

Institutional implementation of a Thiel-embalmed Cadaver Lab for advanced simulation based medical education and patient safety

Implementación institucional de un laboratorio cadavérico con técnica Thiel para educación médica basada en simulación y seguridad del paciente

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ABSTRACT

Over the last decade, simulation-based education has become a cornerstone of contemporary medical training, particularly in high-risk procedural and surgical disciplines. This article describes the institutional implementation of a Thiel-embalmed Cadaver Lab at Universidad Científica del Sur (Peru) as a strategy for advanced simulation and safe surgical training. The Cadaver Lab was developed following an institutional needs assessment and international benchmarking, integrating specialized infrastructure, biosecurity protocols, and a competency-based educational framework. The use of Thiel-embalmed cadavers enabled high-fidelity training across multiple disciplines, including regional anesthesia, aesthetic medicine, neonatal exploration, minimally invasive surgery, and endoscopic spine surgery. This approach allowed learners to practice complex procedures repeatedly in a controlled environment, effectively shifting critical phases of the learning curve away from real patients. The experience demonstrates how cadaveric simulation can enhance technical and non-technical competencies, support patient safety, and serve as a scalable model for advanced medical education in Latin America.

Keywords: Cadaver; Embalming; Simulation Training; Education, Medical; Patient Safety (source: MeSH NLM).

RESUMEN

La educación basada en simulación es fundamental en la formación médica contemporánea, especialmente en disciplinas quirúrgicas de alto riesgo. Este artículo describe la implementación institucional de un Laboratorio de Cadáveres con técnica de Thiel en la Universidad Científica del Sur (Perú) para simulación avanzada y entrenamiento quirúrgico seguro. El laboratorio se desarrolló mediante una evaluación de necesidades y estándares internacionales, integrando infraestructura especializada, bioseguridad y un marco educativo basado en competencias. El uso de cadáveres con técnica de Thiel permitió un entrenamiento de alta fidelidad en anestesia regional, medicina estética, cirugía mínimamente invasiva y de columna. Este enfoque facilitó la práctica repetida de procedimientos complejos en un entorno controlado, desplazando las fases críticas de la curva de aprendizaje lejos de los pacientes reales. La experiencia demuestra que la simulación cadavérica mejora las competencias técnicas, fortalece la seguridad del paciente y es un modelo escalable para el posgrado.

Palabras clave: Cadáver; Embalsamamiento; Entrenamiento Simulado; Educación Médica; Seguridad del Paciente (fuente: DeCS Bireme).

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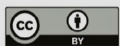
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INTRODUCTION

Over recent decades, medical education has transitioned from traditional models centered on passive knowledge transmission toward training approaches focused on the development of clinical, cognitive, and attitudinal competencies. This transformation reflects broader structural changes in higher education, driven by globalization, increasing demands for academic quality, the expansion of educational technologies, and the need to respond effectively to contemporary health system challenges [1-3]. Within this context, clinical simulation has emerged as a key educational strategy, enabling the recreation of realistic healthcare scenarios in controlled environments where learners can train repeatedly, in a standardized manner, and with structured feedback, without compromising patient safety. Evidence consistently demonstrates that simulation improves clinical skill acquisition, promotes deliberate practice, and reduces the variability inherent to opportunistic learning in traditional clinical settings [4-8].

The incorporation of simulation becomes particularly relevant in contexts where health systems face structural constraints that limit opportunities for safe clinical learning. In Latin America, and especially in Peru, healthcare system overload, limited availability of accredited clinical training sites, shortages of clinical tutors, and the expansion of medical programs have created environments in which training often depends on the fortuitous availability of patients and pathologies, negatively affecting the consistency and depth of education [9-11]. In this setting, clinical simulation moves beyond an optional educational complement and becomes an essential training strategy to ensure the progressive development of core competencies under principles of safety, standardization, and educational equity, in line with recent international recommendations promoting its systematic integration into medical curricula [12,13].

In parallel, patient safety has become a central pillar of healthcare quality, particularly in high-complexity environments such as surgery. It is now widely recognized that adverse events are not solely the result of individual failures, but rather of systemic deficiencies related to process design, organizational culture, and team preparedness [14,15]. The conceptual shift from blame-oriented models toward just culture frameworks has underscored the need for healthcare systems explicitly designed to prevent harm. Within this framework, the surgical learning curve, traditionally accepted as an unavoidable period of increased risk, has become ethically questionable when it implies that patients bear the consequences of preventable errors during early stages of training. Evidence indicates that this learning curve depends not only on individual technical proficiency, but also on team coordination, effective

communication, adherence to protocols, and the ability to anticipate and mitigate risks [16,17].

