Received: 24 March 2022 | Revised: 2 May 2022 | Accepted: 6 May 2022
DOI: 10.1002/ca.23912

COMMUNICATION

CLINICAL ANATOMY WILEY

Presentation of preclinical gastrointestinal anatomy via laparoscopic simulation

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Funding information
University of Nebraska Medical Center, College of Medicine, Educational Support Grant

Abstract

In this report, the authors examine the integration of teaching anatomical science with clinical implications in minimally invasive surgery. The authors hypothesized that implementation of integrated laparoscopic simulation during undergraduate medical education would improve student learning of anatomical structures from in situ, laparoscopic orientations; and subsequently improve student preparation for clinical rotations and clerkships. During the fall of 2020 and 2021, 260 (130 students/year) second year medical students at the University of Nebraska Medical Center participated in a six-week gastrointestinal curriculum. Following a traditional anatomy dissection experience, students completed a laparoscopic event consisting of narrated laparoscopic videos and hands-on laparoscopic simulation. To examine the integrated curricular event, outcome measures focused on technical performance using grasping forceps, anatomical knowledge, and perception of the educational innovation. Outcomes were analyzed via timed performance and a pre and post assessment that was designed to assess student anatomical knowledge and perception. Completion of the technical performance assessment ranged from 1 min, 17 s to 6 min. Student knowledge of anatomical structures from in situ, laparoscopic orientations following the laparoscopic simulation sessions was significantly improved (53.3% pre vs 81.0% post), and almost all students (98.9%) agreed that the simulation sessions improved their understanding of laparoscopic anatomy and procedures. This report demonstrates the implementation of a multidisciplinary, integrated simulation that satisfied basic science anatomy teaching objectives, while enhancing student enthusiasm for the content. Future studies will examine the subsequent impact of the innovation on student preparedness for clinical rotations and clerkships.

KEYWORDS
anatomy, laparoscopic surgery simulation, undergraduate medical education

1 | INTRODUCTION

The traditional structure of undergraduate medical education (UME) across the United States has consisted of a four-year curriculum composed of 2 years dedicated to the basic sciences, and two subsequent years of required clinical clerkships and electives that culminate in being awarded a Doctor of Medicine (M.D.) or a Doctor of Osteopathic Medicine (D.O.). This methodology was a result of the Flexner report; however, more recently, UME has undergone dramatic curricular reform to better integrate the basic and clinical sciences (Brauer & Ferguson, 2015). In this post-Flexnerian world, new integrated curricula dissolve the separation of basic science education and subsequent clinical rotations, thus forcing students to approach the basic sciences alongside clinical correlations and clinical practice. This transformation in UME is the result of medical graduates requiring better preparation for the ongoing rapid growth of medical knowledge, technological advancements, and changing patient and societal expectations (Irby, 2011; Mahan & Clinchot, 2014). These efforts present unique challenges to basic science and clinical course work, which requires significant student contact hours and faculty dedicated to integration of UME.

Beginning in the fall of 2017, The University of Nebraska Medical Center (UNMC) College of Medicine implemented a new curriculum based on active-learning principles that emphasize hands-on learning techniques, small-group interaction, technology, research, and inquiry. Similar changes in medical school curricula that are anchored in integrated, interdisciplinary innovation, have been implemented throughout the United States, Canada, the United Kingdom, Ireland, and Australia (Kingdom, 2009; McOwen et al., 2020; Prideaux, 2009; Quigley, 2007). As part of UME reform at UNMC, an integrated gastrointestinal curriculum was implemented during the fall of 2018. The six-week curriculum covers developmental and adult anatomy, histology, and physiology of each of the major gastrointestinal organs; as well as digestion, absorption, and utilization of macro and micronutrients. Additionally, disease processes of these organs and abdominal regions are presented, focusing on the molecular and physiological mechanisms of disease and approaches to pharmacological and surgical treatment. While the implementation of integrated curricula stresses student acquisition of the basic sciences while at the same time integrating the emerging knowledge and abilities that are critical to patient care and the development of the modern physician, a recent review by Estai and Bunt stated that the impact of curricular reform on the retention of anatomical knowledge and future surgical competencies remains undefined (Estai & Bunt, 2016).

