BMC Medical Education

RESEARCH

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# Anesthesiology competencies in undergraduate medical education: a comparative study of curriculum frameworks in Brazil, Spain, and the United Kingdom

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## Abstract

**Objectives** Medical education is crucial for meeting local needs and achieving global standards, especially in anesthesiology. Key competencies, such as airway management, mechanical ventilation, and sedation, are essential for managing critically ill patients, maintaining surgical and intensive care services, and preventing deaths from surgically treatable conditions. This study evaluated anesthesiology competencies in the curricula of medical schools in Brazil, Spain, and the United Kingdom (UK), highlighting the importance of integrating these skills to prepare for critical situations and support global surgery efforts.

**Methods** Educational frameworks from medical schools in Brazil, Spain, and the UK were analyzed by two independent researchers, who blindly assessed the program structures retrieved from the websites of medical schools and government sources to determine the presence of anesthesiology competency topics, which were organized into the respective disciplines within their academic programs.

**Results** A total of 466 medical schools were analyzed, with Brazil accounting for the majority ($n=374$), followed by the UK ($n=48$) and Spain ($n=44$). Most medical schools in Brazil are private (229, 61.2%), whereas public institutions are predominant in Spain (32, 72.7%) and the UK (46, 95.8%). Anesthesiology courses were present in 24 (54.5%) Spanish schools, 128 (34.2%) Brazilian schools, and 9 (18.7%) British schools. Spanish institutions showed the highest incorporation of anesthesiology competencies in their curricula: acute pain management (52.3%), chronic pain management and preoperative evaluation (50.0%), treatment of shock, fluid replacement, and blood transfusion (47.7%), and cardiopulmonary resuscitation (45.5%). In Brazil, the most frequent competencies were preoperative evaluation (17.9%) and cardiopulmonary resuscitation (17.4%), while all other competencies were present in fewer than 15% of schools. In the UK, despite 95.8% of institutions having accessible curriculum frameworks, specific

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anesthesiology competencies were minimally represented. Multidisciplinary teamwork was identified in only 6.3% of institutions, airway management in 4.2%, and the following competencies in just 2.1%: acute and chronic pain management, cardiopulmonary resuscitation, monitoring, local anesthesia, treatment of shock, fluid replacement, blood transfusion, and vascular access.

**Conclusions** The results highlight the need to show more explicitly competencies within undergraduate medical curricula public websites, particularly in Brazil and the UK. This study emphasizes Spain's more organized curricular structure, which facilitates the clearer identification of competencies, including those related to anesthesiology.

**Keywords** Medical education, Curriculum, Anesthesiology competencies

## Introduction

Medical education plays crucial roles for professionals involved in the management, planning, regulation, teaching, and learning of medicine. It is essential to meet and contextualize local demands according to regional priorities to achieve high global standards in medical education [1, 2].

In the context of medical education in anesthesiology, essential competencies include the establishment of venous access for sample collection for diagnostic tests; provision of fluid and electrolyte replacement; sedation or analgesia; proper management of airways via appropriate devices such as oropharyngeal airways, face masks, laryngeal masks, or tracheal tubes to maintain the fraction of inspired oxygen necessary for tissue oxygenation; and mechanical ventilation, cardiopulmonary resuscitation, and monitoring [3]. These skills are vital for the maintenance of life and vital organs in critical situations, such as major trauma, sepsis, and certain cardiovascular conditions. These competencies, integrated into anesthesiology training, gained prominence during the COVID-19 pandemic, when pulse oximetry monitoring became an essential daily practice for seeking medical care in health units [4–6].

Anesthesiology competencies are particularly complex in countries with public healthcare systems, such as Brazil, Spain, and the UK, which face high demand for healthcare services. Brazil's *Sistema Unico de Saúde* (SUS) is a public, government-funded system that provides universal, free healthcare. While it offers comprehensive coverage, it faces challenges related to wait times and resource allocation. Similarly, Spain's *Sistema Nacional de Salud* (SNS) provides universal healthcare funded through taxes. This approach is efficient but faces regional disparities. The UK's National Health Service (NHS) is a publicly funded system that offers free healthcare at the point of use. It is well regarded for comprehensive services but struggles with funding and long wait times for certain treatments [7–9].

