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Proposal for ex vivo simulation models of rabbit versus 3D to reproduce the laparoscopic gastrostomy technique

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ABSTRACT

Introduction: In order for the surgeon to perform a laparoscopic gastrostomy, he/she must have outstanding skills, therefore, laparoscopic simulators are an essential tool. They are also based on ex vivo, inanimate and virtual reality models. Objetive: To compare simulation models (ex vivo and 3D) to reproduce the laparoscopic gastrostomy technique in the training of novice surgeons at the University Hospital of Caracas.

Materials and Methods: A prospective study was conducted, which included the participation of 8 surgeons, who reproduced the proposed technique through 10 practical sessions in both models. The time of each practice was timed and expert surgeons evaluated the exercises using the GOALS scale. Descriptive calculations of the variables were performed and compared using the Student T test. A value was considered significant if $p<0.05$.

Results: The proposed technique was reproduced in both models. In addition, as the practices progressed, the performance time decreased and the score on the GOALS scale increased, with a slightly higher score in the ex vivo model. On the other hand, the execution time was longer in the 3D model practices.

Conclusions: In both simulation models, the steps were recreated authentically, and they also allowed the acquisition of skills in advanced laparoscopic surgery. The ex vivo model provided greater comfort to the surgeons, but tissue quality is an essential factor and the 3D model was technically more difficult, but proved to be more accessible and cost-effective compared to the ex vivo model.

Keywords: 3D model, ex vivo model, GOALS scale, laparoscopic gastrostomy

Introduction

One of the main challenges of laparoscopic surgery is the high level of technical skill required, including depth perception, fulcrum control, hand-eye coordination, bimanual manipulation, laparoscopic instrument handling, and ambidexterity. These elements represent a significant challenge.[1] For this reason, the use of simulation plays an important role in the acquisition of complex surgical skills.[2] It is particularly valuable during the early stages of training, as it may shorten the learning curve and reduce intraoperative complications.[3,4]

Therefore, laparoscopic simulators are essential tools for surgical training in a risk-free environment.[5,6] Several types of simulators are currently available, including ex vivo animal models, inanimate models, and virtual reality platforms.[7] Ex vivo animal models refer to the removal of an organ, cell, or tissue from an animal organism for use in medical treatments or procedures. These models provide a useful alternative to human experimentation and, in many cases, represent human tissues and anatomy with significant similarity, thus allowing surgeons to train in an environment that closely resembles the real anato-

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my, even though animal tissues and organs usually tend to be smaller than those of humans.[8] In scientific practice, ex vivo animal models have contributed over time to the refinement of different techniques, in addition to promoting research and advances in the health field, while keeping in mind all bioethical elements for the execution of this type of research.[8] With respect to mammalian animals used in experimental surgery, the rabbit (Oryctolagus cuniculus) is widely used as an ex vivo specimen. The rabbit stomach represents 15% of body mass, and it has a volumetric capacity of approximately 90 ml, and measures 8 x 6 centimeters in an adult specimen weighing approximately 2–3 kilograms,[9] making it ideal for simulating surgical procedures (Fig. 1A).

On the other hand, inanimate models are three-dimensional representations of an anatomical system. Many are reusable, or their components can be manufactured with commonly available materials.[10] At the same time, 3D printing is one of the technological fields that has seen the most recent development. Archetypes of body segments have been created using computed tomography or surface scanning images, so the technology exists to produce replicas of body sections or human dissections for educational purposes.[11]

The 3D-printed stomach model (Fig. 1B) represents a low-cost, easily accessible, reproducible, and high-resolution anatomical prototype, and is produced with materials such as polycarbonate, which offer strength and durability.[12] Both models show anatomical similarity to each other and to the stomach they are intended to simulate.

