

Open appendectomy simulation model in virtual education for medical students during the COVID-19 pandemic

Modelo de simulación de apendicectomía abierta en la educación virtual para estudiantes de medicina durante la pandemia de COVID-19

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Abstract

Objective: To evaluate the skills achieved by the undergraduate medical student in performing an open appendectomy and purse string in the simulation model created, to evaluate the degree of satisfaction of its use and to determine its costs. **Method:** Pre-experimental, prospective and longitudinal study. The skills achieved by 24 undergraduate medical students in performing an open appendectomy and purse string in the simulator were evaluated using the OSATS (Objective Structured Assessment of Technical Skills) through virtual teaching. A survey was conducted to the students to evaluate the simulator and its costs were determined. **Results:** There was a significant increase in the OSATS of the skills achieved, from 7 (pre-test) to 26 ± 5.71 points (final post-test) ($p = 0.0001$) and reduction in the operative time from 12 ± 3.81 minutes (first post-test) to 8 ± 2.02 minutes (final post-test) ($p = 0.0001$). 41% of the students were totally satisfied with the achievements obtained and 59% partially satisfied. The cost of the simulator was 4.64 USD. **Conclusions:** The students achieved an improvement in their skills in the surgical technique. This simulation model is low cost and presents an adequate level in the satisfaction of the achievements obtained by the students.

Keywords: Simulation training. Undergraduate medical education. Appendectomy.

Resumen

Objetivo: Evaluar las competencias logradas por estudiantes de medicina en la realización de una apendicectomía abierta y jareta en el modelo de simulación creado, evaluar el grado de satisfacción de su uso y determinar sus costos. **Método:** Estudio preexperimental de grupo único, prospectivo y longitudinal. Se evaluaron las competencias logradas por 24 alumnos de pregrado de medicina en la realización de una apendicectomía abierta y jareta en el simulador, mediante las pautas OSATS (Objective Structured Assessment of Technical Skills) a través de enseñanza virtual. Se realizó una encuesta a los alumnos para evaluar el simulador y se determinaron sus costos. **Resultados:** Hubo un incremento significativo en las pautas OSATS de las competencias logradas de 7 (pre-test) a 26 ± 5.71 puntos (pos-test final) ($p = 0.0001$) y una reducción del tiempo operatorio de 12 ± 3.81 minutos (primer pos-test) a 8 ± 2.02 minutos (pos-test final) ($p = 0.0001$). El 41% de los alumnos estuvieron totalmente satisfechos con los logros obtenidos y el 59% parcialmente satisfechos. El costo del simulador fue de 4.64 dólares americanos. **Conclusiones:** Los estudiantes lograron una mejora de sus competencias en la técnica quirúrgica. Este modelo de simulación es de bajo costo y presenta un nivel adecuado en la satisfacción de los logros obtenidos por los alumnos.

Palabras clave: Entrenamiento simulado. Educación de pregrado en medicina. Apendicectomía.

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Introduction

During the COVID-19 pandemic, on site classes at universities around the world were put on a holding pattern, which led to having to adapt both the teaching and learning process to virtual classes. However, practical classes for medical students that were being conducted in teaching laboratories and hospitals were challenging to replace.

Acute appendicitis is the leading cause of surgical emergencies, accounting for nearly 60% of all emergency surgeries performed in the hospital setting^{1,2}. Laparoscopic appendectomy is the reference technique to treat acute appendicitis, being open surgery spared for exceptional cases, such as patients with a past history of multiple abdominal surgeries, conversion from laparoscopic appendectomy, lack of logistics in remote regions of developing countries, or technical issues with laparoscopy equipment in emergency areas. Therefore, teaching how to perform an open appendectomy on live biological simulation models (experimental animals) is part of the syllabus of the surgery course in medical centers, allowing undergraduate students to understand, assimilate, and perform the surgical procedure, and acquire surgical assistance skills as part of the general physician's professional profile.

A review of the medical literature available was conducted to find some type of simulator that could assist in teaching this type of surgery through e-learning. Some authors presented measurements of the competencies achieved, or the degrees of satisfaction and validation with the use of virtual reality software simulation models³⁻⁵. Other studies were conducted on live biological animal models⁶, or human cadavers⁷, but these options were costly and used in surgical laboratories.

Only 2 studies of low-cost simulation models were found. One used an ex-vivo porcine intestine conditioning model⁸, but these viscera were difficult to obtain during the COVID-19 quarantine. The other used a model with several latex gloves, although its construction was only partially explained⁹. All these simulators were designed for laparoscopic appendectomy in on-site teaching for surgery residents, and not for undergraduate students in virtual classes.

