



CLINICALLY ORIENTED ANATOMY TEACHING IN UNDERGRADUATE MEDICAL EDUCATION: A NARRATIVE REVIEW

Dr. Aparna M Krishnan¹, Dr. Arun Babu E², Dr. Uday Kumar^{3*}

¹Assistant Professor, Department of Anatomy, Neelima Institute of Medical Sciences, Anurag University, Hyderabad, Telangana, India.

²Assistant Professor, MVJ Medical College and Research Hospital Hoskote, Bangalore, Karnataka, India.

³Professor & HOD, Department of Anatomy, Neelima Institute of Medical Sciences, Anurag University, Hyderabad, Telangana, India.

Corresponding Author*: Prof. Dr Uday Kumar, Professor & HOD, Department of Anatomy, Neelima Institute of Medical Sciences, Anurag University, Hyderabad, Telangana, India.

Email ID: doctoruday@gmail.com

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ABSTRACT

Background: Anatomy remains a cornerstone of undergraduate medical education; however, rapidly evolving medical curricula have shifted emphasis from traditional knowledge acquisition towards clinically integrated, competency-based learning. Clinically oriented anatomy teaching aims to enhance students' ability to apply anatomical knowledge in clinical practice through curriculum integration, active learning, medical imaging, simulation, and technology-enhanced education.

Objective: This narrative review aims to summarize current evidence on clinically oriented anatomy teaching in undergraduate medical education, focusing on curriculum integration, contemporary teaching strategies, technology-enhanced learning, assessment approaches, educational outcomes, and future directions.

Methods: A narrative literature review was conducted using electronic databases including PubMed, Scopus, and Google Scholar. Relevant English-language articles published between 2000 and 2025 were identified using combinations of keywords such as anatomy education, clinical anatomy, undergraduate medical education, cadaveric dissection, curriculum integration, medical imaging, virtual reality, active learning, and competency-based medical education. Original research articles, systematic reviews, narrative reviews, educational guidelines, and landmark publications relevant to undergraduate anatomy education were included. Studies focusing exclusively on postgraduate education or unrelated health professions were excluded. The retrieved literature was narratively synthesized according to major educational themes.

Results: Current evidence suggests that clinically oriented anatomy teaching improves learner engagement, contextual understanding, knowledge retention, and early clinical reasoning. Integrated curricula combining cadaveric dissection, prosections, clinical case-based learning, medical imaging, technology-enhanced learning, and formative assessment appear to provide greater educational benefits than reliance on any single instructional approach. Emerging technologies such as virtual reality, augmented reality, and point-of-care ultrasonography further enhance anatomical visualization and clinical integration when used alongside traditional teaching methods.

Conclusion: Clinically oriented anatomy teaching represents an effective educational framework that bridges foundational anatomical sciences with clinical practice. A balanced multimodal curriculum integrating traditional cadaver-based instruction with active learning, clinical correlation, technology-enhanced education, and competency-based assessment

is likely to best prepare undergraduate medical students for contemporary clinical practice. Future research should focus on multicentre studies evaluating long-term educational and clinical outcomes.

KEYWORDS: Anatomy Education, Clinical Anatomy, Undergraduate Medical Education, Curriculum Integration, Cadaveric Dissection, Clinical Reasoning.

Introduction

Anatomy is the structural basis of medical science and forms the foundation of undergraduate medical education. A thorough knowledge of human anatomy is essential for physical examination, interpretation of diagnostic imaging, performance of surgical procedures and safe clinical practice[1]. It also provides the basis for understanding physiology, pathology and other clinical subjects, thus enabling students to integrate the basic sciences with patient care[2,3]. Anatomy education has undergone considerable transformation over the past few decades. Traditional curricula based on cadaveric dissection have gradually evolved towards integrated, competency-based curricula with incorporation of case-based learning, team-based learning, medical imaging, simulation and digital technology[4]. These evolutions have been driven by decreased curricular time, expanding medical knowledge, faculty shortages, and the need to prepare graduates who can apply anatomical knowledge effectively in clinical practice[5,6].