Laparoscopic feeding gastrostomy is a procedure commonly performed in surgical practice. To perform it, the surgeon must possess inherent laparoscopic skills, as well as the ability to execute advanced techniques such as intracorporeal knot tying.[12] This study aimed to compare ex vivo and 3D simulation models for reproducing the laparoscopic gastrostomy technique, contrasting the advantages and difficulties of each, while trainee surgeons recreate the steps of the proposed technique, develop their learning curve, and acquire skills in advanced laparoscopic surgery.

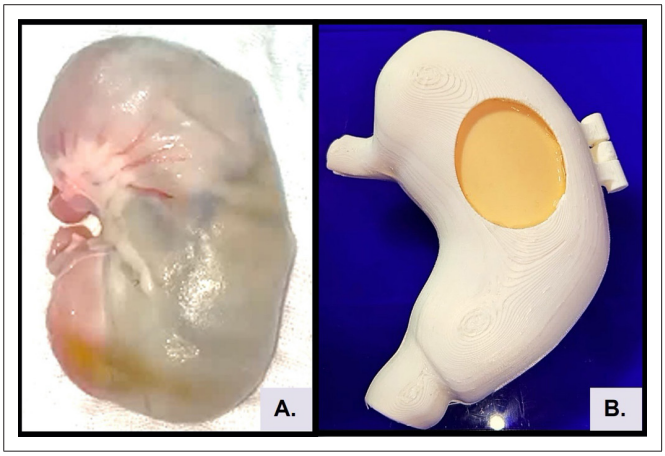


Figure 1. A) Ex vivo model of a removed adult rabbit stomach **B)** 3D printed stomach model.

Objective

To compare simulation models (ex vivo and 3D printed) for reproducing the laparoscopic gastrostomy technique in the training of novice surgeons at the University Hospital of Caracas.

Methods

A prospective, longitudinal study was conducted.[13] Eight novice surgeons, with less than three years of surgical experience, participated. They were randomly assigned to two groups according to the order in which the models were used: Group 1 (first ex vivo – second 3D) and Group 2 (first 3D – second ex vivo). Each participant completed 10 practical sessions for each model. Procedure time was recorded for each session, and three surgeons experienced in advanced laparoscopy evaluated the exercises using the Global Operative Assessment of Laparoscopic Skills (GOALS) scale.[13] Participant satisfaction was assessed using a Likert scale at the end of the training sessions.[14] The study was conducted over a 6-month period during 2023. Descriptive statistics were used to summarize mean procedure time and GOALS scores. These were compared between the first and subsequent practice sessions using a two-sample Student's t-test. A p-value <0.05 was considered statistically significant.

Procedure

For this study, a previously designed 3D-printed stomach model was used,[15] along with a rabbit stomach, laparoscopic endotrainers, and laparoscopic instruments for the exercise (atraumatic grasper, Maryland dissector, laparoscopic needle holder, laparoscopic scissors, and 3-0 Vicryl sutures).

The 3D-printed stomach was made of polylactic acid and thermoplastic polyurethane,[15] measures 8 cm in length and 6 cm in width, and incorporates a 2 x 2 cm opening on its anterior surface, where a replaceable synthetic skin

membrane is subsequently attached. "(Fig. 1B)" and "(Fig. 1A)" The ex vivo adult rabbit stomach measures 8.6 cm in length and 6 cm in width. Gastric emptying was not performed in order to preserve the model's realism (Fig. 1A).

To reproduce the laparoscopic gastrostomy technique in both models, the following steps were performed (Fig. 2).:

1. A purse-string suture with three stitches was created on the anterior wall of the stomach using 15 cm of 3-0 Vicryl (Fig. 2A, B, C, D).
2. Subsequently, a 0.5 mm incision was made in the middle of the purse-string suture using laparoscopic scissors, and the gastrostomy was enlarged with a laparoscopic dissector (Fig. 2E, F).
3. A size 10 FR Foley catheter was inserted through the incision, and the balloon was inflated with 3 cc of air (Fig. 2G, H).
4. The purse-string suture was then tied with three conventional knots to secure the catheter, and the suture ends were cut (Fig. 2I, J).
5. Traction was then applied to the Foley catheter to verify its position within the stomach (Fig. 2K, L).

