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Title: DEVELOPMENT AND EVALUATION OF A LOW-COST **PART-TASK TRAINER**
FOR LAPAROSCOPIC REPAIR OF INGUINAL HERNIA IN BOYS AND THE
ACQUISITION OF BASIC LAPAROSCOPY SKILLS

Hortense Duboureau¹, Mariette Renaud-Petel², MD, Céline Klein¹, MD,
Elodie Haraux, MD, PhD^{1,3}

1. Department of Pediatric Surgery, Amiens University Hospital, F-80054 Amiens, France
2. Department of Pediatric Surgery, Rouen University Hospital, F-80054 Amiens, France
3. PeriTox - UMI 01, UFR de Médecine, Jules Verne University of Picardy, F-80054 Amiens, France.

Corresponding Author:

Elodie Haraux, MD, PhD

Department of Pediatric Surgery

Amiens University Hospital

F-80054 Amiens, France

E-Mail: haraux.elodie@chu-amiens.fr

1 INTRODUCTION

2 Laparoscopy is an essential surgical tool that is now supplanting open surgery in many indications, included those
3 in pediatric surgery [1]. Although surgical skills have traditionally been taught and learnt through companionship
4 in the operating room, this paradigm has recently been challenged by legal and ethical concerns for patient safety,
5 work hour restrictions, the cost of operating room time, and the risk of complications. Simulation offers a potential
6 solution to two conflicting demands: residents want to be trained in surgery but parents want their children to be
7 operated on by experienced surgeons. This has become especially true since the advent of minimally invasive
8 pediatric surgery; a counter-intuitive visuospatial interface and greatly reduced proprioceptive feedback create
9 specific training issues [2]. It has been shown that simulations improve the operating room performance of surgical
10 residents – especially for laparoscopy, a technically demanding procedure that requires regular practice [3].
11 Low-cost models enable laparoscopic skills to be practiced more freely [4]. We therefore developed a novel, low-
12 cost model of laparoscopic inguinal hernia repair (LIHR) in boys. Congenital inguinal hernias are caused by the
13 persistence of the vaginal process. As described by Becmeur et al. [5], the laparoscopic technique reproduces each
14 of the steps in conventional surgery: dissection, division, and suture of the vaginal process at the internal inguinal
15 ring. In boys specifically, the vaginal process is freed from the vas deferens and the testicular artery and then
16 fully divided. Lastly, the peritoneum is closed with an intracorporeal knot. The objectives of the present study
17 were to evaluate this part-task trainer in LIHR and assess its value in resident training programs and, more
18 generally, in the learning of basic laparoscopy skills.

19 MATERIALS AND METHODS

20 We have conceived and designed an LIHR simulation model that can be assembled easily from low-cost, readily
21 available equipment and implemented with a user manual (Appendix 1 online and Video 1 (Video)). Firstly, a
22 plastic bottle (volume: >1 L) was cut 7 cm below the neck and 7 cm from the bottom. The intermediate part was
23 discarded. The plastic ring under the bottle cap is removed from the neck of the bottle before assembly, and kept
24 for later. The bottom part was kept for the end of the assembly. The top part of the bottle (the “funnel”) was
25 turned upside down and inclined, in order to mimic the inguinal canal. A colored non-sterile surgical glove (size
26 L or XL) was applied to the funnel; the fingers were passed through the neck and cut off a few centimeters
27 below. The glove mimicked the inguinal wall; at the end of the procedure, the surgeon could check whether or
28 not the wall had been accidentally perforated. Two elastic loops (e.g. Ethiloops® or “scoubidou” lanyards) of
29 different colors were placed in the bottle neck; these respectively represented the vas deferens and the testicular
30 artery. The threads were fixed with adhesive tape (e.g. Leukoplast® S LF from BSN Medical, Hamburg,