Despite these advancements, a major challenge remains to bridge the gap between anatomical knowledge and application. This has resulted in an increased emphasis on clinically oriented anatomy teaching which integrates anatomy with clinical cases, medical imaging, physical examination, procedural skills and active learning strategies to improve knowledge retention and clinical reasoning[3,7,8]. This narrative review summarizes the current evidence on clinically oriented anatomy teaching in undergraduate medical education, with particular emphasis on curriculum integration, contemporary teaching strategies, technology-enhanced learning, assessment, and future directions.

Methodology

This narrative review was conducted to provide a comprehensive overview of contemporary evidence regarding clinically oriented anatomy teaching in undergraduate medical education. A structured literature search was performed using the electronic databases PubMed, Scopus, and Google Scholar to identify relevant publications. The search included articles published from January 2000 to June 2025. The search strategy employed combinations of Medical Subject Headings (MeSH) and free-text keywords, including anatomy education, clinical anatomy, undergraduate medical education, clinically oriented anatomy, cadaveric dissection, prosection, curriculum integration, medical imaging, virtual reality, augmented reality, active learning, problem-based learning,

team-based learning, competency-based medical education, assessment, and clinical reasoning. Boolean operators (AND and OR) were used to optimize the search strategy. The selected literature was narratively synthesized according to the major themes of clinically oriented anatomy education.

Evolution of Anatomy Education

Anatomy has traditionally been taught as a discipline-based subject and for centuries cadaveric dissection has been the cornerstone of undergraduate medical education. Anatomy was a central part of the medical curriculum, as a sound knowledge of the human form was thought essential to the practice of medicine and surgery. Cadaveric dissection provided a full appreciation of three-dimensional anatomical relationships, normal anatomical variations and hands-on experience with tissue planes that could not be learned through illustrations and models alone[1]. Besides learning anatomy, students would develop observational skills, manual dexterity, teamwork, professional behaviour and respect for body donors and thus dissection became an educational experience that transcended the study of gross anatomy[4]. Traditional anatomy teaching therefore was focused on systematic regional dissection supported by lectures and practical demonstrations with the main goal to build a solid structural basis prior to clinical training[2,6].

The traditional dissection-based model had been very successful for generations of medical students, but profound changes in medical education and healthcare delivery required anatomy curricula to be re-evaluated[5]. The rapid expansion of biomedical knowledge, the increasing emphasis on emerging disciplines and the pressure to accommodate new competencies within already crowded curricula resulted in a progressive reduction in the time allocated for teaching anatomy. At the same time, the increasing number of students, the shortage of trained anatomy teachers, the reduced number of available donated cadavers, and the financial and logistical difficulties of operating dissection laboratories posed serious challenges for the continued use of traditional anatomy courses[8]. Such limitations encouraged educators to explore more efficient and effective educational ways of teaching anatomy, while still maintaining the basic learning goals of traditional anatomy instruction[9,10]. The move to competency-based medical education further accelerated the reform of the curriculum, moving the focus from the acquisition of factual knowledge to the development of measurable competencies, including clinical reasoning, communication, professionalism, teamwork, and lifelong learning[8,9]. Anatomy, therefore, was no longer seen as an isolated preclinical discipline, but rather as a foundational

science that should directly contribute to the development of clinically competent graduates. Curriculum reform did not increase the amount of anatomical content, but sought to improve its relevance, integration and application in contemporary medical education[11,12].