In this context, clinical simulation represents a central educational tool for patient safety, as it allows critical phases of the learning curve to be shifted from real clinical environments to simulated settings. Simulation-based training has been shown to improve technical accuracy, procedural efficiency, and error management, while reducing complication rates during early clinical practice [18-20]. Furthermore, international organizations such as the Society for Simulation in Healthcare and the Institute for Healthcare Improvement have promoted simulation as a standard for the acquisition and maintenance of technical and non-technical competencies, explicitly integrating it into continuous quality improvement frameworks for patient safety [21,22].

Within this ecosystem of high-fidelity simulation, the preserved human cadaver occupies a unique role as an educational model, offering realistic anatomical representation that enables understanding of complex three-dimensional relationships, anatomical variability, and tissue behavior—critical elements for advanced procedural and surgical training [23,24]. Evidence suggests that cadaveric simulation not only accelerates the technical learning curve but also significantly enhances trainee confidence and procedural precision, directly impacting patient safety by shifting the initial stages of the learning process away from the operating room [25,26]. Furthermore, the evolution of soft-embalming techniques has redefined the educational utility of these models, providing a reusable, lifelike platform that preserves the biomechanical integrity of human tissues for repeated, deliberate practice [27-29]. Consequently, cadaveric simulation is widely regarded as a high-fidelity model for high-stakes procedural training in academic environments worldwide.

However, traditional preservation methods, such as formalin fixation, present significant limitations for simulation due to tissue rigidity, altered biomechanical properties, and associated toxicity, restricting their usefulness for invasive and minimally invasive procedures [30,31]. In addition to formalin-fixed specimens, fresh-frozen cadavers are widely used in surgical and procedural simulation because they preserve tissue texture and anatomical relationships comparable to those of the living body. For this reason, fresh-frozen models have been extensively used for training in minimally invasive surgery, laparoscopic procedures, and endovascular interventions where realistic tissue handling is essential [32,33]. Their high anatomical fidelity allows trainees to practice surgical maneuvers and develop spatial orientation in conditions that closely approximate clinical practice.

Nevertheless, the use of fresh-frozen cadavers requires specialized freezing facilities, controlled thawing

cycles, and strict biosecurity measures, which may limit their durability and repeated use across structured educational programs. Repeated freeze–thaw cycles may also progressively alter tissue integrity and anatomical planes. In response to these limitations, the embalming technique described by Thiel preserves tissue elasticity, coloration, and flexibility under lifelike conditions while allowing repeated use without freezing or significant tissue degradation [34,27]. When compared to fresh-frozen specimens, Thiel-embalmed cadavers offer superior logistical advantages, as they do not require complex defrosting protocols and remain stable at room temperature for extended periods. This enhances biosecurity by reducing the risks associated with raw tissue handling and significantly increases reusability, allowing the same specimen to be utilized across multiple educational modules without the progressive decay typical of thawed tissues [35]. Over the last three decades, Thiel embalming has been increasingly adopted in surgical simulation due to its capacity to maintain realistic tissue properties while providing greater durability for repeated educational use [36,37]. These characteristics make Thiel-embalmed cadavers particularly suitable for structured simulation-based training programs in academic environments where repeated procedural practice and multidisciplinary training are required.

Multiple studies have shown that Thiel-embalmed cadavers offer substantial advantages for advanced surgical and procedural simulation, facilitating training in minimally invasive surgery, regional anesthesia, interventional procedures, neonatal exploration, and endoscopic techniques, with high levels of learner acceptance and perceived educational value [38,39,28,40]. This perceived value is increasingly supported by quantified learning outcomes that demonstrate the model's superiority in skill acquisition. In the field of regional anesthesia, research has utilized objective metrics to validate the Thiel model; for instance, procedural success has been quantified by measuring needle-tip visualization accuracy and the quality of fluid distribution under ultrasound, demonstrating that the model's acoustic properties allow for a measurable reduction in 'red-line' errors (accidental nerve contact) during simulated nerve blocks [41,42]. Furthermore, the impact of Thiel-based training on surgical proficiency has been objectively assessed using the Objective Structured Assessment of Technical Skills (OSATS) and Global Rating Scales (GRS). Studies comparing training modalities have found that participants using Thiel specimens achieve higher technical scores and faster completion times in laparoscopic and vascular procedures than those using synthetic models [37]. Quantitative evidence also extends to orthopedic research, where Thiel-embalmed specimens have been used to evaluate biomechanical properties under near-physiological conditions, including

load-deformation behavior [43]. These measurable gains in technical performance confirm that Thiel simulation facilitates the transfer of skills that is fundamental for achieving clinical competency