After completing the procedures, photographic and digital documentation was obtained.

Results

The laparoscopic gastrostomy technique was successfully reproduced in both proposed models. Results for GOALS scores and procedure time are presented below: A statistically significant relationship was found between the number of practical sessions performed and a progressive increase in the score obtained on the GOALS scale in both simulation models. As the number of sessions increased, participants demonstrated better technical performance in both models. Scores for GOALS domains such as depth perception, bimanual dexterity, efficiency, tissue handling, and autonomy were slightly higher in the ex vivo model than in the 3D model (Table 1).

Regarding procedure time, a progressive decrease was observed in both models from the initial sessions onward, with stabilization during the intermediate sessions and the shortest times recorded in the final sessions. Mean procedure time was shorter in the ex vivo model than in the 3D model (Table 2). In both models, procedure time decreased while GOALS scores increased across sessions.

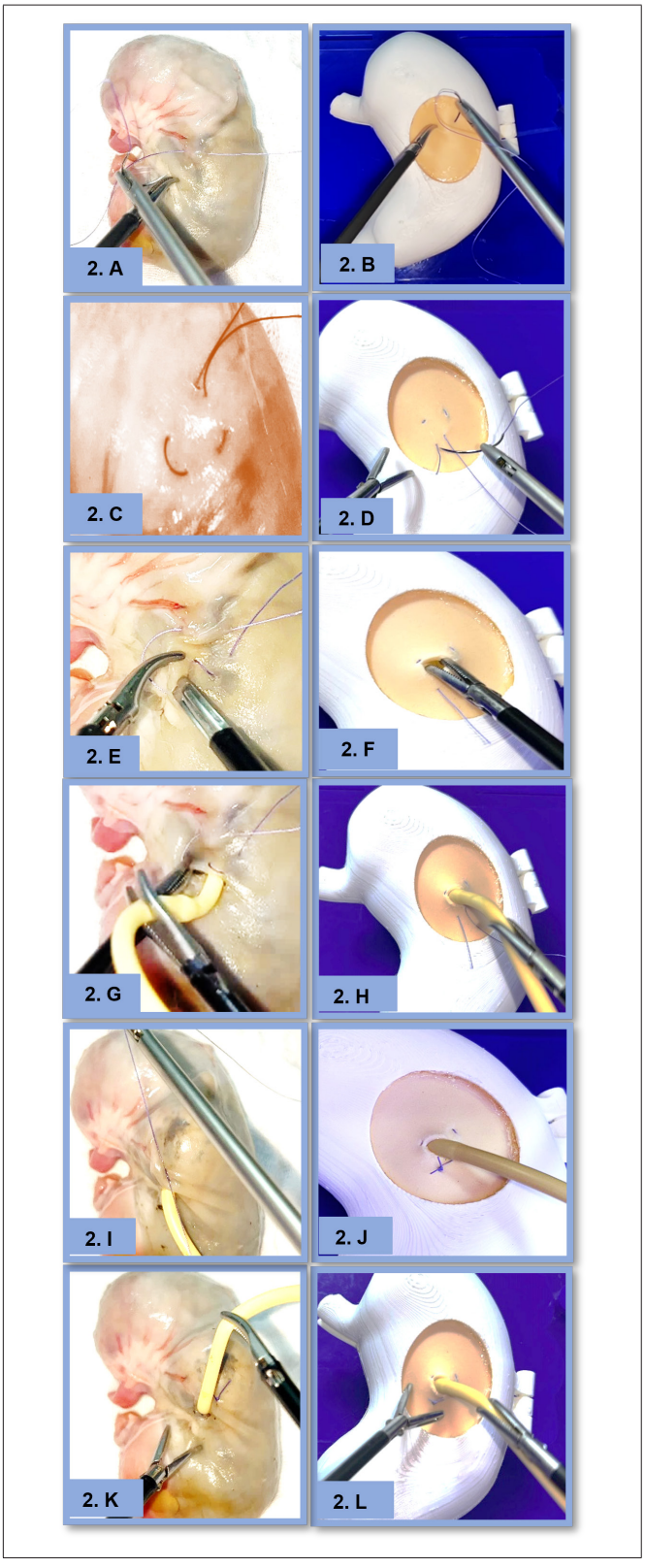


Figure 2. Reproduction of the steps of te paparoscopic gastronomy technique in both models.

