)
Consultant 2	78 (85–75)	70 (75–65)
Consultant 3	81 (95–70)	65 (90–50)
Consultant 4	72 (80–65)	55 (70–40)
Consultant 5	74 (85–65)	60 (75–45)

4. Discussion

Laparoscopy is becoming the technique of choice for multiple procedures, both in adults and in children, with exponentially growing importance [8]. Nevertheless, the learning curve is slower, more prone to mistakes and more complex compared to traditional surgery [9]. In laparoscopy, surgeons should overcome some difficulties such as video–eye–hand coordination, the loss of the third dimension, haptic sensation through laparoscopic instruments and the fulcrum effect, which inverts instrument motion and increases trembling. Furthermore, the introduction of laparoscopy took longer in pediatric surgery, as a result of limited indications and the reduced availability of instruments adequate for pediatric sizes, further slowing down the laparoscopic learning curve for pediatric surgeons, both experienced ones and trainees [10]. Inguinal hernia repair is one of the most common surgical operations performed in children, and laparoscopy represents a valid alternative to open surgery; seemingly, there is no clear agreement on the best surgical approach for pediatric inguinal hernia repair; both of these are recognized as effective options, yielding similar results [11]. Minimally invasive surgery in the case of inguinal hernia allows for the contralateral exploration and simultaneous repair of the contralateral hernia, if it is present, avoiding the risk of a metachronous hernia, and might be advantageous in children with bilateral inguinal hernia in terms of reduced operation time [12,13]. It may be useful even in selected cases to enable a differential diagnosis among different types of hernias (femoral, direct, etc.), improving management and treatment strategies [14]. Advancements in LIHR techniques are progressing in tandem with their growing popularity. There are various outlined procedures for LIHR, which can be classified based on the choice of suturing technique to obliterate the internal inguinal ring, either extracorporeal suturing through the preperitoneal side or intracorporeal suturing through the transperitoneal approach, with or without the dissection of the hernial sac [6]. In our Pediatric Surgery Department, LIHR with iliopubic tract redress is routinely adopted as the therapeutic strategy for patients older than 1 year of age affected by Congenital Inguinal Hernia. It is performed employing three trocars, a 5 mm subumbilical trocar for the 5 mm 0° or 30° camera and two 3 mm trocars positioned in the right and left flanks for laparoscopic needle holders, a Maryland dissector and scissors. For the suture, we use a braided, non-absorbable thread with a half-circle round needle. LIHR with iliopubic tract redress allows for tissue reinforcement, usually needed in cases where the ligature of the hernia sac at the internal ring alone may be inadequate, as in dilated internal ring and recurrent hernia; after the lateral dissection of the hernial sac, the internal inguinal ring is closed by a deeper suture layer involving the iliopubic tract and the transverse abdominal muscle and a superficial one closing the peritoneum [4,15] (Figure 4).

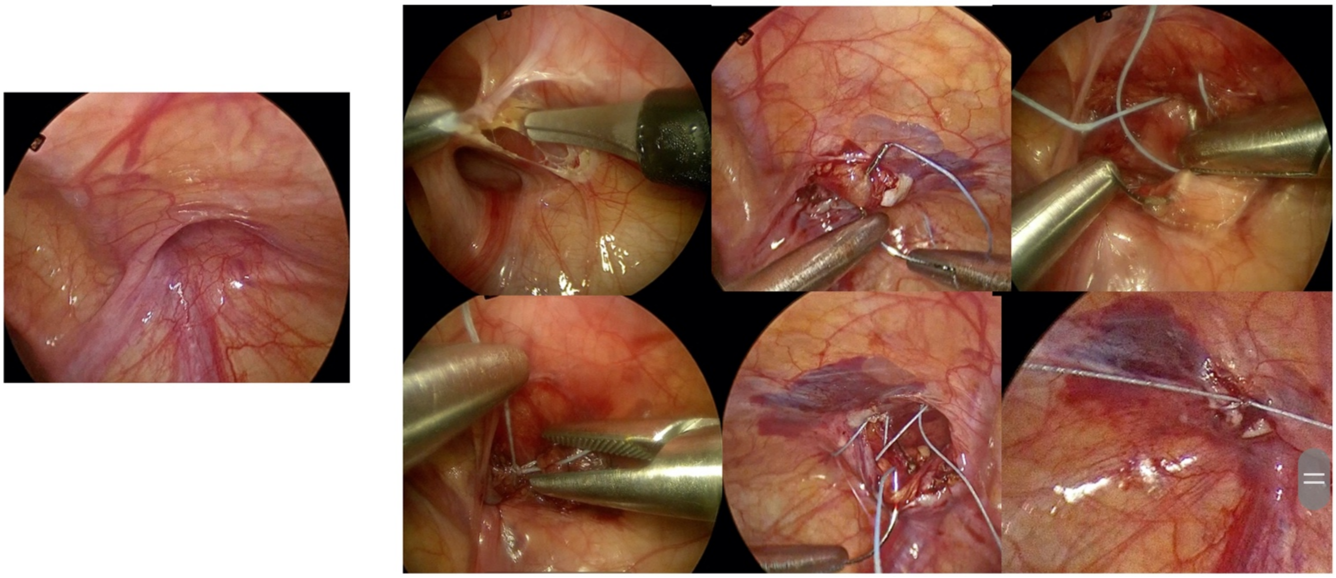

Figure 4. LIHR with iliopubic tract redress requires two layers of suturing: a deeper one involving the transverse abdominal muscle and the iliopubic tract and a more superficial one involving the peritoneum.

Having established a standardized surgical approach and anesthesiologic setup, in our practice, routine LIHR with iliopubic redress allows for effective outcomes and has become an opportunity for the whole surgical team to enhance their laparoscopic skills in the theater. LIHR may not be suitable for pediatric surgeons lacking sufficient experience. Overcoming initial laparoscopic challenges through observation and supervised training requires time and numerous procedures [1,16]. Nowadays, simulation is a well-established component of surgical training. It is known to allow for the acquisition of surgical skills in a preclinical and safe environment and has been shown to improve performance quality in vivo [3]. Evaluation scores are used to support the learning process by objectively measuring training progress. Higher evaluation scores are associated with better surgical skills. Trainees can assess their individual skills and receive constructive feedback on aspects such as movement precision, depth perception in a two-dimensional environment, dexterity, proficiency, and task autonomy [17–19]. The LIHR model object of this study, validated in terms of a laparoscopic box trainer simulator, proved to be reproducible, simple to assemble and user-friendly.

The advantages of tailoring model setups for male or female anatomy and right- or left-sided inguinal hernias and being able to adjust the inclination and rotation of the operative field to simulate multiple anatomical configurations involving the internal inguinal ring in vivo have made the training experience realistic for practicing LIHR with iliopubic tract redress, thereby enhancing laparoscopic skills such as tissue dissection, suturing and knot-tying. The training program involving our model demonstrated educational value for residents and experienced surgeons, suggesting that simulation experiences benefit surgical training. The positive impact observed in the operating room suggests that the skills acquired during simulation training effectively translated into clinical practice. The findings of this study underscore the importance of effective training methodologies in laparoscopic surgery, confirming that a valid training exercise should be initiated outside clinical practice to properly perform a laparoscopic procedure.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/std15020016/s1, Video S1: Simulated versus in vivo LIHR.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The original contributions presented in this study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author(s).

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

LIHR	Laparoscopic Inguinal Hernia Repair
OSATS	Objective Structured Assessment of Technical Skills

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