To address these educational challenges, anatomy curricula slowly transitioned from discipline-based instruction to integrated and clinically relevant educational models[3]. One important development was the introduction of horizontal integration, where anatomy is taught together with related basic science disciplines such as physiology and biochemistry[8,9]. This approach helps students to get a more holistic understanding of the relationship of structure and function and at the same time to reduce fragmentation of knowledge across individual subjects. Another reform of equal importance was the introduction of vertical integration where anatomical concepts are revisited during the clinical years through radiological imaging, surgical teaching, physical examination, bedside demonstrations and specialty-specific clinical modules[3]. Instead of limiting the study of anatomy to the preclinical phase, vertical integration consolidates anatomical knowledge throughout the undergraduate medical training, allowing students to apply foundational concepts in increasingly complex clinical settings. This longitudinal reinforcement enhances knowledge retention, facilitates transfer of learning, and stimulates clinical reasoning development by connecting anatomical principles to patient care[8,11].

Modern anatomical curricula have thus evolved into multimodal educational programmes that combine traditional cadaveric teaching with complementary instructional approaches including prosections, clinical case discussions, radiological imaging, simulation and digital learning resources. These strategies are not intended to replace dissection, but rather to maximise the educational benefit of the limited time available in the curriculum while providing students with different perspectives on human anatomy[2,6]. Current evidence consistently indicates that there is no single teaching method that is the best choice in all circumstances, but rather well thought out curricula that incorporate complementary teaching methods offer greater flexibility, better student engagement and better prepare graduates for modern clinical practice[8,9]. Along with curricular reform came a fundamental change in educational philosophy. Traditional teaching of anatomy was largely teacher-centred, with learning by way of lectures and instructor-led practical demonstrations, where students were mainly passive recipients of information[6]. However, contemporary medical education increasingly recognises that meaningful learning requires active participation, self-directed inquiry, collaboration and continuous reflection[8]. As a result, anatomy educators have gradually adopted learner-centred approaches that encourage students to take greater responsibility for their own learning while faculty

members move from being providers of information to facilitators of knowledge acquisition and application[9,10].

This shift in educational philosophy has also affected the expected learning outcomes of anatomy education. Contemporary curricula focus on the development of higher order cognitive skills such as critical thinking, problem solving, communication, teamwork and lifelong learning rather than on the mere memorization of anatomical facts[7, 8]. Students are encouraged to integrate their anatomical knowledge with functional and clinical concepts, apply their understanding to authentic clinical situations and progressively develop clinical reasoning from the early stages of undergraduate training. This strategy not only improves conceptual understanding but also promotes long-term retention by encouraging learners to actively and repeatedly construct and reinforce anatomical knowledge[13,14]. The move towards learner-centred education has also introduced more flexibility to the curriculum. To meet the needs of diverse learning styles and to foster independent learning beyond the classroom, anatomy curricula are increasingly including self-directed learning, peer-assisted learning, collaborative discussions, reflective exercises, and blended learning environments[6,10]. While the educational strategies differ in their application, they all share the goal of enhancing deeper learning via active engagement instead of passive absorption of information. This educational philosophy forms the basis of many current approaches to teaching anatomy and has become an integral part of clinically relevant anatomy education[13].

Along with curriculum reform, remarkable progress in the field of healthcare has deeply transformed the anatomical competencies required of medical graduates[2]. The extensive use of cross-sectional imaging, minimally invasive and image-guided procedures, endoscopy, microsurgery, and point-of-care ultrasonography has revolutionized the way clinicians visualize and utilize anatomical knowledge in their daily practice[3]. As a result, anatomy education has evolved from the study of gross morphology to include radiological, sectional, surface, and living anatomy, allowing students to understand anatomical relationships in clinically relevant settings. This broader view allows students to see anatomy as more than a descriptive discipline. Rather, it can be viewed as a practical science that underlies diagnostic reasoning, safe procedures, and clinical decision making[10,11]. These developments have also affected the expected results of undergraduate anatomy education. Thus, modern curricula are designed to train graduates who interpret medical images, identify anatomical landmarks in physical examination and clinical procedures, recognize normal anatomical variation, and apply anatomical principles in patient management, as opposed to training students for written examinations only[2,8]. These expectations have prompted closer collaboration among anatomists, clinicians, radiologists and surgeons in curriculum planning, to ensure

that anatomical learning is aligned with contemporary healthcare practice without sacrificing the scientific basis of the discipline[11,15,16].