31 Germany). A second (transparent) surgical glove was placed over this structure, to represent the peritoneum. The
32 end of the second glove's fingers were also cut off a few centimeters below the neck of the bottle. The plastic
33 ring present around the neck of the bottle can be used to hold the distal part of the folded gloves and the loops.
34 The gloves must be tight. The bottom of the bottle was then used. A small hole was made in the center of the
35 bottom, using a pair of scissors. A resistant elastic loop or an elongated balloon was knotted around the neck of
36 the bottle and then passed through the hole in the bottom of the bottle, in order to attach the two parts together. It
37 is important to place the neck of the bottle at an angle and to tape it tightly to the laparoscopic trainer.
38 We mailed an user manual and an evaluation questionnaire to all of the university medical center performing
39 pediatric surgery in France (32), to one university medical center in Belgium, and to all the other surgical units
40 in our university medical center (urology, visceral surgery, and gynecology) that used laparoscopy (Appendix 1,
41 online only). We proposed to all the surgical teams to test and to evaluate this model in order to have various
42 level of laparoscopic practitioners. We collected participant's characteristics (status (resident, expert), surgical
43 specialty), time for model construction and for the procedure (min). The evaluation questionnaire featured 11
44 items rated on a 5-point Likert scale (Table 2). The item scores were described as the median [interquartile range
45 (IQR)] and compared as a function of the level of expertise (residents vs. experts) using Student's t test. The
46 threshold for statistical significance was set to $p < 0.01$. We calculated an overall score by summing the median
47 scores for all but three of the items. Two of the excluded items concerned the ease of the procedure (the ease of
48 glove resection and the ease of suturing); in retrospect, we considered that they were not directly related to the
49 model's quality and were very dependent on the participant's level of expertise. The third item was the quality of
50 the view; in retrospect, we considered that this item was imprecise. We considered the model had been of value
51 when the median overall score was 4 or over.

52 –RESULTS

53 From April 2018 to April 2019, 55 practitioners from 10 university medical centers (34 departments, including
54 31 pediatric surgery departments and 3 general surgery departments) participated in the study. The participants'
55 characteristics are summarized in Table 1. Forty-one of the 55 participants (74.6%) were pediatric surgeons. The
56 scores given by the participants are detailed in Table 2. In both groups, all the participants managed to assemble
57 the model and perform the training procedure.

58 The time needed to assemble the model was relatively short: 15.0 ± 6.2 minutes overall, 12.0 for the residents
59 and 15.0 minutes for the experts ($p=0.07$). The mean duration of the laparoscopy procedure was significantly
60 longer for the residents (30.0 ± 16.8 min) than for the experts (26.5 ± 11.7 min; $p=0.01$).

61 The participants had a good overall impression of the model (4.0 ± 1.0) and had no difficulty in obtaining the
62 required equipment (76.3% of the participants gave a score of 5 out of 5 for this item).

63 The participants considered that the user manual was very easy to understand (score: 5.0 ± 0.6) and that the
64 model was very easy to assemble (25.4 % of the participants gave a score of 4, and 49% gave a score of 5); there
65 were no significant intergroup differences for these scores. Furthermore, the participants considered that the
66 model was moderately easy to use (3.0 ± 0.9) and quite realistic (4.0 ± 0.9).

67 The model was considered to be very easy to use by 7% of the participants, easy to use by 12.8%, moderately
68 easy to use by 49%, difficult to use by 23.6%, and very difficult to use by 5.4%. Middling scores were given for
69 the quality of the view (3.0), resection of the glove (3.0) and suturing (3.0). Suturing was reported more difficult
70 for the residents (with a mean score of 4.0, vs. 3.0 for the experts; $p=0.01$). The model's value in learning basic
71 laparoscopy skills was rated at 5.0 (5.0 for the residents vs. 4.0 for the experts; $p=0.004$). Although both groups
72 awarded a high score for this item, the score was significantly higher among the residents than among the
73 experts. The median overall score was 4.0 (4.1 for the residents vs. 4.0 for the experts; $p=0.36$); according to our
74 criterion, the evaluation was therefore positive.

75 **DISCUSSION**

76 Simulators are educational tools that enable physicians to repeatedly practice medical procedures in complete
77 safety. The use of a simulator avoids the stress induced by real operating conditions [3]. Moreover, laparoscopic
78 surgery training for residents is a major need [6,7]. Training on animals, human cadavers and high or low fidelity
79 simulators is possible, but these models are not always widely available. The cost of simulation systems, the
80 large number of residents (relative to the number of simulators) and the shortcomings of this type of training
81 restrict continuing medical education for residents [6].