Acknowledging the pedagogical benefits of active learning and the advancements in surgical simulation, the authors developed and implemented a novel event that integrates the teaching of anatomical science with clinical implications in minimally invasive surgery (MIS) via laparoscopic simulation. The research aims associated with this curricular event were designed to address the national trend in UME curriculum integration and the unknown impact that curricular reform will have on both the anatomical sciences and future surgical competency via annual analysis of the efficacy of the active learning event. The authors hypothesized that implementation of integrated laparoscopic simulation would improve student understanding of laparoscopic anatomy and procedures. The authors also hypothesize that secondary benefits would be achieved by simultaneously offering students the opportunity to obtain laparoscopic skills and recognize the clinical application of basic sciences which will better prepare students for clinical rotations and clerkships.

2 | MATERIALS AND METHODS

2.1 | Study design

A retrospective cohort study of 260 second year preclinical medical students (cohort demographics: 79.5% Nebraska residents and 20.5% non-residents; 51% male and 49% female; 94% of age 20–25, 4.5% of age 25–30, and 1.5% of age over 30; 3.85 average entrance GPA and 512 average entrance MCAT) who in the fall of 2020 and 2021 (130 students per year) participated in a six-week integrated gastrointestinal curriculum at a single allopathic medical school in the United States was performed. An educational innovation involving laparoscopic simulation (detailed below) was included as an adjunct to lecture and gross anatomy laboratory coursework. This study was deemed IRB exempt, UNMC IRB #258-21-EX. Additionally, the use and study of cadaveric donors at UNMC is classified IRB exempt, UNMC Policy 8007. The authors state that every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research (Iwanaga et al., 2022).

2.2 | Educational innovation (intervention)

During the first 2 weeks, students completed a traditional anatomy dissection experience of the anterior abdominal wall, peritoneal cavity, and abdominal viscera. Four students were assigned per cadaveric donor with hands-on dissection occurring over the course of 16 faculty-facilitated hours.

As part of the six-week integrated gastrointestinal curriculum, a traditional gross anatomy practical examination consisting of 64 pinned cadaveric, constructed response questions was administered at the end of the second week to assess student learning. Eighteen days later, students were provided with a novel educational innovation involving a laparoscopic simulation event that was presented as three subsequent sessions designed to build upon one another (Figure 1).

2.2.1 | Session 1

This session consisted of seven laparoscopic videos (combined length of 12 min and 25 s) that were made available on the UNMC Canvas Learning Management System (LMS) via a campus multi-tactile video wall. Student groups were able to view the videos as a preview for Session 2 and Session 3. Videos included instruction on port-insertion and a visual review of abdominal anatomy from a laparoscopic view (Figure 2A). The videos were taken during a training session for MIS at UNMC using a lightly embalmed cadaveric donor and captured specifically for this activity. This session was developed by one UNMC MIS faculty member and one UNMC faculty director of the gastrointestinal curriculum.