Importantly, educational innovation has been driven not only by advances in technology but also by the recognition that clinical competence depends on the ability to integrate anatomical knowledge across multiple contexts[3,8]. Thus, modern anatomy curricula increasingly emphasize contextual learning, repeated reinforcement, and meaningful clinical application throughout undergraduate training rather than isolated acquisition of factual knowledge during the preclinical years. This has helped to reorient anatomy into a dynamic and clinically responsive discipline that changes with advances in medicine and health care delivery[14]. Despite considerable progress in curriculum design and educational innovation, a number of challenges continue to undermine the effectiveness of anatomy education globally. Numerous attempts to standardize medical education have not eliminated significant disparities between medical schools in terms of curriculum structure, teaching hours, instructional methods, and assessment approaches. These differences result in variations in the level and uniformity of anatomical knowledge among graduates[5]. Student surveys consistently express concerns regarding inadequate anatomical readiness for clinical practice. Meanwhile, educators face challenges in ensuring thorough anatomical instruction amidst increasingly packed medical curricula. This suggests that curriculum reform should be informed not only by educational trends but also by evidence of concrete improvements in learning outcomes and clinical competence[11,12].

Another major problem is the sustainability of anatomy education in the face of changing institutional and societal demands. The lack of experienced anatomy faculty, limited access to cadaveric material, financial constraints, and the increasing pressure to implement new educational technologies continue to challenge many medical schools[5,15]. Although digital resources and simulation have opened new avenues for teaching and learning, they cannot entirely replace the educational benefits of faculty mentorship, cadaveric experience, and clinically contextualized teaching[13]. Therefore, the successful reform of the curriculum will require ongoing investment in faculty development, interdisciplinary collaboration, and evidence-based educational practices rather than the mere adoption of newer technologies or the reduction of traditional teaching methods[14,17]. The present evidence favors a balanced and flexible approach to anatomy education and does not support one best way to teach anatomy. Modern curricula should retain the strengths of traditional anatomy teaching but incorporate educational strategies that are clinically relevant, learner centred and enhanced by technology and well defined learning objectives[2, 6]. Such an approach is more likely to produce graduates with not only sound anatomical knowledge but also the ability to

apply that knowledge effectively throughout their clinical training and professional practice[8, 9].

Together, these advances have transformed anatomy education from a largely descriptive, discipline-based subject into an integrated, learner-centred, and clinically relevant component of undergraduate medical education[2]. The evolution of anatomy curricula reflects a broader shift in medical education from passive factual knowledge acquisition to competency development that enables students to interpret, integrate, and apply anatomical concepts in diverse clinical settings[6]. As a result, contemporary anatomy education has expanded beyond the dissection laboratory to encompass clinical correlations, diagnostic imaging, procedural skills, and contextual learning experiences that highlight the significance of anatomy throughout medical training. While there are differences in the way this has been implemented across institutions, there is general agreement that teaching anatomy should be relevant to clinical practice, integrated with other disciplines within the curriculum, and address the competencies that are required of modern health care professionals[3]. This pedagogical evolution has provided the conceptual underpinning for the clinically oriented teaching of anatomy, an approach that systematically relates the anatomical sciences to clinical reasoning, patient care, and professional practice, and which is the subject of the next section[16].