82 Low-cost simulation models constitute a very interesting option for surgical education, since they offer unlimited
83 access to training. However, it is essential to find an appropriate model that meets the surgeon's training needs.

84 A number of low-cost models have been described in the literature [8,9]. The main objective of the present study
85 was to **evaluate** a low-cost model of LIHR. Even though the majority of pediatric inguinal hernias are repaired
86 through open surgery, laparoscopic surgery is a minimally invasive treatment option. Although this operation is
87 often performed laparoscopically, we chose to model this particular procedure because it involves a variety of
88 basic laparoscopy skills. Indeed, we focused more on the precise performance of laparoscopic procedures than
89 on LIHR *per se*. Our trainees used the model to learn to grip, resect, suture and knot in different directions.

90 Our **part-task trainer** is easily assembled from material that is cheap and readily available. We also designed a
91 questionnaire so that surgeons could evaluate our model.

92 Firstly, we achieved our main objective; the model was evaluated by our participants as a tool for learning
93 LIHR and basic laparoscopy skills. The participants had a good opinion of our manual and our model,
94 regardless of their level of expertise and their surgical specialty. **In this study, we recorded data concerning our
95 creation of the model, the performance of the procedure and the users' level of satisfaction. Despite the apparent
96 common-sense validity, our study design prevented us from formally validating the model or confirming its
97 ability to train surgeons effectively.**

98 The participants considered that the procedure was moderately difficult to perform, and the suturing was a
99 little more difficult. The residents took significantly longer to perform the simulated procedure. This disparity
100 can be explained by the fact that suturing is the most technically difficult procedure and by the difference in
101 the level of expertise between the two groups. This may also be why the residents gave a higher score than the
102 experts did for the model's value in learning basic laparoscopy skills.

103 Judging from the scores given by the participants, easy access to the material required to build the model is an
104 asset of our design. Moreover, the time taken to assemble the model was acceptably short. It noteworthy that
105 once the model had been built, it can be used to perform another procedure by fitting new gloves. Robert et al.
106 have described a low-cost laparoscopy home training model [10] that could be combined with our model for
107 training purposes. Building a low-cost model from easy-to-source material may enable a resident to progress by
108 training at hospital or at home.

109 The study participants judged that the model was realistic. Although this plastic model clearly does not
110 simulate human tissue, it does schematically represent the main anatomical features needed to understand and
111 learn the surgical procedure. **When designing the model, we tested various types of equipment. The neck of
112 the bottle was selected because it mimicked the internal inguinal ring. We also wanted to make the model
113 smaller, and so tried to build it with a smaller bottle. Unfortunately, this test was not satisfactory. Firstly, the
114 glove was not fully stretched over a smaller bottle, and the remaining folds would have hindered the
115 procedure. Secondly, the mouth of the smaller bottle was the same size as in the bigger bottle, and so did not
116 resemble the baby's anatomy. The study participants' main criticism concerned the view, with a mean score of
117 3.3 out of 5.** In retrospect, we admit that this item was too imprecise to be useful in evaluating the model, since it
118 concerned both the model and the laparoscopic trainer. Hence, we decided to exclude this item from the mean
119 overall score. In fact, the view in a conventional laparoscopic trainer is not optimal, since the fixed tablet camera

120 provides a view along a single axis; in contrast, the coelioscopy camera held by the surgical assistant can track
121 the surgeon's movement. In our experience, repeated training with simple, nonrealistic model is more beneficial
122 than the occasional use of a high-fidelity model.

123 It has been proven that simulation improves the operating room performance of surgical residents [11].
124 Development of standardized training curricula is an absolutely necessity – particularly for minimally
125 invasive surgery [1]). The French National Pediatric Surgery Simulation Program was initiated in 2015 [12].
126 Following the present study, our model was used as a training tool in this national program. We now would like
127 to validate this model as an educational tool - mainly for the acquisition of basic laparoscopic surgical skills. By
128 collating data from the French national program's annual evaluation, we also intend to study the model's
129 potential for translation into clinical practice and the retention of the learned skills over time. Repeated practice
130 with our model might accelerate the learning curve, as has been described in the literature for other models
131 [1,13,14].