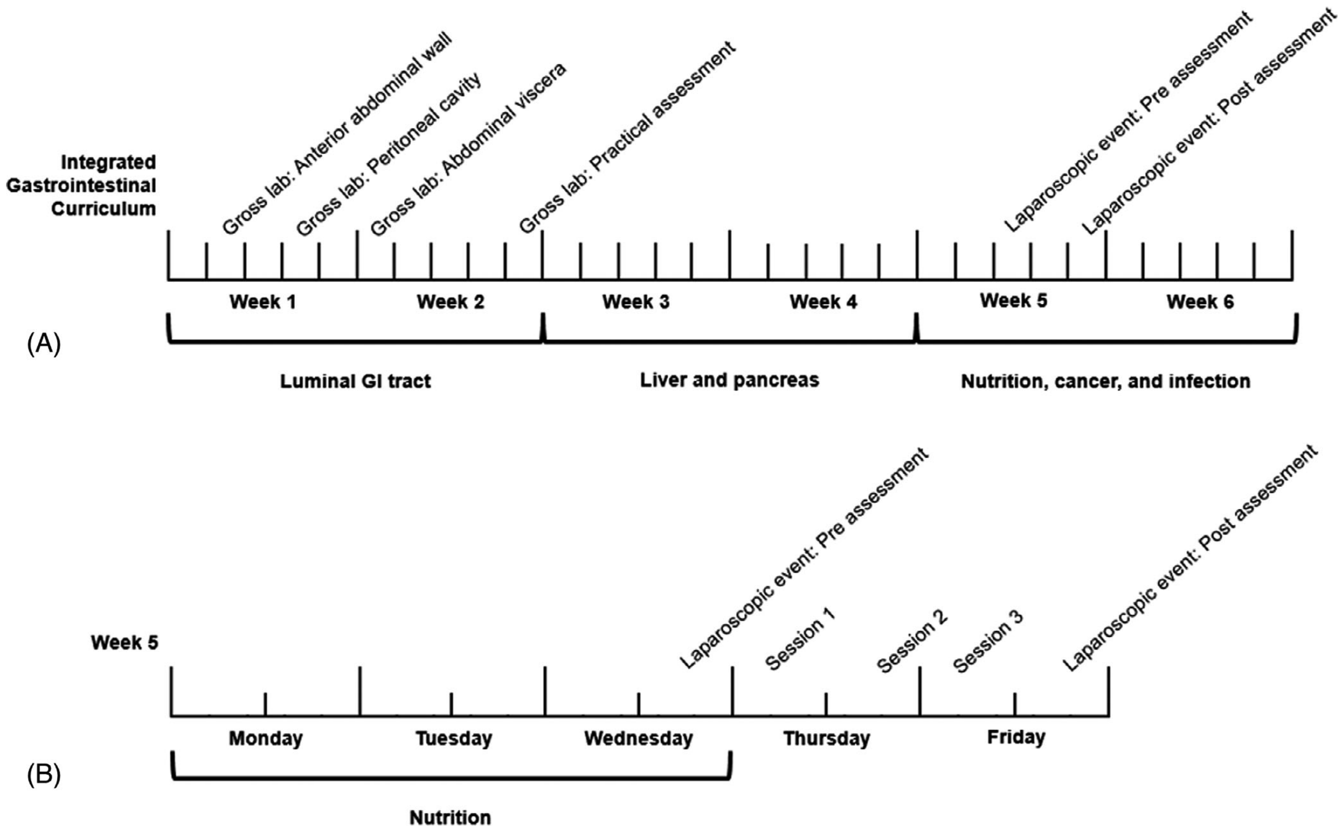

FIGURE 1 Study design. (A) During the first 2 weeks, students completed a traditional anatomy dissection experience of the anterior and posterior abdominal wall, peritoneal cavity, and abdominal viscera. A traditional anatomy practical examination was administered at the end of the second week to assess student learning. Three weeks later, week 5, students were provided with a novel educational innovation involving a laparoscopic simulation event that was presented as three subsequent sessions designed to build upon one another. (B) The three novel education sessions were framed by immediate pre and post assessments.