This model positions itself as an intermediate educational resource between artificial simulation and real clinical practice, enabling the consolidation of both technical and non-technical competencies within a controlled environment aligned with contemporary principles of patient safety and competency-based education. Despite the growing body of evidence supporting cadaveric simulation, reports describing large-scale institutional implementation in Latin America remain limited. In this context, the present article describes the institutional implementation of a Thiel-embalmed Cadaver Lab at Universidad Científica del Sur, analyzing its integration as an advanced simulation strategy for medical education and patient safety, its contribution to reducing the clinical learning curve, and its potential as a replicable model for medical education institutions in Latin America.

MAIN CONTENT – EXPERIENCE REPORT

The implementation of the Cadaver Lab at Universidad Científica del Sur originated from an institutional analysis conducted in 2020, aimed at identifying critical gaps in advanced clinical training at both undergraduate and, especially, postgraduate and continuing medical education levels. This assessment revealed a structural gap: although universities play a central role in theoretical training and academic certification, a large portion of high-complexity practical skill development had been delegated to hospitals, with limited and heterogeneous academic involvement. In addition, within the Peruvian context, there was a lack of medical training centers with infrastructure, technology, and pedagogical models comparable to international benchmarks, which compelled professionals and institutions to seek training opportunities abroad. In response to this scenario, the university defined a strategic vision aimed at reclaiming the leading role of academia in advanced clinical training and positioning itself as a regional reference in medical education.

As part of this process, a systematic benchmarking exercise was conducted with international reference centers, including the University of Dundee, the Royal College of Surgeons of England, and the Miami Anatomical Research Center. This process incorporated technical standards, management models, and successful experiences, including training in the Thiel embalming technique. In 2021, the Cadaver Lab project was formally approved, allocating significant investment to infrastructure, equipment, and the design of

educational programs. The laboratory was conceived as an advanced simulation space, with an explicit focus on patient safety, academic excellence, and the articulation of undergraduate, postgraduate, and specialized training.

The design and implementation of the Cadaver Lab were based on technical standards from reference anatomical centers and took advantage of an operational opportunity during the pandemic period, which allowed for ad hoc construction without interference from clinical activities. A dedicated health pavilion was built with functional isolation, controlled ventilation, and differentiated circulation flows, incorporating specific considerations for training supported by radiological equipment. The infrastructure was complemented with world-class technology, including surgical and mortuary equipment, as well as integrated audio and video systems that enable real-time observation and transmission to adjacent auditoriums. Biosecurity principles structured

both spatial design and operational protocols, establishing exclusive routes for biological material and strict handling standards, consistent with a deliberate governance model integrating academic, technical, and administrative teams (Figure 1).

During the initial training activities conducted in the Cadaver Lab, it became evident that the type of cadaveric preservation directly conditioned the quality of training. Early experiences using traditional preservation methods revealed significant limitations, such as tissue rigidity, loss of anatomical planes, and limited specimen durability, which restricted the possibility of repeated practice and complex procedures. These limitations were particularly evident in courses focused on aesthetic medicine, regional anesthesia, minimally invasive surgery, spine surgery and interventional procedures, where anatomical and tactile realism is a critical requirement for meaningful learning. Based on this experience, an institutional decision was



Figure 1. Cadaver Lab infrastructure, layout, and learning environment. **A.** Advanced cadaveric training environment equipped with surgical tables, C-arm fluoroscopy, and integrated audiovisual systems, enabling high-fidelity procedural and image-guided simulation. **B.** Structured theoretical-practical session on Thiel cadaver maintenance and biosecurity protocols, illustrating the integration of didactic instruction with hands-on training. **C.** Dedicated preparation and preservation area, including Thiel immersion tanks and auxiliary workstations, designed to ensure biosecurity, controlled workflows, and ethical handling of cadaveric material. **D.** Main cadaveric simulation laboratory configured to replicate a real operating room environment, with surgical lighting, endoscopic towers, monitoring systems, and modular workstations supporting multidisciplinary training.

made to adopt the Thiel embalming technique as the core preservation method for cadaveric training.