Countries with well-structured healthcare systems — those with surgical infrastructure, intensive care units, diagnostic centers, and professionals trained in airway management — are better equipped to treat critically ill patients. In this context, evaluating the training of specialists becomes essential for the effective operation of these interconnected components. These systems align with the concept of global surgery, which focuses on improving access to timely and high-quality surgical care. This includes perioperative care, acute and chronic pain management, intensive care, and palliative care.

The World Health Organization, in its Global Strategy on Human Resources for Health: Workforce 2030 [10], emphasized that the increasing demand for qualified healthcare professionals capable of handling more complex situations justifies the inclusion of expanded competencies in medical education, such as those related to surgical disciplines. In this scenario, this study aims to map the presence of anesthesiology competencies within the undergraduate medical curricula of Brazil, Spain, and the UK.

## Methods

### Data collection

We utilized government databases from Brazil, Spain, and the UK to identify medical schools in each country. In Brazil, we consulted the *Escolas Médicas do Brasil* (available at https://escolasmedicas.com.br) and the Min istry of Education and Culture (available at https://emec.mec.gov.br/emec/nova) databases. For the UK and Spain, we used the Medical Schools Council (available at https://www.medschools.ac.uk/studying-medicine/how-to-apply-to-medicalschoolinthe-uk/medical-schools) and the Ministry of Science, Innovation, and Universities (available at https://www.ciencia.gob.es/) databases, respec tively. Additionally, data from the World Federation for Medical Education (WFME) (available at https://wfme.org/) were included to further consolidate the information. The survey was conducted in January 2025.

We accessed the websites of each medical school to verify the curricular structure of their undergraduate medical programs. The overall structure of the curricula was analyzed, identifying thematic axes (basic sciences, clinical, surgical, and public health), academic cycles (basic, clinical, and internship), curricular components (mandatory and elective courses), course descriptions, practical activity scenarios (internships and clinical rotations), and criteria for interdisciplinarity.

We specifically sought the presence of anesthesiology as a distinct discipline and the description of its competencies. In cases where anesthesiology was not offered as a standalone course, we examined the presence of anesthesiology-related competencies within other disciplines, such as surgery, internal medicine, gynecology and obstetrics, pediatrics, and pharmacology.

The anesthesiology competencies considered were those outlined by the Brazilian Society of Anesthesiology [11] and the European Society of Anesthesiology [12], including perioperative medicine, patient assessment and risk reduction, general anesthesia and sedation, airway management, regional anesthesia, postoperative care and acute pain management, intensive care medicine, critical emergency medicine, obstetric anesthesiology, cardiothoracic anesthesiology, neuroanesthesiology, pediatric anesthesiology, and multidisciplinary chronic pain management.

### Data analysis

The results, organized under the headings faculty, country, year of foundation, online curriculum, anesthesiology competencies in syllabi, discipline, and course description, were compiled into an Excel table for calculating frequencies and percentages. Descriptive statistical analysis was also performed using GraphPad Prism version 10.3.1.22.

## Results

### Analysis of medical schools per country

Brazil has a total of 374 medical schools, of which 145 (38.8%) are publicly administered and funded by the government, whereas 229 (61.2%) are privately managed and operated by private entities, as illustrated in Fig. 1. The establishment of the first medical school dates back to the 19th century (Fig. 2). Notably, significant expansions occurred in three distinct decades: 1961–1970, 2001–2010, and 2011–2020, with the creation of 46, 77, and 170 medical schools, respectively. The accreditation of these institutions is overseen by the Medical School Accreditation System [13], ensuring compliance with the standards required for delivering quality medical education. In Brazil, the standard duration of medical courses is six years.

Spain has 44 medical schools, with 32 (72.7%) publicly funded and administered by the government and 12 (27.3%) privately managed (Fig. 1). Twelve medical schools have become inactive over the years. As depicted in Fig. 2, the first Spanish medical school was founded in the 15th century, with additional establishments in the 16th and 17th centuries, reflecting a longstanding tradition in medical education.

In the UK, 48 active medical schools were identified, of which 46 (95.8%) are publicly funded and government-administered and 2 (4.2%) are privately managed (Fig. 1). Among the countries studied, the UK has the fewest private medical schools. Figure 2 shows that the UK hosts the oldest medical schools, dating back to the 12th century, signifying nearly a millennium of medical education history. The most significant expansions in the number of medical schools occurred during the 19th century and between 1991 and 2020, with the establishment of 17 and 26 new schools, respectively.