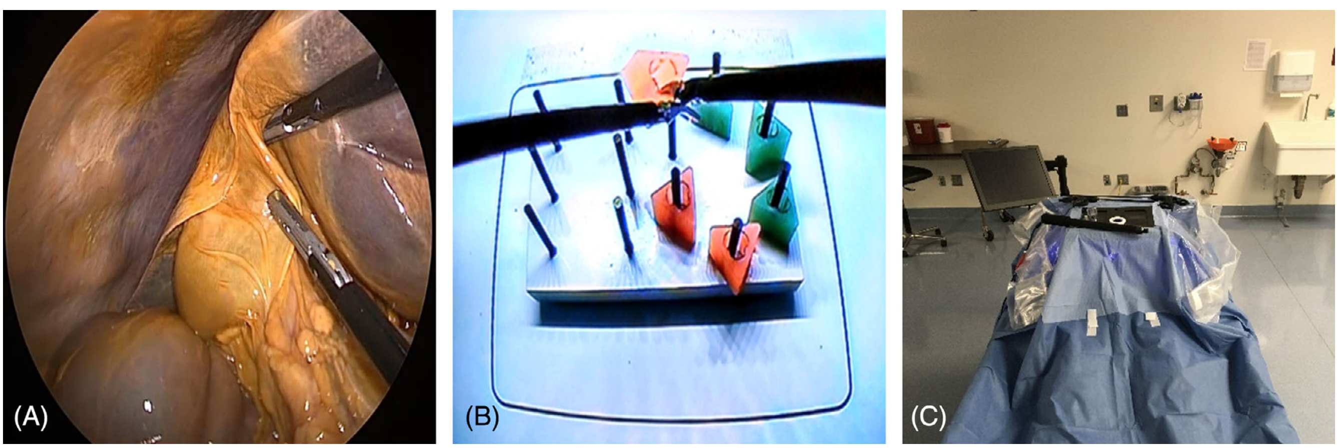

FIGURE 2 Laparoscopic simulation sessions. (A) Session 1 consisted of seven laparoscopic videos that included instruction on port-insertion and a visual review of abdominal anatomy from a laparoscopic view (video still frame). The videos were taken during a training session for MIS at UNMC using a lightly embalmed cadaveric donor and were captured specifically for this activity. (B) Session 2 consisted of a hands-on student activity, practicing the basic operation of laparoscopic grasping forceps using a commercial FLS laparoscopic trainer (Limbs & Things, #50302). (C) Session 3 consisted of a hands-on student activity that included a visual review of abdominal anatomy from a laparoscopic perspective while using a commercial laparoscopic simulator to practice fundamental skills of laparoscopic surgery: Trocar insertion via laparoscope guidance, camera operation and navigation skills, and fundamentals of viscera manipulation. Two anatomically embalmed human cadaveric donors and laparoscopic simulators (Inovus Medical Pyxus Pro Move, Laparoscopic Simulators) were utilized.

2.2.2 | Session 2

This session consisted of a hands-on student activity, practicing the basic operation of laparoscopic grasping forceps. This session utilized commercial Fundamentals of Laparoscopic Surgery (FLS) laparoscopic trainer boxes with camera and pegboard with triangles for transfer (Limbs & Things, #50302). Working in groups of two, students had 50 min to practice the maneuvering and transfer of small three-dimensional objects across the pegboard while viewing the field in two dimensions (Figure 2B). It should be noted that students had no previous formal training or time to practice prior to Session 2. While this session helped prepare students for Session 3 and provided a foundation in MIS technique, a vast majority of students were handling laparoscopic instruments for the first time. Each 50-min session event was directed by one UNMC faculty director of the gastrointestinal curriculum who oversaw eight students at a time, four pairs each pair working with their own FLS laparoscopic trainer box.

2.2.3 | Session 3

This session consisted of a hands-on student activity that included a visual review of abdominal anatomy from a laparoscopic perspective and practicing fundamental skills of laparoscopic surgery: trocar insertion via laparoscope guidance, camera operation and navigation skills, and fundamentals of viscera manipulation.

Two anatomically embalmed (isopropyl alcohol, ethylene glycol, phenol, formaldehyde) human cadaveric donors were utilized and prepared via an incision through the superficial fascia, musculature, and deep fascia along the entire length of the subcostal margin to the midaxillary lines, and from the midaxillary lines to the iliac crests. Subsequently, the peritoneal cavity was exposed via reflection of the anterolateral abdominal wall inferiorly. Laparoscopic simulators (Inovus Medical Pyxus Pro Move, Laparoscopic Simulators) were custom mounted on adjustable legs and positioned over the peritoneal cavity. Donors were covered with surgical draping leaving only the pseudo abdominal wall of the laparoscopic simulators exposed (Figure 2C). Donor preparation was completed by one UNMC faculty anatomist.

Working in groups of four, students had 50 min to practice trocar insertion and exploration of the abdominal organs. Each student had a chance to maneuver the camera and to utilize the grasping forceps. Each 50-min session event was directed by two UNMC MIS faculty members who oversaw eight students at a time, two groups of four students each group working with their own donor and simulator. MIS faculty provided students with a verbal presentation and walkthrough of the simulation model followed by a guided verbal and manual introduction to laparoscopic ports, instruments, and camera. Students rotated between the role of laparoscopic camera operator, laparoscopic instrument operator, and assistant. With each rotation student groups were provided with a specific task for identification of particular anatomic structure (such as gallbladder and appendix), and then asked guiding questions regarding relevant anatomic landmarks to confirm landmarks and features to determine if the task was achieved. The instructions encouraged students to use anatomical relations and topographical features of solid organs and abdominal viscera when discussing teamwork in laparoscopic tasks.

The laparoscopic simulation sessions involved three different venues on the UNMC campus and took place on back-to-back days during week five of the six-week, integrated gastrointestinal curriculum.