Clinically Oriented Anatomy Teaching: Concept and Educational Framework

Clinically oriented anatomy teaching is an educational approach that connects the knowledge of anatomy with its application in clinical practice. Unlike traditional teaching of anatomy, where the focus was on learning descriptive anatomical knowledge in the preclinical years, clinically oriented anatomy tries to teach anatomical concepts in meaningful clinical contexts from the very start of undergraduate medical education[6]. The aim is not only to enable students to identify anatomical structures, but also to understand their functional significance, clinical relevance and contribution to patient care. This approach encourages students to see anatomy as a living discipline underpinning clinical decision making, rather than as an isolated basic science subject, through the consistent linking of anatomy to clinical situations, diagnostic techniques and health care practice[8]. Contextual learning is the conceptual basis of clinically oriented anatomy teaching. Knowledge is acquired and retained better if presented in authentic and meaningful situations. Rather than studying anatomical structures in isolation, students are encouraged to learn how anatomy relates to physiological function, pathological processes, physical examination, diagnostic imaging, and therapeutic interventions. Such contextualization promotes meaningful learning by allowing learners to integrate newly acquired anatomical knowledge with previously learned knowledge and apply that knowledge to different clinical situations[2].

Anatomy then becomes a basis for clinical thinking rather than a subject to be memorized for examinations[3].

A key goal in teaching clinically oriented anatomy is to develop clinical reasoning early. This doesn't mean that at the undergraduate level the students are expected to formulate complex diagnoses. Instead, anatomy education develops morphological reasoning, where students interpret clinical signs and symptoms by understanding the anatomical relationships. For example, students learn to explain how the location of a lesion affects neurological deficits, how vascular anatomy determines patterns of ischemia, or why anatomical variations may influence surgical approaches. The exercises are designed to provide students with a cognitive framework upon which to build more sophisticated diagnostic reasoning in the clinical years. Integration of anatomy and clinical interpretation in a progressive fashion promotes students' analytical thinking and enhances long-term retention of anatomical knowledge[3,7,8]. Educational frameworks that stress constructive alignment between learning objectives, teaching strategies and assessment also support clinically oriented anatomy teaching[13]. Learning outcomes are increasingly moving beyond factual recall to include interpretation, application, communication and professional competence. This means that anatomy curricula must revisit clinically relevant concepts throughout undergraduate training, progressively increasing their complexity, but maintaining continuity between basic and clinical sciences. This longitudinal reinforcement allows students to link the anatomical knowledge with subsequent learning experiences and to transfer knowledge from classroom learning to patient care[16].

In addition to the goal of enhancing anatomical knowledge, clinically oriented anatomy seeks to achieve educational objectives that are directly pertinent to clinical practice[3,8]. Students who have taken clinically integrated anatomy courses have shown a greater appreciation of the relevance of anatomy, greater confidence during their clinical training, enhanced ability to interpret radiological images and physical examination findings, and better preparation for procedural and surgical learning. More importantly, clinically oriented anatomy encourages students to view anatomical knowledge as a practical tool for solving clinical problems, thereby fostering lifelong learning and supporting the development of safe, competent healthcare professionals[18]. These principles make the teaching of clinically oriented anatomy more than simply adding clinical examples to traditional anatomy lectures. Rather, it is an integrated educational model where anatomical sciences are constantly integrated with clinical reasoning, professional competencies, and patient-centred learning throughout the undergraduate medical education. This framework is successfully implemented when multiple instructional strategies are thoughtfully integrated, each offering distinct educational benefits.

Teaching Strategies in Clinically Oriented Anatomy

Cadaveric Dissection and Prosections

In a clinically oriented anatomy curriculum, cadaveric dissection remains an integral educational experience, providing an opportunity for the translation of theoretical anatomical knowledge to a spatial three-dimensional understanding[2]. Dissection serves not only as a method to identify anatomical structures, but as an opportunity for students to explore anatomical relationships, develop an appreciation for normal anatomical variation, and correlate structural findings with their clinical relevance[4]. Faculty-led clinical correlations allow students to connect anatomical observations with surgical approaches, diagnostic procedures, radiological interpretation, and common pathological conditions, thus reinforcing the practical relevance of anatomy in the patient care setting[6]. Cadaveric dissection, while still highly valued, is increasingly supplemented by prosections as a complementary resource in contemporary curricula. Prosections are prepared specimens that allow students to efficiently study complex anatomical regions and demonstrate clinically important structures that are difficult for the novice learner to identify during independent dissection[5,9]. Prosections also allow for standardized teaching, time efficiency, and more emphasis on anatomical interpretation rather than technical dissection alone. Therefore, many medical schools combine dissection and prosection depending on curricular objectives, available resources and institutional infrastructure[11].