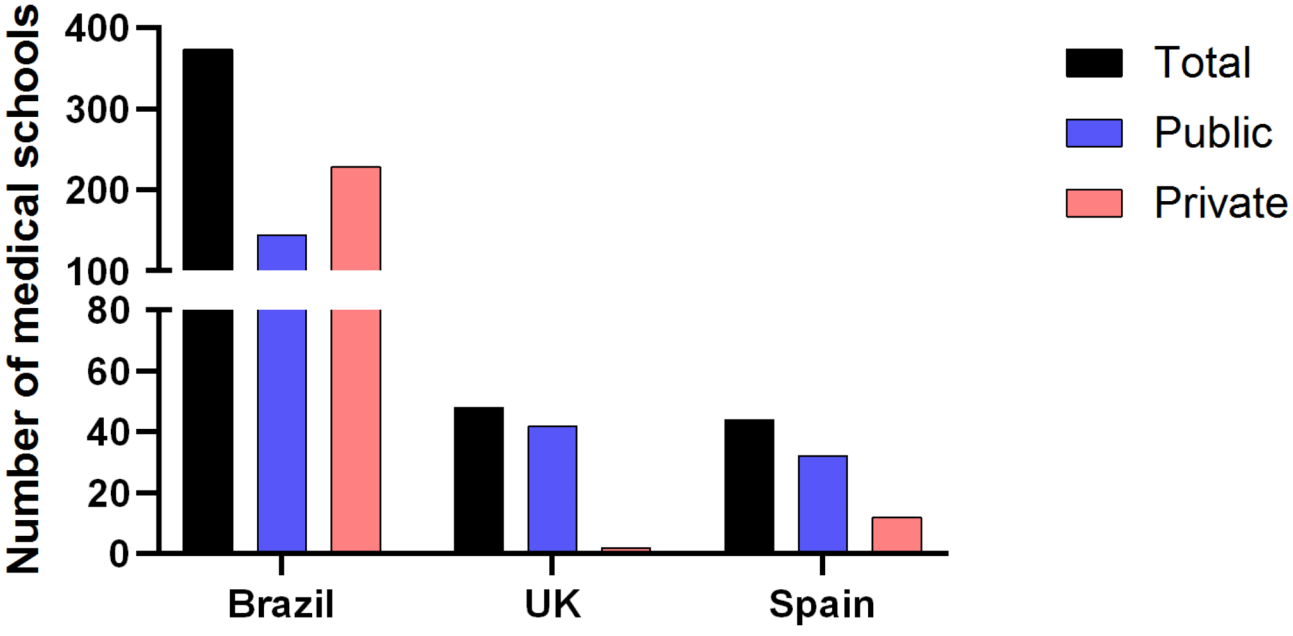


**Fig. 1** Distribution of medical schools in Brazil, the UK, and Spain concerning public and private schools

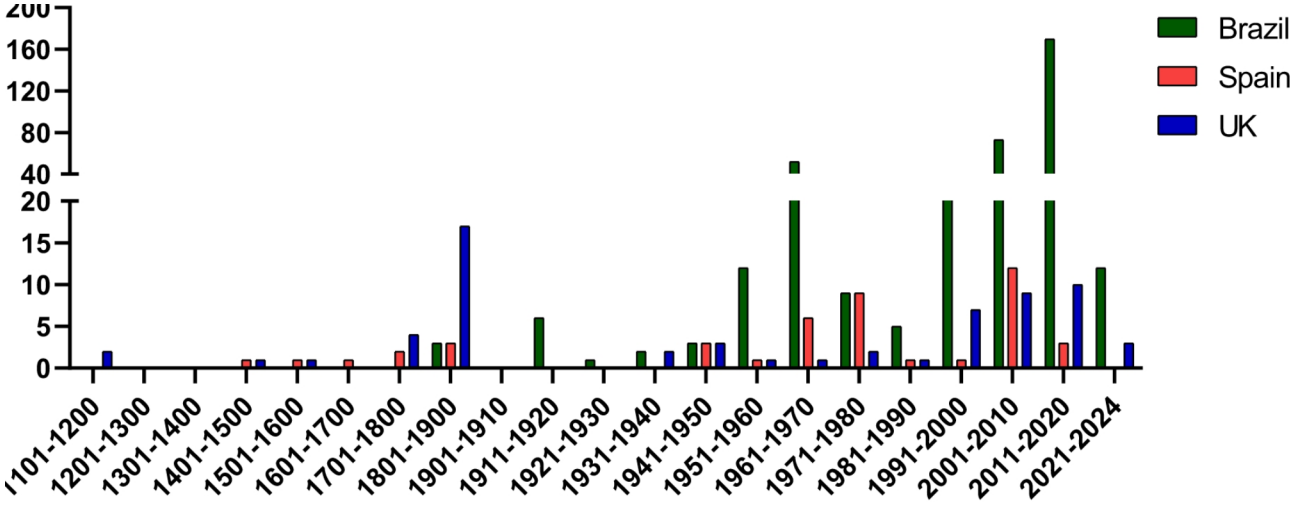


**Fig. 2** Temporal evolution (in years) regarding the creation of new medical schools by country. Brazilian ($n=374$), Spanish ($n=44$), and the UK medical schools ($n=64$) are represented in green, red, and blue, respectively

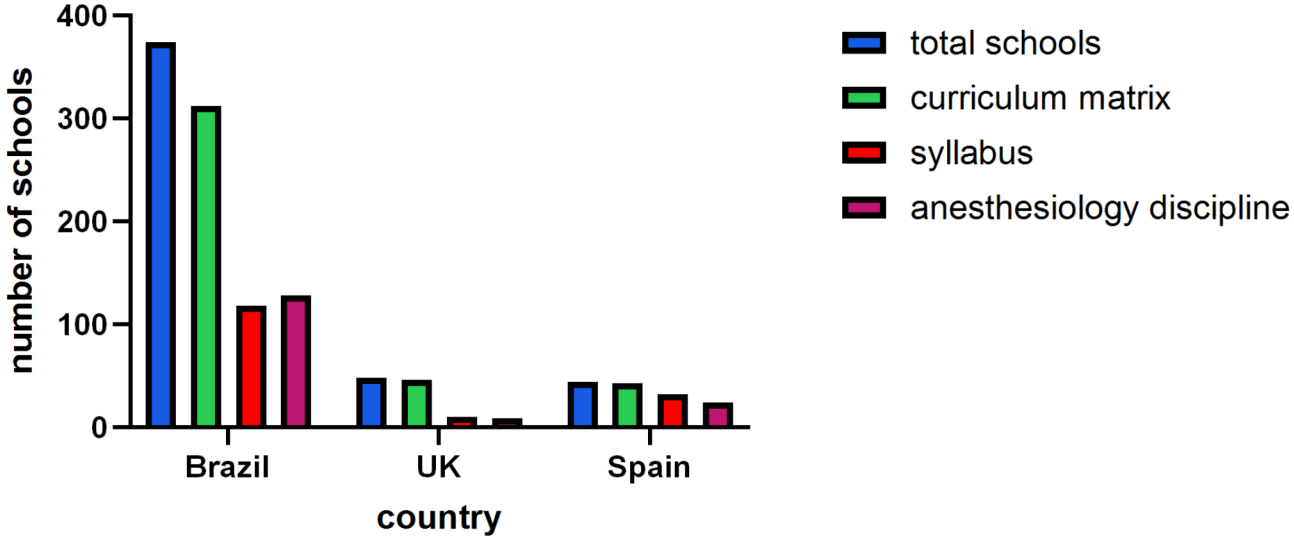


**Fig. 3** Total number of medical schools that offer curriculum frameworks and anesthesiology-related disciplines across the studied countries

### Analysis of anesthesiology competencies in curricular matrices of medical schools

Among the Brazilian institutions analyzed, 312 (83.4%) provide curriculum frameworks, 118 (31.5%) include course descriptions or syllabi, and 128 (34.2%) specifically reference terms related to the discipline of anesthesiology, as shown in Fig. 3. Among these 128 institutions with references to anesthesiology, 72 (56.25%) are public, and 56 (43.75%) are private. Among the 118 schools with accessible syllabi, 83 (70.3%) are public, and 35 (29.7%) are private.