2.3 | Outcome measures

2.3.1 | Student technical performance of laparoscopic skill

Student technical performance of laparoscopic skill was measured as the time to complete the peg transfer task (Session 2) which was modeled on the FLS certification exam. Students working in pairs were allowed to interact and practice with the FLS laparoscopic trainer boxes previously described. This practice session concluded with each student completing a timed transfer. Each student completing a timed transfer of all six objects from one side of the peg-board to the other and back, including a mid-air handoff. Any dropped objects could be retrieved if they remained in the designated rectangle and were excluded if dropped outside this area. Times for completion were plotted as a waterfall or box-and-whiskers plot.

2.3.2 | Student anatomical knowledge

Due to the similarity of assessment format (cadaveric gross anatomy), results from the gross anatomy practical examination administered at the end of the second week were used to establish a baseline level of gross anatomical knowledge. The three laparoscopic sessions were framed by immediate pre and post assessments via UNMC Canvas LMS. Assessments consisted of 20 digitally pinned cadaveric questions, including five abdominal anatomy images from an open field view and 15 abdominal anatomy images from a laparoscopic view. The pre and post assessments in 2020 and 2021 consisted of the same 20 digitally pinned cadaveric questions; however, in 2020 the assessment questions were formatted as constructed response questions, while in 2021 the assessment questions were formatted as multiple-choice questions. Pre and post performance were compared to the established baseline level of gross anatomical knowledge. Gross baseline and pre and post assessment of student performance were analyzed via ANOVA with post-hoc Tukey Test, $p < 0.05$.

2.3.3 | Student perception of the educational innovation

Student perceptions and evaluation of the laparoscopic simulation sessions were collected following the anatomical knowledge post assessment. Data collection utilized the UNMC Canvas (LMS) and included one Likert based statement, "The laparoscopic simulation improved my understanding of laparoscopic anatomy and procedures" and one constructed response statement, "Please provide any comments you have on the laparoscopic clinical skills events." Examination of student constructed responses were performed to subjectively categorize positive or negative student perceptions. Words or phrases such as: beneficial, great opportunity, and helpful, were viewed as positive remarks while words or phrases such as: rushed, not enough time, and difficult, were viewed as negative remarks.

3 | RESULTS

3.1 | Student technical performance of laparoscopic skill

Two hundred fifty-seven second-year medical students who participated in the six-week integrated gastrointestinal curriculum during 2020 and 2021 completed Session 2. Students took from 1 min, 17 s to 6 min to complete all 12 peg transfers, 6 forward and 6 back. The median time in 2020 was 2 min, 35 s and in 2021 was 2 min 33 s (Figure 3).

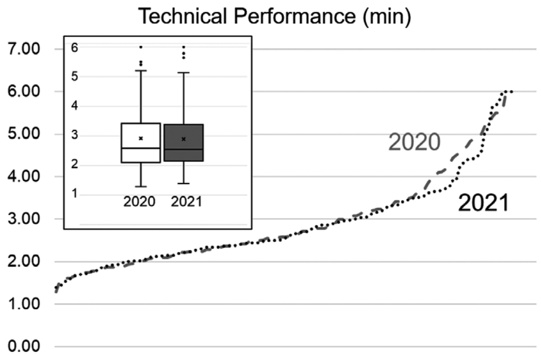

FIGURE 3 Student technical performance of laparoscopic skill for consecutive years. Students took from 1 min, 17 s to 6 min to complete all 12 peg transfers, 6 forward and 6 back. The median time in 2020 was 2 min, 35 s and in 2021 was 2 min 33 s.

3.2 | Student anatomical knowledge

One hundred fifty-four of the second-year medical students who participated in the six-week integrated gastrointestinal curriculum during 2020 and 2021 submitted complete pre and post assessments. Of the five questions on pre and post assessments that were open field views of abdominal anatomical structures, student gross baseline performance (86.0%) was significantly better than pre assessment performance (74.0%), and student post assessment performance (84.4%) was significantly better than pre assessment performance (Figure 4A). Of the 15 questions on pre and post assessments that were laparoscopic views of abdominal anatomical structures, student gross baseline performance (86.0%) was significantly better than pre assessment performance (53.3%), and student post assessment performance (81.0%) was significantly better than pre assessment performance (Figure 4B). Additionally, student pre assessment performance on open field view questions (74.0%) was significantly better than pre assessment performance on laparoscopic view questions (53.3%), (Figure 4A,B, #).