An asymptotic crossover between these variables was observed at session 7 in the 3D model and at session 8 in the ex vivo model (Fig. 1 & Fig. 2).

Table 1. Average scores according to the GOALS Scale in 3D Model and ex vivo

Practice	Model 3D	Model ex vivo
Depth perception	4.0875	4.325
Bimanual dexterity	4.5625	4.55
Efficiency	4.5375	4.5375
Tissue manipulation	3.4	3.925
Autonomy	4.675	4.9
T-test	**Model 3D**	**Model ex vivo**
Average	4.2525	4.4475
Variance	0.27745313	0.12784375
Observations	5	5
Pearson correlation coefficient	0.94810338	
Hypothesized difference of means	0	
Degrees of freedom	4	
T - statistic	-1.9866567	
P(T<=t) one tailed	0.05895022	
Critical value of T (one tailed)	2.13184679	
P(T<=t) two tailed	0.11790044	
Critical value of T (two tailed)	2.77644511	

Table 2. Average time spent per practice in the 3D model and ex vivo

Practice	Model 3D	Model ex vivo
1	8.94875	8.12
2	9.67625	8.19875
3	9.52375	6.97375
4	11.44	7.87
5	10.06125	7.045
6	8.6975	6.6425
7	8.44125	7.24875
8	8.72	6.26375
9	7.3675	5.94875
10	7.32375	5.5825
T-test	**Model 3D**	**Model ex vivo**
Average	9.02	6.989375
Variance	1.52967604	0.810674
Observations	10	10
Pearson correlation coefficient	0.71638003	
Hypothesized difference of means	0	
Degrees of freedom	9	
T - statistic	7.44037434	
P(T<=t) one tailed	1.9659E-05	
Critical value of T (one tailed)	1.83311293	
P(T<=t) two tailed	3.9319E-05	
Critical value of T (two tailed)	2.26215716	

At the end of the final session, all Likert scale items received the maximum score of 5, indicating a high level of participant satisfaction.

Discussion

Simulation in laparoscopic surgery provides surgeons with a safe environment in which they can practice technical skills and apply theoretical knowledge without compromising patient safety. Previous studies have shown that simulation may help reduce operative time and postoperative complications.[2-5,7]

Previous studies have evaluated the use of simulation in surgery, utilizing anatomical models based on 3D printing and ex vivo animal models, which have proven to be efficient and cost-effective.[9,10,16,17] These models make it possible to reproduce key steps of surgical procedures with a high degree of anatomical and technical realism,[17,18] as was achieved in the present study, recreating the laparoscopic gastrostomy technique in a 3D-printed stomach model and an ex vivo rabbit stomach model.

The present study showed that repeated practice was associated with improved GOALS scores in both models; that is, with a greater number of practice sessions, the participants' skills improved in both the 3D and ex vivo models. In paral-

lel, procedure time decreased progressively across sessions and reached its lowest value during the final sessions in both models compared to the first practice sessions and finally reaching its lowest execution time in the last practice sessions for participants in both simulation models. These data are similar to those reported by Etlinger et al.[16], Rubin and Vassallo,[15] Hernández et al.[17], who demonstrated that with a greater number of practice sessions, the score obtained improved, and the time it took surgeons in training to complete the simulation exercises decreased.