Concerning the UK, 46 (95.8%) institutions provide curriculum frameworks, 10 (20.8%) include course descriptions, and 9 (18.7%) explicitly reference anesthesiology as a discipline, as demonstrated in Fig. 3. Importantly, all these institutions are public.

Almost all Spanish medical schools, i.e., 43 (97.7%) schools, provide curriculum frameworks (Fig. 3). Thirty-two (72.7%) medical schools also provided course descriptions, of which 7 (21.9%) were private and 25 (78.1%) were public institutions. Additionally, 24 (54.5%) featured anesthesiology as a discipline, which was distributed between 20 (83.3%) public and 4 (16.7%) private institutions.

This scenario provides a comparative perspective on how each country integrates and specifies anesthesiology-related competencies within its academic programs. In the three countries investigated, Anesthesiology competencies are predominantly taught either as a standalone anesthesiology course or as a combined course of anesthesiology and surgery. In other instances, these competencies are integrated into broader disciplines

**Table 1** Anesthesiology-related courses in the curricular matrices of medical schools in Brazil, Spain, and the UK

| Anesthesiology discipline | Brazil (*n* = 374) | Spain (*n* = 44) | UK (*n* = 48) |
|---|---|---|---|
| Unidentified | 246 | 20 | 39 |
| Advanced life support | 0 | 1 | 0 |
| Anesthesia and critical care | 0 | 0 | 1 |
| Anesthesiology | 28 | 6 | 3 |
| Anesthesiology and emergency | 1 | 0 | 0 |
| Anesthesiology and pain | 6 | 5 | 0 |
| Anesthesiology and pharmacology | 1 | 1 | 0 |
| Anesthesiology and rehabilitation | 1 | 0 | 0 |
| Anesthesiology and surgery | 19 | 8 | 0 |
| Anesthesiology, ophthalmology, and otorhinolaryngology | 1 | 0 | 0 |
| Anesthesiology, pain, and palliative care | 1 | 0 | 0 |
| Anesthesiology, pharmacology, and nutrition | 0 | 2 | 0 |
| Anesthesiology, surgery, and pain | 2 | 0 | 0 |
| Pain | 46 | 0 | 0 |
| Current surgical and anesthetic research and its methods | 0 | 0 | 1 |
| Oncology and palliative care | 1 | 1 | 0 |
| Pain and palliative care | 6 | 0 | 0 |
| Palliative care | 14 | 0 | 4 |
| Palliative care and basic life support | 1 | 0 | 0 |

such as pain management, palliative care, and life support, among others, as depicted in Table 1.

The more detailed curricula observed in Spanish institutions reflected a greater presence of specific anesthesiology competencies, as illustrated in Table 2. Among these, acute pain management was cited in 52.3% of institutions, followed by chronic pain and preoperative evaluation (50%), treatment of shock, fluid replacement, and blood transfusion (47.7%), and cardiopulmonary resuscitation (45.5%). Other competencies, such as airway management, neuroaxial block or puncture, peripheral nerve blocks, local anesthesia, the use of intravenous and inhalational anesthetics, neuromuscular blockers, monitoring, palliative care, vascular access, the use of vasoactive drugs, and multidisciplinary teamwork, were identified in fewer than 45% of Spanish institutions.

In Brazil, the most prevalent competencies were preoperative evaluation (17.9%), cardiopulmonary resuscitation (17.4%), and acute pain management (15.5%). The remaining competencies were mentioned in fewer than 15% of the analyzed institutions.

In contrast, in the UK, although 95.8% of institutions had curricular matrices, the incidence of specific competencies was notably low, as shown in Table 2. Multidisciplinary teamwork was identified in only 6.3% of institutions, airway management in 4.2%, and the following competencies in 2.1%: acute and chronic pain management, cardiopulmonary resuscitation, monitoring, local anesthesia, treatment of shock, fluid replacement, blood transfusion, and vascular access.

The details of the anesthesiology competencies described in the syllabi of the countries analyzed are presented in Table 2.

## Discussion

This study analyzed three countries that share public health systems with universal access: Brazil, Spain, and the UK. This common feature justified the selection of these countries for a comparative investigation into the presence of anesthesiology competencies in the curricula of their medical schools.