3.3 | Student perception of the educational innovation

One hundred ninety-eight of the second-year medical students who participated in the six-week integrated gastrointestinal curriculum during 2020 and 2021 provided a response to the Likert based statement, "The laparoscopic simulation sessions improved my understanding of

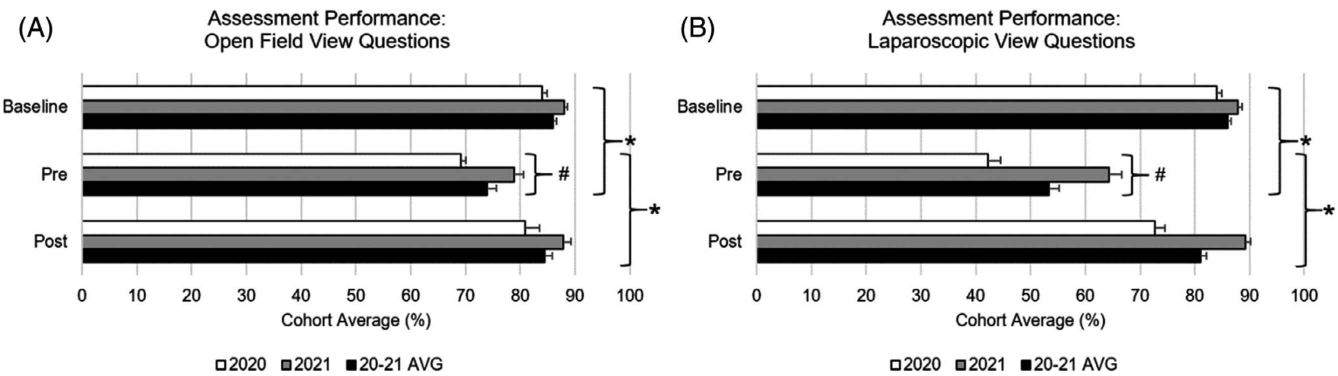

FIGURE 4 Student anatomical knowledge. (A) Open field view performance. Student gross baseline performance (mean 2020–2021: 86.0%) was significantly better than pre assessment performance (mean 2020–2021: 74.0%), and student post assessment performance (mean 2020–2021: 84.4%) was significantly better than pre assessment performance ($p < 0.05$, *). (B) Laparoscopic view performance. Student gross baseline performance (mean 2020–2021: 86.0%) was significantly better than pre assessment performance (mean 2020–2021: 53.3%), and student post assessment performance (mean 2020–2021: 81.0%) was significantly better than pre assessment performance ($p < 0.05$, *). Additionally, student pre assessment performance on open field view questions (mean 2020–2021: 74.0%) was significantly better than pre assessment performance on laparoscopic view questions (mean 2020–2021: 53.3%) (Panels A and B, #)

laparoscopic anatomy and procedures." Almost all students (98.9%) agreed that the simulation sessions improved their understanding. Of those students who agreed, 68.1% strongly agreed and 30.8% agreed with the statement. Two students neither agreed nor disagreed that the simulation sessions improved their understanding, and no students disagreed with the statement (Figure 5). When asked to provide comments on the laparoscopic simulation sessions, results were overwhelmingly positive, including the following selected statements.

> *This event helped me to remember why I am studying. It was nice to get some hands-on time away from a computer screen. It will be **beneficial** to have this basic understanding when we get to our surgery rotation next year. Thank you.*

> *Laparoscopic skills day was awesome. The only thing I wish, was that we had **more time** to spend practicing with some of these skills! I also want to say thank you all for the **opportunity** and for taking the time to begin teaching us these cool skills!*

> *This was my favorite clinical skills day we have had. It **helped** me to better understand the abdominal anatomy in a clinical setting and was fun.*

The primary criticism of the laparoscopic simulation sessions was that students wanted more time with the hands-on sessions. Of the 118 commentaries that were received, 22 students (18.6%) mentioned that more time with the hands-on sessions would have been beneficial.

4 | DISCUSSION

In 2001, Fitzpatrick et al reported on the feasibility of laparoscopic anatomy training in embalmed cadavers (Fitzpatrick et al., 2001).