In addition, scores for GOALS domains such as that in the ex vivo model, the scores obtained on the GOALS scale items, such as depth perception, bimanual dexterity, efficiency, tissue handling, and autonomy,[13] were slightly higher than in the 3D model. It should also be noted that the average execution time was longer in the 3D model exercises than in the ex vivo model. The 3D model[15] is fixed to the base of the endotrainer, is rigid and static, thus limiting mobility, and includes a synthetic skin membrane whose fragile texture created technical difficulties in preventing laceration during suturing. These characteristics may explain the lower scores and longer execution times observed with the 3D model.

On the other hand, the ex vivo model is elastic and dynamic, providing greater mobility and confidence for the participants when performing the suture. However, tissue quality is an important factor,[18] and it varied considerably from one stomach to another. A significant number of stomachs were stored and subjected to freezing and thawing processes, affecting their integrity and requiring the acquisition of more specimens. Furthermore, their handling required a greater quantity of sterile and prophylactic resources, increasing training costs. In contrast, the 3D model, which was created from ecological materials, proved to be accessible, efficient, cost-effective, and transferable,[10,11] without requiring the use of gloves or other additional supplies, thus reducing training costs.

The Likert scale is commonly used in validation studies of surgical training models because it provides structured feedback on participant satisfaction is also relevant in the evaluation of laparoscopic simulation models, as it provides structured feedback and it is commonly included in validation protocols for surgical training models. Therefore, it is widely used as part of the validation protocol for surgical training models.[14] This research demonstrated, through the application of the Likert scale, a high degree of satisfaction with the ex vivo and 3D models used in the practice sessions for replicating the laparoscopic gastrostomy technique. Although the number of participants was limited, the data obtained offer valuable insights into simulation models for replicating laparoscopic surgical techniques; however, these results should be interpreted with caution, and it is imperative to conduct larger studies to confirm these trends.

According to the literature review conducted using search resources such as PubMed®, Cochrane®, SciELO®, Google Scholar®, and Elsevier in English and Spanish, no studies were found that evaluated ex vivo simulation models with rabbit stomachs and 3D models for replicating the laparoscopic gastrostomy technique. The present study contributes to the field of experimental surgery by proposing two simulation-based training models for this procedure. It also supports the development of experimental surgery by proposing simulation-based models for surgical training with proposed training models for surgical procedures based on simulation.

Conclusion

Laparoscopic gastrostomy requires advanced surgical skills. In both proposed simulation models, surgeons in training were able to reproduce the surgical procedure the surgical procedure in a risk-free environment before performing the technique in patients. In addition to authentically recreating the steps, the models allowed for the acquisition and refinement of skills in minimally invasive surgery, confirming that a greater number of practice sessions improved the GOALS scale score and decreased the participants' execution time. Furthermore, participants reported a high level of satisfaction, with the highest possible scores on the Likert satisfaction scale at the end of the practice sessions.

Likewise, the ex vivo model provided greater mobility, comfort, and confidence for the surgeons when performing the exercises. However, tissue quality is an important factor, making its maintenance and reuse difficult, and consequently increasing training costs. On the other hand, the 3D model was technically more difficult to use during the practical exercises during the practical exercises, but it proved to be easily accessible, efficient, cost-effective, and low-cost compared to the ex vivo model. Finally, it is important to point out that in both models, the tube was not secured to the abdominal wall. This is a disadvantage of both models, but not an essential step in replicating the technique.

Disclosures

Ethics Committee Approval: This study is approved by the Central Venezuela University Ethics Committee (No: 2026-03-29_22_07_53, Date: 19/03/2026).

Peer-review: Externally peer-reviewed.

Informed consent: Consent was obtained from all participants included in the study.

Conflict of Interest: The authors declare no conflict of interest.

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Author contributions: Concept – M.V.; Design – S.L.; Supervision – M.V.; Fundings – A.M.; Materials – J.M.; Data Collection – J.M., A.M., S.L.; Analysis and/or interpretation – M.V., S.L.; Literature Search – S.L.; Writing – J.M., A.M., S.L.; Critical Review – M.V., S.L.

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