At our faculty, a simulation model of the cecal appendix was designed so that students could build at home so to learn and develop the skills required for this type of surgery through synchronous virtual classes.

The objective of this study was to evaluate the competencies achieved in performing an open appendectomy, establish

the degree of satisfaction and evaluation of the simulation model by the students, and finally, determine the costs of its construction.

Method

Research design

This was a pre-experimental, single-group, prospective, longitudinal, and descriptive study.

Population and sample

- Sampling type: census. The study included 24 5th-year students of Human Anatomy from Universidad Ricardo Palma during the 2021-II semester.

Inclusion criteria

- All students who were on the virtual surgery course for the first time, without prior surgical knowledge, and who were taught how to build the simulation model and perform an open appendectomy through synchronous virtual classes.
- Signature of prior written informed consent by the participant accepting inclusion in the study.
- Complete evaluations of the performance of the surgical procedure.

Data collection tools

- Cost breakdown sheet of direct materials for building the cecal appendix simulation model.
- Competency assessment sheet according to the OSATS (Objective Structured Assessment of Technical Skills) guidelines and recording of the surgical time involved (in min) regarding the performance of antegrade and purse-string suture appendectomy. These internationally validated guidelines evaluate 7 elements: tissue sparing, time and motion, instrument handling, instrument knowledge, assistance use, operation flow and planning, and specific procedure knowledge. It has minimum and maximum scores of 7 and 35 points, respectively¹⁰.
- Student survey sheet regarding the degree of satisfaction in learning and achievements, and evaluation of the simulator, validated by a panel of 7 experts (surgeons and university professors with extensive experience) with an Aiken's V coefficient of 1 ($p < 0.05$). This instrument was assessed using a Likert scale from 1 to 5, where

1 stands for strong disagreement, 2 for somewhat disagree, 3 for neutral, 4 for somewhat agree, and 5 for strong agreement.

Procedures

FIRST STAGE: DESIGN AND CONSTRUCTION OF THE SIMULATION MODEL (FIGURE 1)

The simulator was designed by the lead author, and suggestions from a group of six general surgeons and experienced university teachers from different colleges were observed for improvement purposes. An initial pilot experience with the students was also considered.

In this stage, the direct cost of the materials used to build the simulation model¹¹ was determined, considering the exchange rate for 2021 (3.99 Peruvian soles per US dollar). The materials needed to build the simulation model of the cecal appendix included a glass or hard plastic cup, a bar of yellow plasticine (preferably), a pair of sterile latex gloves sized 7 or 8, a conventional straight needle and black thread, a red pen or marker, and silicone glue or a similar adhesive.

SECOND STAGE: EVALUATION OF ACHIEVED COMPETENCIES, LEVEL OF SATISFACTION, AND SIMULATION MODEL ASSESSMENT

The virtual course on surgery and operative technique consisted of 15 practical sessions and 8 synchronous theoretical sessions via the Blackboard Collaborate platform. The 24 participating students were divided into five practice groups of 4 or 5 students, each supervised by a research teacher who showed them how to build the simulation model through a video tutorial during the fourth session of the course. This video tutorial was recorded and made available in the virtual classroom for students to build their models at home (<https://drive.google.com/file/d/1IVN1QvaZgN9xmbWy06xH1bqkzvDdYAZ0/view?usp=sharing>).

In the 6th synchronous virtual session (that went on for 3 hours), the students were taught the technique of open and laparoscopic appendectomy, both antegrade and retrograde techniques, and how to create a purse-string suture in the cecum of patients with acute appendicitis using selected YouTube videos. Afterwards, the students were shown video tutorials (Fig. 2) on how to perform an open appendectomy using the antegrade technique and purse-string suture in the simulation models built. They were taught that the purse-string suture was only performed in cases of acute appendicitis



Figure 1. Cecal appendix simulation model.

with gangrene or perforation. Students replicated the technique on their home-based simulators, and the teacher, with support from the on-site simulator, the camera, and telementoring, gave personalized guidance to improve the students' surgical skills.

At the end of this session, the teacher gave the students 2 tasks, which involved the creation of 2 unedited videos of the surgical procedure described using the simulation models. Students were required to e-mail these videos halfway through and at the end of the course. The teacher evaluated both tasks and e-mailed the corrections and recommendations to each student via email during synchronous classes.