Studies comparing cadaveric dissection to prosection have not demonstrated consistent superiority of one over the other. Active participation in dissection promotes spatial understanding, psychomotor skills development, formation of professional identity and appreciation of anatomical variation. Alternatively, prosection provides a concentrated exposure to high-quality specimens and maximizes the learning within the constraints of the time available in the curriculum[4,5,9]. Instead of viewing these approaches as competing options, the current evidence in education supports their complementary use within integrated anatomy curricula. The decision to use one or the other, therefore, should be based on the intended learning outcomes rather than on tradition alone[6]. One of the key strengths of cadaver-based learning is the meaningful clinical integration it allows[8]. Anatomy laboratories incorporate clinical scenarios, radiological images, operative photographs and guided discussions that encourage students to apply anatomical knowledge as they examine cadaveric specimens. This kind of contextual learning provides learners with an understanding of the anatomical basis of clinical signs, diagnostic procedures and surgical interventions, without detracting from the educational value of traditional dissection. The faculty facilitation to help students to identify clinically relevant structures and to integrate anatomical

observations with future professional practice is of special importance [18]. In addition to knowledge acquisition, cadaveric teaching also promotes professionalism, empathy, ethical awareness, communication and respect for body donation. These qualities are difficult to reproduce with digital resources alone and remain important educational outcomes of anatomy education[3,5]. Therefore, even with continued technological advances, the majority of modern reviews find that cadaveric teaching should continue to be an important part of undergraduate anatomy education, alongside other teaching methods, not as a substitute for them[13,14].

Clinical Case-Based and Active Learning

Unlike the traditional approach to teaching anatomy, which often relied on the passive acquisition of facts, clinically oriented anatomy focuses on the active involvement of students in the process of learning. Active learning strategies motivate students to analyse, discuss and apply anatomical concepts rather than just memorising structures, thus encouraging deeper understanding and long-term retention[6,8]. In clinically oriented anatomy teaching, learning is based on solving authentic clinical problems, integrating anatomical knowledge with functional and pathological concepts and developing the analytical skills needed for future clinical practice. Thus the role of the educator has shifted from the provision of information to that of discussion facilitator, inquiry guide and giver of constructive feedback during learning[7,19].

A very common way of contextualising anatomy education is through the use of clinical case-based learning. Patient scenarios encourage students to link anatomical structures with the clinical presentation, physical examination findings, diagnostic investigations and therapeutic interventions[3]. Such discussions promote meaningful learning by demonstrating the relevance of anatomy, while simultaneously promoting knowledge integration across various disciplines. Case-based learning fosters morphological reasoning by enabling learners to explain clinical findings in terms of underlying anatomical relationships rather than requiring students to make complex diagnoses[3,8]. This gradual transition from anatomical understanding to clinical interpretation establishes an important foundation for future clinical reasoning and decision-making[20]. Problem-based learning (PBL), team-based learning (TBL) and peer-assisted learning (PAL) are examples of active learning that put more onus on the students to learn. These teaching methods promote independent preparation, discussion with peers and the application of anatomical knowledge in small group learning. Students learn from not only faculty members, but also their peers, which allows them to identify misconceptions, improve communication skills, and build confidence in their ability to explain anatomical concepts[2,9,19]. While these methods differ in their educational design, they all

have the common goal of encouraging critical thinking and self-directed learning rather than passive memorization. Current evidence suggests that these strategies are most effective when used in conjunction with structured faculty guidance and clear learning outcomes[21,22].