Following this decision, the Cadaver Lab progressively incorporated hands-on training activities across multiple disciplines, allowing the academic team to observe concrete educational outcomes associated with high-fidelity cadaveric simulation using Thiel-embalmed specimens. One area in which the impact became particularly evident was aesthetic medicine. Cadaver-based training sessions enabled participants to explore preserved facial and cervical anatomy in depth, facilitating precise identification of deep anatomical planes, vascular trajectories, and high-risk zones. The ability to correlate surface landmarks with underlying structures through guided dissection enhanced three-dimensional anatomical understanding and facilitated spatial orientation during procedural planning. Although preliminary, the educational outcomes of this training model were formally evaluated through a study titled “Perceptions of Students and Teachers on the Use of Thiel-Embalmed Cadavers in the Teaching of Anatomy Applied to Aesthetic Medicine.” This research utilized a quantitative approach, revealing high levels of satisfaction among participants, with over 90% of trainees reporting a significant improvement in their confidence to identify high-risk vascular zones compared to traditional learning methods. Qualitatively, participants highlighted the “lifelike tissue resistance” and the “unparalleled ability to visualize plane-specific filler distribution” as critical

factors for their clinical preparation. This work received significant external recognition, winning First Place at the XLV Congress of the Chilean Society of Anatomy and the III Latin American Congress of Clinical Morphology. Such distinction reinforces the quantifiable value of Thiel-embalmed simulation as a reference model for specialized training in aesthetic procedures^[44] (Figure 2).

Regional anesthesia training also emerged as a major educational component of the Cadaver Lab. Ultrasound-guided courses allowed participants to integrate applied anatomy with real-time imaging in a controlled environment. The preservation of tissue elasticity and fascial planes enabled accurate visualization of neurovascular structures and realistic simulation of needle trajectories. Learners were able to repeat procedures, refine hand-eye coordination, and receive immediate feedback without the pressure associated with first attempts on live patients. This educational effectiveness is supported by studies demonstrating that the Thiel model exhibits ultrasonographic properties and needle-tissue resistance that are highly comparable to those of living patients^[45,46]. Furthermore, practicing on Thiel specimens has been shown to significantly improve the accuracy of needle-tip placement and the successful identification of fascial planes, which are critical steps in regional anesthesia^[46,47]. This approach supports the transfer of technical skills to clinical practice and contributed to reducing the early learning curve in anesthesia (Figure 2).