The evaluation of the competencies achieved by the students (using the OSATS assessment form), and the measurement of surgical time, were conducted as follows:

- Pre-test (at the start of the 6th session of the course).
- First post-test (between the 6th and 7th sessions).
- Final post-test (between the 14th and 15th sessions).

The evaluations were performed by each teacher; however, for the sake of this research, such assessments were reviewed by a research surgeon and professor to make sure that assessment criteria were consistent across the evaluations.

At the end of the course, a survey was conducted among the students regarding their level of satisfaction with the achievements made in the operative technique and the evaluation of the simulation model used. Survey was anonymous via Google forms.

Data processing and analysis

The data were coded and analyzed using the Statistical Software package for the Social Sciences

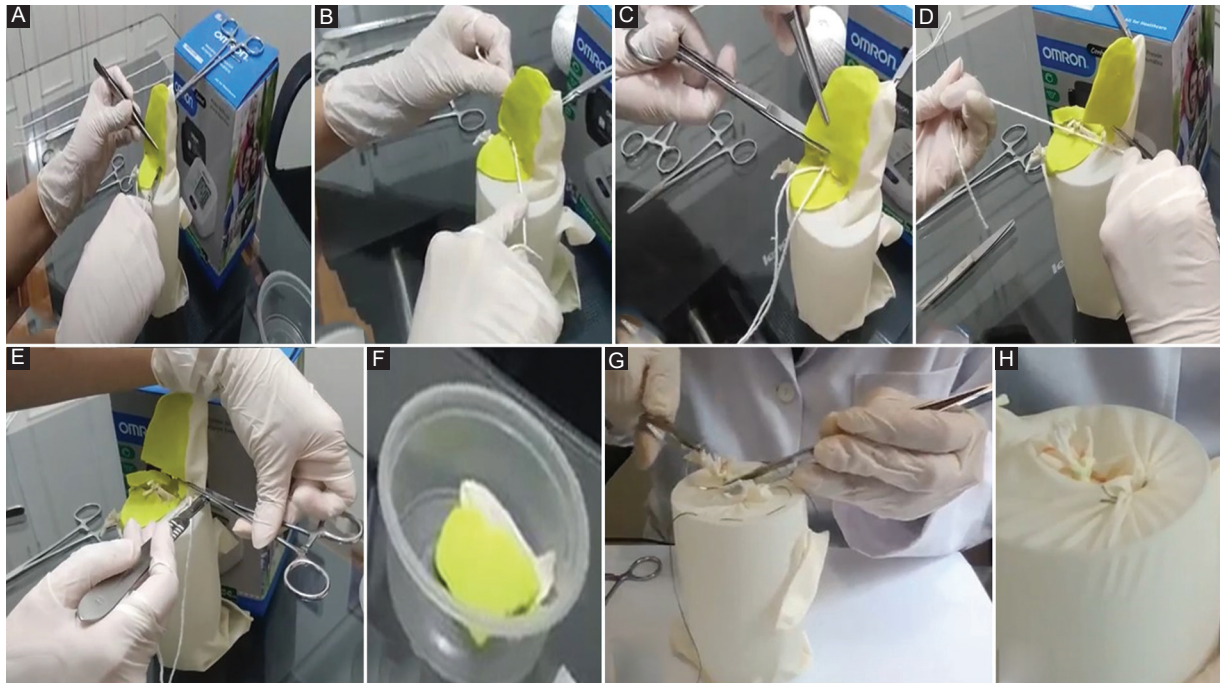


Figure 2. Steps involved in performing an antegrade appendectomy and purse-string closure. **A:** dissection of the appendiceal mesentery. **B:** ligature of the appendiceal mesentery. **C:** section of the appendiceal mesentery. **D:** ligature of the appendiceal base. **E:** appendiceal cutting. **F:** surgical piece. **G:** creation of a purse-string suture in the cecum. **H:** completed purse-string suture.

(SPSS) version 22. Data from the assessments were analyzed using the Wilcoxon test for paired non-parametric variables and the Student's t test for related parametric samples. p values < 0.05 were considered statistically significant.

Ethical considerations

Data were kept confidential to protect the identity of the participants, while ethical principles were respected across the entire study. Informed consent was explained to the students at the beginning of the course through virtual sessions and was sent to the students as a Word document. Subsequently, students filled out and signed the consent forms to participate in the study.

The research project was approved by the Research Ethics Committee of the School of Medicine of Universidad Ricardo Palma Medical School, Santiago de Surco, Peru (Committee Code: PI-010-2021).