Several educational innovations have shown that clinically oriented anatomy learning can be successfully achieved by combining cadaveric dissection with active and contextual learning strategies[23]. The integration of cadaveric dissection with problem-based learning cases increases students' confidence and perceived readiness by reinforcing anatomical concepts within relevant clinical scenarios, although performance on examinations may be similar. Likewise, clinically oriented dissection courses that incorporate peer teaching, team-based activities and clinical discussions improve student engagement, allow for a deeper understanding of anatomical relationships and complement system-based curricula[24]. Extracurricular dissection programmes have also been associated with improved application of anatomical knowledge, particularly in higher-order assessment items, while allowing students the flexibility to partake in self-directed learning. In conclusion, these results indicate that the educational value of cadaveric dissection is best realised when integrated with clinically relevant, student-centred teaching strategies rather than as an isolated learning activity[25,26]. Another key element of clinically oriented anatomy teaching is the introduction of real clinical experiences in early years of medical education. Students are able to correlate anatomical knowledge with physical examination and common clinical conditions through standardized patients, bedside demonstrations, clinical skills workshops, and faculty-led discussions [27]. These experiences help bridge the traditional gap between preclinical and clinical education by demonstrating the direct application of anatomy in patient care. Students consistently demonstrate greater motivation and improved appreciation of anatomy when learning activities are explicitly connected to clinical practice, supporting the idea that contextual relevance is a major determinant of meaningful learning[18,28].

In summary, evidence from current anatomy education suggests that no one active learning strategy is superior across the board. Rather, the judicious inclusion of several complementary approaches, each with their own educational benefits, is helpful in the teaching of clinically oriented anatomy[2,6]. Case-based discussions promote contextual understanding, collaborative learning improves communication and teamwork, innovations in laboratory work enhance the application of anatomical knowledge and authentic clinical encounters promote the professional relevance of anatomy. Together, these strategies promote deeper learning, enable knowledge retention and allow the progressive development of clinical reasoning while keeping anatomy as the core basis of undergraduate medical education[19,20,27].

Technology-Enhanced Anatomy Teaching

Technological innovations have greatly expanded the resources available for anatomy education and have become valuable adjuncts to clinically oriented teaching. Rather than replacing traditional instructional methods, contemporary technologies are providing students with additional avenues to visualize complex anatomical structures, explore spatial relationships, and integrate anatomical knowledge with clinical practice[10,29]. As digital learning resources become increasingly available, anatomy educators have been able to implement blended learning strategies that combine face-to-face teaching with interactive educational platforms, thereby extending learning beyond the classroom and catering to diverse learning preferences[30,31]. One of the most important advances has been the integration of medical imaging in undergraduate anatomy education. Radiographs, computed tomography (CT), magnetic resonance imaging (MRI), ultrasonography and three-dimensional reconstructions allow students to correlate cadaveric anatomy with living anatomy and to develop an understanding of the anatomical basis of diagnostic imaging[2,15]. Early exposure to imaging enhances spatial understanding and makes students familiar with investigations they encounter routinely during clinical training. The integration of radiological interpretation with anatomy teaching thus strengthens the link between basic anatomical knowledge and modern clinical practice, and it also reinforces the clinical relevance of anatomical sciences[16,32].

Immersive technologies such as virtual reality (VR), augmented reality (AR), and mixed reality (MR) provide an interactive three-dimensional visualization of anatomical structures that might be challenging to understand using traditional teaching methods alone. These technologies enable students to manipulate anatomical models, explore sectional anatomy and revisit complex regions from various perspectives. There is evidence that immersive technologies can enhance spatial understanding, learner engagement, and self-directed study particularly when used with faculty guidance and cadaveric teaching[33,34,35]. However, the literature consistently states that these technologies should be adjuncts rather than replacements to cadaveric learning as they do not replicate the tactile experience, anatomical variation, and professional development associated with dissection[30]. Technology has also changed the way we learn anatomy with digital atlases, online repositories, recorded lectures, interactive applications and virtual learning environments. These resources enable students to revisit anatomical concepts outside of scheduled teaching sessions and facilitate flexible, self-paced learning and support blended educational models[36]. Their value was especially evident during the COVID-19 pandemic that saw the worldwide adoption of digital anatomy education as remote learning became the norm. However, the educational effectiveness of these resources depends on the degree of

integration into the curriculum and the guidance offered by the faculty to ensure the effective use of technology for promoting meaningful learning as opposed to passive consumption of information[37,38,39].