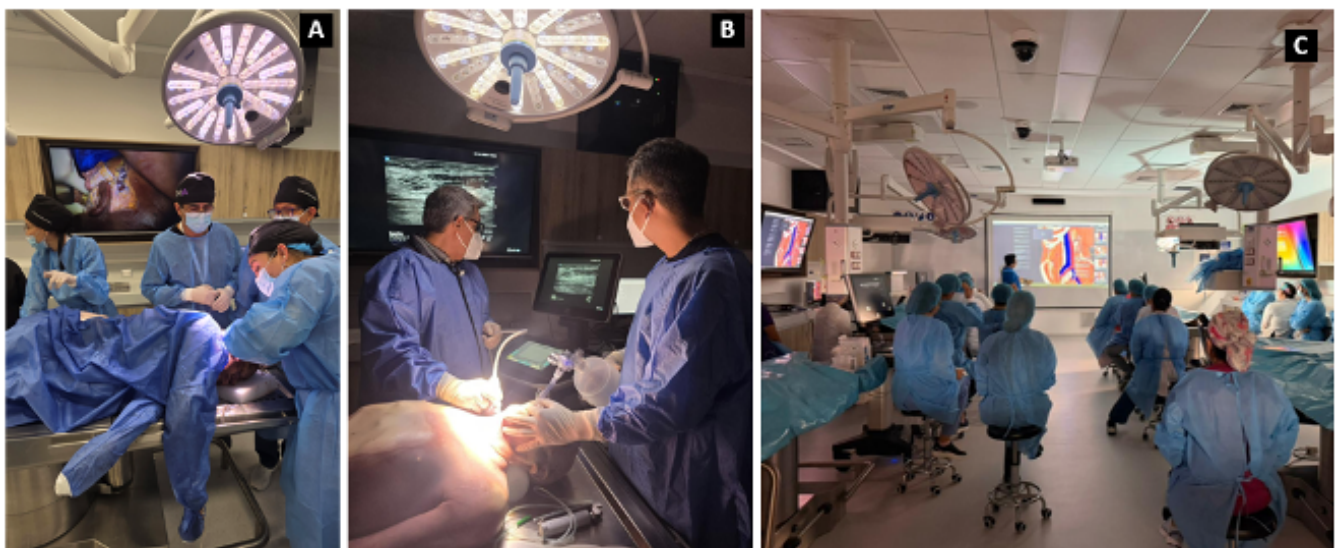


Figure 2. Cadaver-based training in aesthetic medicine and ultrasound-guided anesthesia using Thiel-embalmed specimens. **A.** Supervised cadaver-based deep-plane procedural training in aesthetic medicine, allowing identification of facial anatomical planes and critical structures under realistic conditions. **B.** Ultrasound-guided anatomical identification in adult cadaveric models as part of regional anesthesia training, enabling correlation between real-time imaging and underlying neurovascular and fascial structures. **C.** Applied anesthesia teaching session integrating anatomical knowledge and ultrasound guidance in a simulated operating room environment to support safe procedural planning and execution.

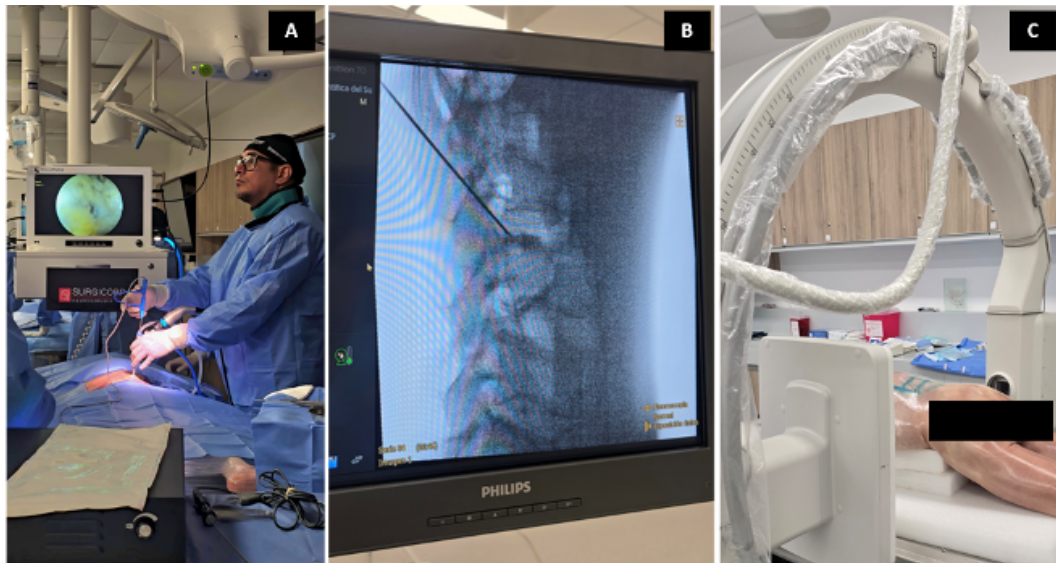


Figure 3. Advanced cadaveric training in endoscopic spine surgery. **A.** Cadaver-based endoscopic spine surgery training using Thiel-embalmed specimens, allowing realistic simulation of minimally invasive spinal approaches, endoscopic navigation, and anatomical orientation within confined operative corridors. **B.** Use of intraoperative X-ray imaging (C-arm) during cadaver-based endoscopic spine training, enabling spatial orientation and anatomical correlation under radiological guidance in a controlled educational setting. **C.** Simulation of spinal surgical positioning and instrument handling in a controlled cadaveric environment, supporting deliberate practice of access techniques, ergonomics, and procedural planning for endoscopic spine surgery.