Results

The students' mean age was 23 ± 1.47 years, 79.2% of them were women and 20.8%, men.

The OSATS score increased significantly. The OSATS measures the competencies achieved by the

students in performing an appendectomy and purse-string closure. The score went up from 7 points in the pre-test stage to 26 ± 5.71 points in the final post-test stage ($p = 0.0001$) (Fig. 3). Additionally, the time required to perform the surgical procedure shortened from 12 ± 3.81 min in the first post-test to 8 ± 2.02 min in the final post-test ($p = 0.0001$) (Fig. 4).

The results of the survey conducted among the students on their satisfaction on the achievements made and the evaluation of the simulation model are shown in figure 5. We should mention that all students were satisfied with the achievements made, 41% being completely satisfied and 59% partially satisfied.

The main advantages identified by the students in the applicability of the simulator were the ease of acquiring materials (100%), low cost (83%), reproducibility (83%) easy building, (67%) and realism (58%). On the other hand, the setbacks were difficulties handling plasticine models that were too hard or did not adhere properly if the instructions for gluing were not followed properly (33%), the model not bleeding like live models (4.2%), and the model not having the same consistency as real organs (4.2%).

The direct costs of the materials used to build the simulation model of the cecal appendix amounted to USD 4.64 (Table 1).

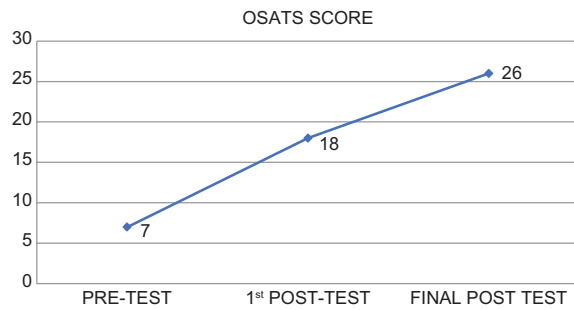


Figure 3. Comparative score of the OSATS assessment tool to evaluate the competencies in performing antegrade appendectomy and purse-string closure.

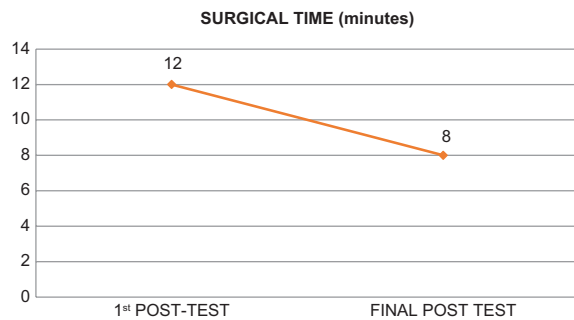


Figure 4. Comparative operative time between the first post-test and the final post-test.

Table 1. Direct costs of materials for building the cecal appendix simulation model

Quantity	Description	Cost (Soles)	Cost (US Dollars)
1	Box of modeling clay	4.9	1.22
1	Pair of latex gloves, size	1	0.25
1	Spool of thread	2	0.5
1	Straight needle	1	0.25
1	Red pen	1	0.25
1	Glass tumbler	4.9	1.22
1	Bottle of silicone	3.8	0.95
Total		18.6	4.64

Discussion

During the COVID-19 pandemic, the paradigm of surgical simulation had to shift from teaching laboratories to the students' homes. Therefore, it was essential to

create a simulation model using easily accessible materials to allow students to perform the surgical procedure and develop the necessary skills and competencies. At the same time, it was crucial to assess the surgical competencies achieved.

A review of the PubMed database revealed a lack of studies evaluating cognitive performance, or competencies in surgeons, surgery residents, or medical students in performing open appendectomies¹². Overall, there are very few studies on the skills acquired by surgeons or residents using open surgery simulation models¹³.

Most existing studies on appendectomy simulation were for laparoscopic surgery training and conducted in an on-site setting. They used materials such as latex gloves and foam rubber or similar materials^{9,14}, porcine visceral models^{8,15}, ex vivo chicken parts¹⁶, in vivo biological animal models, human cadavers⁷, and even virtual reality simulators^{3-5,7}. Some of these studies showed improved skills and proficiency in this surgical technique with the use of these simulators^{3-5,7}. However, none of them presented a simulator for open appendectomy in virtual teaching.