132 It might be possible to extrapolate our model to other methods of congenital inguinal hernia repair (such as non-
133 dismembered repair, where the whole vaginal process is left in place) or to adult inguinal hernia repair (by
134 placing the inferior epigastric vessel either medial or lateral to the defect, so that the surgeon can also open up
135 the preperitoneal space).

136 Lastly, we hope that this model will be disseminated and will improve the surgical skills of surgical residents,
137 including those in developing countries where access to practical training may be more limited.

138

139 **CONCLUSION**

140 We developed a low-cost simulation model of LIHR for surgical training and skills acquisition. This low-cost
141 model was evaluated positively and as an effective teaching and training tool for LIHR and basic laparoscopy
142 skills. This type of practical work should be integrated into resident training programs. Our model has already
143 been used in the French National Pediatric Surgery Simulation Program and might be of value in many other
144 countries – especially developing countries.

145

146

147 **Declaration of Interest:** None

148

149

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Table 1: Characteristics of the participants

Surgical specialty	UROLOGY	PEDIATRICS	VISCERAL SURGERY	GYNECOLOGY	TOTAL n (%)
EXPERTS (SENIORS/ ASSISTANTS)	4 (1/3)	25 (15/10)	0	0	29 (52.7%) (29.1/ 23.6)
RESIDENTS	7	16	2	1	26 (47.3)
TOTAL n (%)	11 (20.0)	41 (74.6)	2 (3.6)	1 (1.8)	55 (100)

Table 2: Results of the evaluation

Median duration [IQR] (min)	All participants (n=55)	Residents (n=29)	Experts (n=26)	p
Assembly	15.0 [10.0-16.0]	12.0 [10.0-22.7]	15.0 [10.0-15.0]	0.07
Procedure	26.5 [15.0-33.2]	30.0 [20.0-42.2]	20.0 [13.2-30.0]	0.01*
Total	43.0 [31.2-50.0]	47.5 [42.2-55.0]	33.5 [30.0-45.00]	0.006*
Median scores [IQR] (each out of 5)				
General impression	4.0 [4.0-4.2]	4.0 [4.0-5.0]	4.0 [4.0-4.0]	0.18
Realism	4.0 [3.0-4.0]	4.0 [3.0-4.0]	4.0 [3.0-4.0]	0.14
Ease of access to the equipment	5.0 [5.0-5.0]	5.0 [5.0-5.0]	5.0 [5.0-5.0]	0.30
Quality of the user manual	5.0 [4.0-5.0]	5.0 [4.0-5.0]	5.0 [4.0-5.0]	0.49
Ease of assembly	5.0 [4.0-5.0]	5.0 [4.0-5.0]	4.0 [4.0-5.0]	0.06
Difficulty of the procedure	3.0 [4.0-5.0]	3.0 [3.0-3.5]	3.0 [3.0-3.7]	0.33
Value in resident training programs	4.0 [4.0-5.0]	4.5 [4.0-5.0]	4.0 [3.7-5.0]	0.19
Value in learning basic laparoscopy skills	5.0 [4.0-5.0]	5.0 [5.0-5.0]	4.0 [4.0-5.0]	0.004*
Median overall score	4.5 [4.0-5.0]	4.75 [4.0-5.0]	4.0 [4.0-4.2]	0.36
Procedure scores [IQR] (each out of 5)				
Quality of the view	3.0 [2.0-4.0]	3.0 [3.0-4.0]	4.0 [2.0-4.2]	0.22
Difficulty of glove resection	3.0 [2.0-3.0]	3.0 [3.0-4.0]	3.0 [2.0-4.0]	0.50
Difficulty of suturing	3.0 [3.0-4.0]	4.0 [3.0-4.0]	3.0 [2.0-3.0]	0.01*