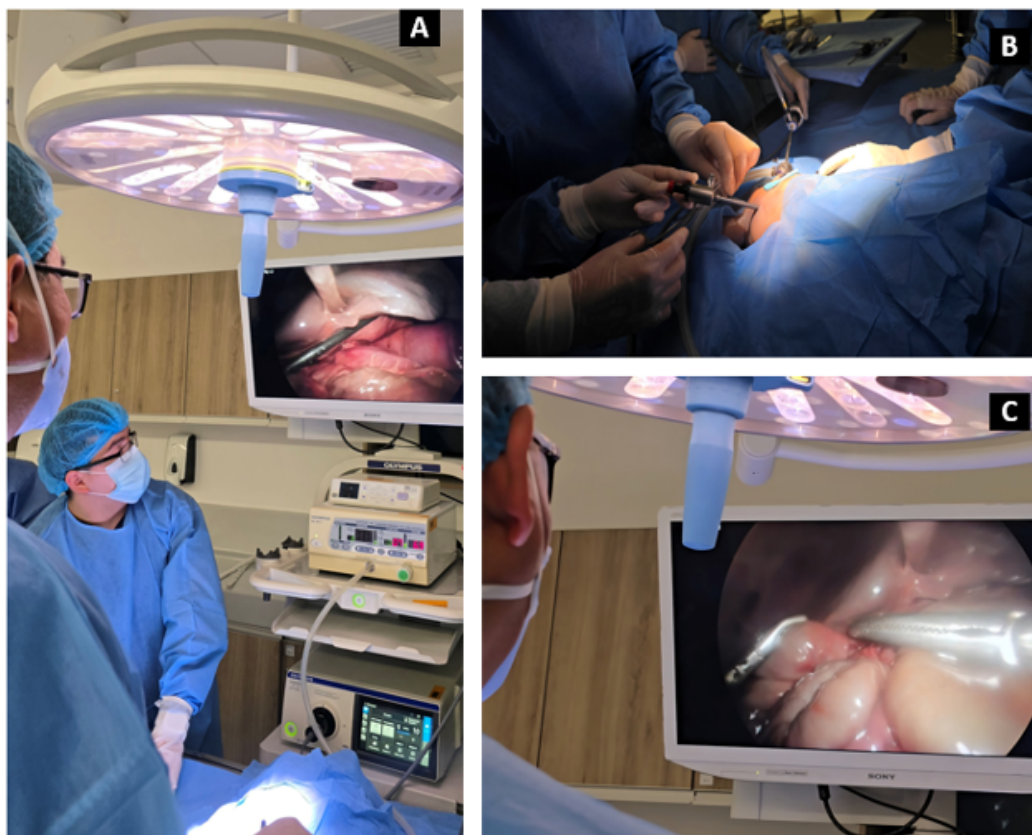


Figure 4. Advanced cadaveric training in neonatal laparoscopic abdominal exploration. **A.** Neonatal cadaver-based laparoscopic abdominal exploration, allowing trainees to practice trocar placement, tissue handling, and exploration under conditions closely approximating neonatal minimally invasive surgery. **B.** High-fidelity neonatal surgical training scenario integrating laparoscopic visualization and operative lighting, facilitating understanding of neonatal anatomical constraints and safe execution of minimally invasive techniques. **C.** Laparoscopic visualization of neonatal intestinal structures during simulated exploration, enabling recognition of anatomical relationships within the abdominal cavity in a high-fidelity cadaveric environment.

High-complexity surgical training was further addressed through programs in endoscopic spine surgery. The Cadaver Lab provided a realistic setting for rehearsing minimally invasive spinal approaches, endoscopic navigation, and anatomical orientation within confined operative corridors. Preservation of soft tissue properties and anatomical relationships allowed for faithful replication of surgical steps, including positioning, access, and endoscopic visualization. These sessions supported deliberate practice of technically demanding maneuvers and fostered interdisciplinary discussion regarding anatomy, instrumentation, and procedural planning, facilitating safer adoption of advanced endoscopic techniques in clinical practice (Figure 3).

A particularly relevant experience involved the use of the Cadaver Lab for neonatal laparoscopic abdominal exploration. Given the ethical and safety constraints inherent to neonatal surgical training, opportunities for hands-on learning in this field are extremely limited. Thiel-embalmed neonatal specimens enabled trainees to explore abdominal anatomy, practice trocar placement, and perform laparoscopic exploration in conditions closely approximating real surgery. This experience allowed learners to understand spatial constraints, tissue handling, and anatomical variability specific to neonates, effectively shifting critical phases of the learning curve away from vulnerable patients (Figure 4).