The only reported research on measuring the skills of undergraduate medical students in performing open appendectomies on a live biological model (rabbit) after completing an in-person surgery training course determined a modified OSAT score of $70 \pm 14\%$ ¹⁷, which is almost similar to what our study found in the final post-test stage (26 ± 5.71 points) representing $74 \pm 16\%$. This demonstrates that the educational objective can be achieved with the model presented through e-learning, just as in face-to-face learning.

Considering that open appendectomy is performed when laparoscopy is not feasible, it is essential for medical interns, general practitioners, rural service doctors, and surgery residents to be prepared to provide surgical care in these cases. Additionally, practical training in this type of surgery allows students to develop their surgical skills, including dissection of structures, coordination of movements, ambidextrous instrument handling, performing knots and sutures, knowing and synchronizing the steps of this surgical procedure as a comprehensive exercise to optimize and refine the surgical competencies of a general practitioner for the benefit of patients in all urban and rural regions of the country.

Regarding the cost of creating the simulator, it has the lowest reported cost (USD4.64) compared to a model of the cecal appendix made from porcine intestines ex vivo⁸, (£15). Also, our simulator offers the advantages of easier

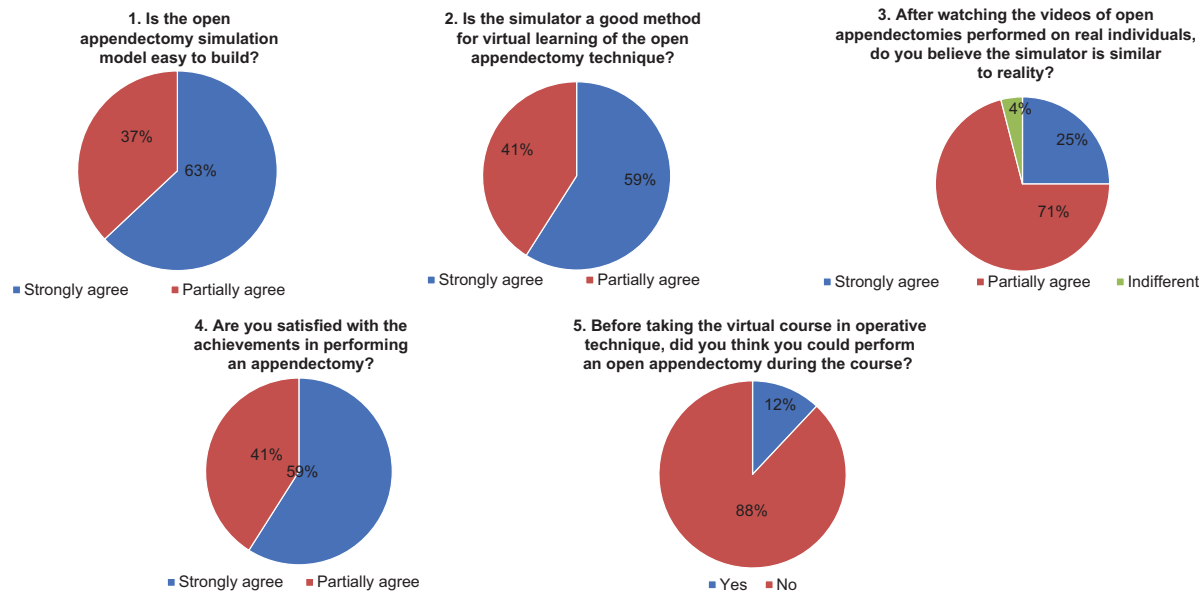


Figure 5. Descriptive graphs of the survey results.

construction and availability of the materials used while silicone intra-abdominal organ laparoscopic training simulation models are available online for USD361, which makes them economically inaccessible for most teaching students, especially during the pandemic.

The presented simulation model achieves the educational objective at a low economic cost, making it cost-effective. This ensures inclusive, equitable, and high-quality education. One of the challenges of educational virtualization is to identify and leverage the most efficient learning tools developed during the pandemic for ongoing use in virtual, face-to-face, or hybrid education based on the students' needs.

Limitations of the study

Due to the pandemic, the study limitation was not measuring the competencies achieved in clinical practice or live animal experimentation models in laboratories and comparing them to those of students in the in-person course. This should be considered in future research.

Conclusions

Students were able to develop surgical skills and competencies, improved their scores in the assessment of competencies achieved in the surgical technique used, and reduced the operating time for open appendectomies.

This simulation model is easily reproducible and feasible due to the low cost of the materials used and received an appropriate level of satisfaction from the students.

Funding

None declared.

Conflicts of interest

None declared.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

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