**Table 2** Anesthesiology skills in the syllabi of medical schools in Brazil, Spain, and the UK

| Anesthesiology skills | Brazil | % | Spain | % | UK | % |
|---|---|---|---|---|---|---|
| Acute pain | 58 | 15.5 | 23 | 52.3 | 1 | 2.1 |
| Chronic pain | 55 | 14.7 | 22 | 50.0 | 1 | 2.1 |
| Airway management | 52 | 13.9 | 18 | 40.9 | 2 | 4.2 |
| Cardiorespiratory resuscitation | 65 | 17.4 | 20 | 45.5 | 1 | 2.1 |
| Monitoring | 35 | 9.4 | 11 | 25.0 | 1 | 2.1 |
| Multidisciplinary teamwork | 55 | 14.7 | 10 | 22.7 | 3 | 6.3 |
| Neuromuscular blockade | 29 | 7.8 | 7 | 15.9 | 0 | 0 |
| Local anesthesia | 55 | 14.7 | 19 | 43.2 | 1 | 2.1 |
| Neuraxial blockade | 45 | 12.0 | 20 | 45.5 | 0 | 0 |
| Palliative care | 35 | 9.4 | 11 | 25.0 | 0 | 0 |
| Peripheral blocks | 40 | 10.7 | 19 | 43.2 | 0 | 0 |
| Preoperative evaluation | 67 | 17.9 | 22 | 50.0 | 0 | 0 |
| Shock, volume replacement and blood transfusion | 50 | 13.4 | 21 | 47.7 | 1 | 2.1 |
| Vascular access | 43 | 11.5 | 14 | 31.8 | 1 | 2.1 |
| Vasoactive drugs | 32 | 8.5 | 4 | 9.1 | 0 | 0 |
| Venous anesthetics | 41 | 10.9 | 19 | 43.2 | 0 | 0 |
| Inhalation anesthetics | 44 | 11.7 | 16 | 36.4 | 0 | 0 |

Initially, a mapping of medical education institutions in each country was conducted, revealing two key findings. The first was that Brazil has 374 medical schools, the second-largest number globally, serving a population of 210 million. Brazil is surpassed only by India, which has 632 medical schools [14] with a population of 1.45 billion. The second finding concerns the low proportion of public medical schools in Brazil (38.8%) compared with the UK (95.8%) and Spain (72.7%), which have populations of 69.1 million and 47.9 million, respectively [15].

The rapid growth of private institutions in Brazil between 2000 and 2020 was not mirrored in the UK or Spain. However, a similar phenomenon was observed in countries such as India, Bangladesh, Japan, Nepal, Pakistan, South Korea, Taiwan, Yemen, Bahrain, and Qatar [16–18]. Future studies are recommended to evaluate whether this expansion in Brazil addresses population demands while prioritizing quality over profitability.

The findings highlight the need to improve anesthesiology competencies in undergraduate medical curricula, particularly in Brazil and the UK, whereas Spain has a comparative advantage. However, this underrepresentation may not necessarily indicate the absence of these competencies. Instead, it could reflect inadequacies in how curricula are described. This discrepancy might also be influenced by the nature of the study, which was documentary in design, conducted across three countries with distinct languages, and based on digital documents intended for general public access. Such documents may not comprehensively capture all the elements of pedagogical projects.

The full availability of the pedagogical project, along with other indicators, can have an individual impact, helping students choose the institution and organize their study plans throughout their undergraduate education. This supports the transversal learning of competencies, the rational selection of subjects, and exposure to medical specialties. For example, the institution ranked number 1, Havard University, in the QS Quacquarelli Symonds rankings (topuniversities.com, accessed on November 08, 2024) and the Shanghai Ranking's Global Ranking of Academic Subjects (shanghairanking.com, accessed on November 08, 2024) for medicine presents a detailed and publicly accessible curriculum matrix, including syllabi, bibliographic references, workload, evaluation processes, and information about the professors. Anesthesiology offers six courses: clinical anesthesia, pain management, respiratory-surgical care, intraoperative and postoperative management of the cardiac surgical patient, and anesthesia for infants and children [19].

In addition to individual impact, teaching anesthesiology competencies is relevant from both educational and public health perspectives. A study by MacQuene and collaborators 2021 highlighted that deaths from surgically treatable conditions surpass those caused by infectious diseases such as HIV, tuberculosis, and malaria combined. They also noted that decentralized surgical services improve access for rural populations and that the strength of a surgical system could influence the response to the COVID-19 pandemic, given that the disease results in severe cases for a minority of patients who can die without intensive care services, including mechanical ventilation [20, 21].