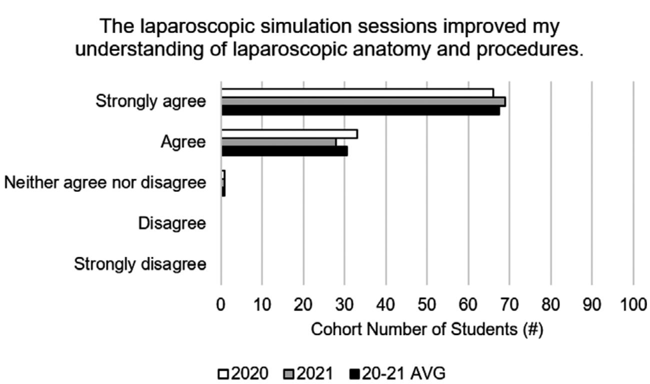

FIGURE 5 Student perception of the educational innovation. Almost all students (98.9%, 196/198) agreed (68.1%, 135/198, strongly agreed and 30.8%, 61/198, agreed) with the statement, "The laparoscopic simulation sessions improved my understanding of laparoscopic anatomy and procedures." Two students neither agreed nor disagreed that the simulation sessions improved their understanding, and no students disagreed with the statement.

Subsequently, Glasgow et al. and Saberski et al. have shown that instruction in gross anatomy with laparoscopy supplement resulted in positive student perception and stimulating of interest in general surgery (Glasgow et al., 2006; Saberski et al., 2015). In addition, Shakir et al has previously highlighted the benefits of medical students acquiring laparoscopic skills, and ultimately developed a laparoscopic course prior to student placement in surgical specialties (Shakir et al., 2014). Acknowledging the national trend in UME curriculum integration and the unknown impact that curricular reform will have on both anatomical science retention and future surgical competency, the authors of this study implemented integrated teaching of anatomical science with clinical implications in minimally invasive surgery. The described curriculum builds upon curricula reported in prior publications and echoes previous findings of positive student perception (Glasgow et al., 2006; Saberski et al., 2015; ten Brinke et al., 2014). In addition, the authors quantified the benefit of students using hands-on laparoscopic simulation to improve their understanding of laparoscopic abdominal anatomy, thus complementing their open field dissection experience.

Throughout the analysis of student technical performance of laparoscopic skill, friendly competition was encouraged as the top times were periodically posted throughout the activity. As previously noted, a vast majority of students were handling laparoscopic instruments for the first time and had no previous formal training or time to practice prior to Session 2. For reference, a time of 48 seconds is required for proficiency for fourth-year surgery residents (Hafford et al., 2013; McCluney et al., 2007).

Following the laparoscopic simulation event, student global understanding of clinical abdominal anatomy was significantly better. Most notably, was the drastic improvement in student performance on questions associated with laparoscopic views of abdominal anatomy. It should be noted that students participating in the six-week integrated gastrointestinal curriculum had little to no experience viewing abdominal anatomy from a laparoscopic view and as second year (preclinical) medical students had only formally been assessed on their anatomy knowledge from an open field view. The discrepancy in pre and post performance between 2020 and 2021 data and can be explained by the change in question formatting from a more challenging constructed response format to multiple-choice format. The change to multiple-choice format allowed for ease of performance analysis, and it is important to note that the ratio of percent differences between pre and post performance were still consistent in 2020 and 2021. In addition, it is important to acknowledge that while the assessment format (cadaveric constructed response questions) used to establish the baseline level of gross anatomical knowledge was similar, the framed pre- and post- assessments were presented as digital images opposed to pinned cadaveric tags. At this point in their medical curriculum, students had little to no experience taking digital anatomy practicals and had an 18 day "anatomical break" in their curriculum at the time of pre assessment.

A Study by Rosenthal et al on training for laparoscopic skill development have demonstrated that students trained to competency retain their skills for at least a year, while Sant'Ana et al observed that even 1 year after a short training session, medical students without previous surgical experience had retained a great part of the skills acquired through training (Rosenthal et al., 2010; Sant'Ana et al., 2017). Orlando et al demonstrated that there is some benefit of cross-training between robotic and laparoscopic skills when skills were practiced at least 10 consecutive times (Orlando et al., 2017). While the current study did not attempt to train students toward surgical skill proficiency, it did seek to increase anatomic knowledge with clinical integration. The strength of the current study is in focusing on improved abdominal anatomical knowledge rather than improved skills. As this curricular event is part of a preclinical course, our primary goal is related to the basic science foundation of MIS more than advancing student skill in surgical technique. The quantitative improvement seen following the laparoscopic simulation events reflected an improved understanding of content designed to test abdominal anatomy knowledge. The questions on the pre and post assessment were intentionally designed to be challenging, allowing for a significant change upon improved understanding.