Beyond discipline-specific training outcomes, cadaveric surgical simulation at the Cadaver Lab has been structured around patient safety as its primary objective. Ethical management of human remains, respect for body donation, and strict operational protocols constitute the foundation of all activities. Cadaveric simulation is consistently preceded by clinical simulation, ensuring that learners first develop theoretical knowledge and non-technical skills using standardized patients or high-fidelity manikins.

The articulation between clinical simulation and cadaveric simulation follows a stepwise educational model combining low- and medium-fidelity simulators (such as box trainers, synthetic models), and virtual reality with high-fidelity cadaveric simulation. Learners initially acquire basic skills in lower-complexity environments and, upon achieving predefined competencies, progress to biological models and ultimately to cadaver-based training. At this stage, competency-based curricula emphasize applied anatomical review, familiarization with surgical equipment, and supervised surgical exploration. Once learners demonstrate adequate performance within a defined number of training hours, they advance to procedure-specific modules tailored to each specialty.

Within this pedagogical architecture, the Cadaver Lab has established standardized specimen preparation

according to specialty-specific objectives, as well as structured execution of complete procedures under controlled conditions. Defined operative times, assigned roles, and formal briefing–debriefing processes allow instructors to assess not only technical skills (such as exposure, dissection, energy use, and suturing) but also transversal competencies, including teamwork, communication, and operative time management. Integration of cadaveric simulation as a formal requirement for progression and assessment, supported by objective rubrics, has consolidated the Cadaver Lab as a core educational axis linking anatomy, technique, patient safety, and professionalism.

Additionally, clinical–cadaveric simulation has facilitated the incorporation of crisis scenarios and simulated adverse events in a risk-free environment. Hemorrhage, simulated iatrogenic injury, and equipment failure scenarios can be recreated to train leadership, communication, and team responses in real time. Through this approach, cadaveric simulation not only reinforces technical performance but also strengthens safety culture and situational awareness, which are essential components of safe surgical systems.

The use of the Cadaver Lab extends across the educational continuum. In undergraduate training, it supports applied anatomy learning and basic exposure techniques, providing spatial understanding that is difficult to achieve through atlases or synthetic models alone. In postgraduate and advanced training, the focus shifts to complex procedures, new techniques, and adoption of emerging technologies, including minimally invasive and endoscopic approaches. External courses for practicing specialists further position the Cadaver Lab as a platform for continuous professional development, linking academia, clinical services, and industry within an ethical and safe framework. Collectively, these experiences demonstrate that cadaveric simulation plays a critical role in reducing the surgical learning curve and enabling safe, reflective practice prior to patient exposure.

CONCLUSIONS

The implementation of a Thiel-embalmed Cadaver Lab at Universidad Científica del Sur represents a strategic institutional contribution to medical education in Peru. This initiative has enabled the university to reclaim an active and leading role in advanced clinical training by integrating specialized infrastructure, deliberate governance, and a competency-based educational approach. The Cadaver Lab has consolidated itself as a transversal educational platform connecting undergraduate education, postgraduate training, and continuing medical education, strengthening academic quality, professionalism, and ethical respect for the human body as a central element of medical training.

The value of the Cadaver Lab as an advanced simulation strategy lies in its direct impact on patient safety. By shifting critical phases of the surgical learning curve away from real clinical environments, cadaveric training allows healthcare professionals to develop both technical and non-technical competencies in a controlled, supervised, and risk-free setting. This approach supports the training of new specialists, facilitates recertification and upskilling of experienced clinicians, and contributes to reducing preventable harm associated with surgical procedures, reinforcing patient safety as a foundational principle of clinical practice.

Finally, the experience developed at Universidad Científica del Sur positions the Cadaver Lab as a model with strong potential for regional projection and replicability across Latin America. The combination of institutional vision, investment in infrastructure, adoption of the Thiel embalming technique, and curricular integration demonstrates that high-level cadaveric simulation centers can be successfully implemented in the region. This model offers a scalable and adaptable framework capable of improving the quality of medical training, enhancing patient safety, and strengthening health systems, reaffirming the role of academic institutions as key drivers of innovation and continuous improvement in healthcare.

Author contributions

JGM: Conceptualization, Methodology, Project Administration, Writing – Review & Editing. JCFS: Methodology, Investigation, Writing – Review & Editing.

SMDCA: Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing. All authors assume full responsibility for the content of the manuscript.

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