From this perspective, which encompasses the concept of global surgery [22], the results from Spain suggest that the country theoretically presents a better curricular organization, allowing a clearer identification of competencies, including those in anesthesiology, which could positively impact the teaching and learning process for medical students.

Teaching requires an understanding that education is a form of intervention in the world, which demands conscious decisions and methodological rigor [23]. In the context of medical education, it is essential to critically evaluate curriculum design and its applicability to ensure that general practitioners develop the necessary competencies for professional practice by the end of their training. These competencies should enable them to manage critically ill patients, perform life-saving interventions — such as establishing venous access, providing oxygen supplementation, and performing cardiopulmonary resuscitation — and safely perform suturing with local anesthesia. They should also be able to adequately prepare patients for referral to secondary and tertiary care networks when surgical procedures are needed; conduct preoperative assessments; understand general and regional anesthesia techniques; monitor vital functions in the pre, peri-, and postoperative periods; manage acute and chronic pain; and communicate effectively with patients, families, and multidisciplinary and multiprofessional teams, both in institutional and community settings [24].

However, the competencies required by general practitioners and anesthesiologists differ significantly, reflecting the depth of training, scope of practice, and responsibilities in patient care. These differences may also have legal implications that vary across countries. For example, in Australia, there are large regions, particularly in small towns and rural areas, where general practitioners are responsible for administering anesthesia. This scope of practice follows the guidelines established by the Joint Consultative Committee on Anesthesia (JCCA), a tripartite committee that includes representatives from the Australian and New Zealand College of Anesthetists (ANZCA), the Royal Australian College of General Practitioners (RACGP), and the Australian College of Rural and Remote Medicine (ACRRM) [24].

**Table 3** Essential anesthesiology competencies for non-specialist doctors

| Skills and abilities | Description |
|---|---|
| *1. General* | |
| The relational dimension | Involves the ability to establish and maintain good professional relationships with patients, families, colleagues, and other team members. |
| The affective dimension | Involves the ethical and moral values of medical practice. |
| The integrative dimension | Corresponds to the appropriate use of clinical reasoning strategies, incorporating biological, clinical, humanistic, and social elements in the analysis and decision-making process. |
| The contextual dimension | Encompasses contextualized practice, considering the structural and functional potentialities and limitations of the places where health care is provided. |
| *2. Specific* | The technical dimension essentially involves the development of physical examination skills and the performance of procedures. |
| Preoperative evaluation | Conduct anamnesis, perform a physical examination, and request and/or evaluate complementary tests for surgical risk stratification and to formulate the therapeutic plan. |
| Airway management | It involves knowledge about the indication of devices for oxygen supplementation, ventilatory masks, oropharyngeal and nasopharyngeal cannulas, tracheal tubes, supraglottic devices, tracheostomy cannulas, intubate styles (Frova or boogie laryngoscopes, videolaryngoscopes, and bronchofibroscopes). |
| Cardiorespiratory resuscitation | It involves understanding of the series of maneuvers designed to reestablish vital functions. |
| Monitoring | Demonstrate an understanding of the indications and appropriate use of equipment for monitoring respiratory, cardiac, cerebral, and renal functions, including devices such as a cardiac monitor, pulse oximeter, invasive and non-invasive blood pressure monitoring, capnograph, urinary catheterization for urine output assessment, cerebral and renal oximetry, as well as the use of point-of-care ultrasound for bedside diagnostic and therapeutic support. |
| Vascular access | It involves knowledge of vascular anatomy and its application in performing procedures for both diagnostic examinations and the safe and effective administration of drugs and fluids. |
| Volume and hydroelectrolyte replacement | It involves understanding the indications for the infusion of fluids and electrolytes for the prevention or treatment of disturbances during the preoperative, perioperative, and postoperative periods. |
| General anesthesia | It involves knowledge of the drugs and equipment used during general anesthesia, which requires the induction and maintenance of hypnosis, analgesia, neurovegetative protection, and neuromuscular blockade. |
| Local anesthesia | It involves understanding the indications for local anesthetics in topical or local anesthesia. |
| Regional anesthesia | It involves understanding the indications for regional anesthesia in surgical and diagnostic procedures. |
| Management of acute and chronic pain | It involves understanding that pain management is complex and requires steps for the use of drugs and procedures, as well as protocols with a multidisciplinary and multiprofessional approach. |