The benefits of our approach have been shown in the areas of positive perception and engagement, feasibility, teamwork, relevance, and initial skill development. Foremost, this activity is feasible for UME with low capital expenses and utilizing local expertise available at all medical schools. We engaged clinical and basic science faculty and observed student engagement and enlivened education. Even during the coronavirus pandemic of 2020, we were able to safely implement this activity, with the added acknowledgement of the role of personal protective equipment in protecting the patient and caregiver during surgery, in this case protecting the students and instructor. The need for teaching and practicing teamwork in medicine is clear (Lerner et al., 2009). Teamwork in designing the activity included faculty from four different departments. Teamwork among students included having student pairs for timing and observing the peg transfer activity, and student coordination of camera position and grasper use in the cadaver lab. As a single student cannot complete the task of locating and identifying structures, teamwork is built into the task. Students in our program receive training on teamwork largely based on the TeamSTEPPS program (King et al., 2008). This activity requires the practice and implementation of teamwork, especially communication and situation monitoring concepts. We strived for an experience that would emphasize anatomical science but would also prime students for the clinical application. Thus, we incorporated on of the laparoscopic training tasks already in place for licensing surgical trainees, the peg transfer. Next, we consulted with faculty from the surgical clerkship and included a minimally invasive surgeon on our team to ensure that the simulated surgical activity was relevant for the students' next steps. Without intending to promote skills competency or retention, we still introduced initial skill development through this intentional consideration of the surgical skills most commonly tasked to a medical student (camera operation) and relevant for future surgical training (instrument utilization for peg transfer) (Abbas et al., 2015).

It is important to acknowledge that the assessment of the laparoscopic simulation sessions included curricular limitations. A quantitative control group who did not experience the activities but took the pre- and post- assessment could not be utilized due to academic fairness and the desire for all students to experience the simulation sessions. Additionally, it is possible that exposure to the Pre assessment aided student performance on the Post assessment. Ergonomic limitations in hands-on sessions should also be noted (Armijo et al., 2022). Accommodations were made for all heights through adjustable tables and operating room steps/platforms during Session 2 and Session 3; however, it has been shown that operators with smaller hands have increased muscle strain using the most common laparoscopic instruments (Berguer & Hreljac, 2004; Sutton et al., 2014). We recognize and agree that smaller hands deserve instruments designed to fit and perform (Catanzarite et al., 2018; Schlussel & Maykel, 2019; Sutton et al., 2014).

5 | CONCLUSIONS

This study and curriculum advance the literature demonstrating the benefits of utilizing cadaveric donors to educate and train medical students in anatomy and MIS techniques. Acknowledging that the long-term impact of curricular reform on the retention of anatomical knowledge and future surgical competencies are not yet determined, the authors envision the described laparoscopic simulation event as an ideal platform for the continued assessment of the impact of curricular reform. The authors aim to reevaluate student performance and perception during required clinical clerkships and electives, and potentially into surgical residency programs. Overall, this study demonstrates that clinical and basic science faculty could implement an integrated experience that satisfied basic science anatomy teaching objectives and also maintained and enhanced student enthusiasm for the content.

ACKNOWLEDGMENTS

This project was supported by University of Nebraska Medical Center, College of Medicine Educational Support Grants. The authors would like to thank the College of Medicine for their unwavering support of UNMC students, faculty, and innovative medical education. We thank our students who maintain a drive to serve others. Additionally, we thank anatomical donors for graciously donating their bodies for the continued advancement of basic and clinical science education.

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How to cite this article: McCumber, T. L., Mott, J. L., Merani, S., & Rochling, F. A. (2022). Presentation of preclinical gastrointestinal anatomy via laparoscopic simulation. *Clinical Anatomy*, *35*(7), 953–960. https://doi.org/10.1002/ca.23912