This study may serve as an initial reference for discussions on which anesthesiology competencies should be considered essential in undergraduate medical education. Under this premise, after the results of this research and the recommendations from various organizations for anesthesiology practice — such as the American Society of Anesthesiologists [25], the Brazilian Society of Anesthesiology [26], the European Society of Anesthesiology and Intensive Care [12], the World Federation of Societies of Anesthesiologists [27], the Department of Anesthesiology and Critical Care at a Government Medical College in India [28], the International Anesthesia Research Society [29], the Royal College of Physicians and Surgeons of Canada [30], and the Accreditation Council for Graduate Medical Education [31] — the authors summarized in Table 3 the competencies suggested as essential for general practitioners.

The final curricular definition of these competencies may result from an analysis of recommendations from various organizations, such as the Latin American and Caribbean Association of Medical Schools (ALAFEM), the Pan-American Federation of Medical Schools (FEPAFEM/PAFAMS), the Association for Medical Education in the Western Pacific Region (AMEWPR), the European Union of Medical Specialists (UEMS), the Association of Medical Councils of Africa (AMCOA), the China Medical Board (CMB), the Japan Accreditation Council for Medical Education (JACME), the Arab Board of Medical Specializations (ABMS), and the International Federation of Medical Students' Associations (IFMSA).

Internationally, the structure and depth of medical curricula vary significantly. The World Federation for Medical Education (WFME) provides prescriptive but nonmandatory recommendations, emphasizing that curricular content across all domains should be sufficient for students to achieve the intended learning outcomes and transition safely to the next stage of training or clinical practice [32]. However, determining the ideal level of exposure to anesthesiology for medical students requires considering a broader range of perspectives beyond national guidelines.

Although anesthesiology is often associated with procedural skills, it also involves critical aspects, such as preoperative patient assessment, perioperative care, and pain management, which are fundamental to medical practice. Furthermore, while intensive care and critical care medicine share significant overlap with anesthesiology, these topics are generally addressed within a broader

multidisciplinary context rather than being confined to a specific anesthesiology rotation [33].

Future discussions should explore how different countries and medical education organizations integrate anesthesiology training into their curricula. By analyzing global standards and professional recommendations, medical education frameworks can be refined to ensure that all graduates acquire essential competencies, including those related to anesthesiology, regardless of their future specialization.

## Conclusions

The results highlight the need to show more explicitly the competencies on public websites detailing undergraduate medical curricula, particularly in Brazil and the UK. This study emphasizes Spain's more organized curricular structure, which facilitates the clearer identification of competencies, including those related to anesthesiology. Furthermore, it is crucial to propose a standardized curricular matrix model to ensure the training of physicians with comparable competencies who can work in any country, for example, under future pandemic conditions, while also enabling comparative studies across different nations.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-025-07086-x.

Supplementary Material 1

**Acknowledgements**
We would like to thank the Program in Education in Biosciences and Health at the Oswaldo Cruz Institute for their support in the development of this work.

**Author contributions**
DSAR conceived the study, designed the methodology, provided the resources, conducted the investigation and the formal analysis, managed the data, produced the data presentation, and wrote the original draft. MASA conducted the investigation and the formal analysis, managed the data and produced the data presentation. NCSF conducted the formal analysis, prepared the figures, and wrote the original draft. LAA conceived and supervised the study, administrated the project, designed the methodology, provided the resources, and reviewed and edited the manuscript. All authors have approved the final manuscript.

**Funding**
None declared.

**Data availability**
The datasets generated during and/or analyzed during the present study are available from the corresponding author upon reasonable request.

## Declarations

**Ethics approval and consent to participate**
None sought.

**Consent to publish**
Not applicable.

**Consent to participate**
Not applicable.

**Clinical trial number**
Not applicable.

**Generative AI and AI-assisted technologies in the writing process**
During the preparation of this work, the author(s) utilized ChatGPT to assist in identifying grammatical errors, including punctuation and grammatical concordance. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

**Competing interests**
The authors declare no competing interests.

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Received: 5 December 2024 / Accepted: 31 March 2025
Published online: 11 April 2025

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