Another trend in clinically oriented anatomy training is the growing importance of living (versus cadaver) anatomy through surface anatomy and point-of-care ultrasonography (POCUS)[32]. Surface anatomy assists students in correlating underlying structures to palpable anatomical landmarks during physical examination, while ultrasonography enables real-time visualization of normal anatomical structures in living persons. These approaches help bridge the gap between preclinical anatomy and bedside clinical practice by stimulating students to think about anatomical relationships in functional and dynamic terms. As ultrasonography becomes more integrated into routine clinical practice, early exposure during undergraduate training further enhances the clinical applicability of anatomy education[11]. Technology-enhanced anatomy education supports clinical education via improved visualization, self-directed learning, and integration of anatomy and clinical practice[2]. However, the current evidence consistently supports a blended educational approach where digital technologies, medical imaging, and immersive learning complement rather than replace cadaveric teaching, faculty mentorship, and active learning approaches. Thus, successful integration is not merely about the adoption of technology but rather its thoughtful alignment with educational objectives, curriculum design, and student learning needs[36,37].

Assessment and Evaluation of Clinically Oriented Anatomy Teaching

Assessment is an integral part of clinically oriented anatomy education since it influences not only the manner in which students are assessed but also the manner in which they learn. The current thinking in education recognises that assessment has to be constructively aligned with the aims of the curriculum and the methods of teaching. Therefore, if anatomy teaching is to be directed towards clinical application, reasoning and integration, assessment should also evaluate the students' ability to apply anatomical knowledge in real clinical situations as opposed to being solely dependent on recall of isolated facts[8,9,40]. Traditional assessment methods such as written examinations and practical spotter tests still have an important role to play in the assessment of basic anatomical knowledge. However, these techniques may not be sufficient in assessing higher order cognitive skills such as interpretation, problem solving and clinical application[2,16]. In this context, modern anatomy curricula are increasingly adopting clinically oriented assessment formats where students are required to interpret radiological images, analyse clinical scenarios, identify anatomical landmarks in physical examination and explain the anatomical basis of disease and procedural techniques. Such assessments promote the integration of

knowledge from different disciplines and maintain the clinical relevance of anatomy throughout the undergraduate curriculum[40,41].

Clinically-oriented anatomy teaching has also become more important in terms of formative assessment. Regular quizzes, structured feedback, reflection exercises, peer assessment and case-based discussions enable students to identify gaps in learning and progressively improve understanding prior to summative examinations. Continuous feedback promotes active involvement, encourages self-directed learning, and allows teachers to adjust their teaching strategies in response to student success. These formative approaches are especially helpful in anatomy education, where cumulative comprehension and frequent reinforcement are vital for long-term retention[8,19,40]. The evaluation of clinically oriented anatomy programmes should not be limited to student examination results. Contemporary educational research recommends assessing broader outcomes such as learner satisfaction, confidence in applying anatomical knowledge, clinical preparedness, professional development, and achievement of curriculum competencies[8,13]. Programme evaluation should also include faculty perspectives, resource utilization and long-term educational impact to determine whether instructional innovations truly improve learning, rather than simply adding new teaching methods. This wide-ranging evaluation supports ongoing curriculum development and evidence-based educational decision-making[40].

Ultimately, assessment is an integral component of clinically oriented anatomy education rather than a means of assigning grades. Assessment strategies linked to educational objectives, focused on clinical application and providing meaningful feedback are conducive to deeper learning and better preparing students for future clinical training. Thus a balanced blend of formative and summative assessment integrated with clinically relevant learning activities is required to ensure that graduates have a sound anatomical knowledge and the ability to apply it safely and effectively in patient care[40].

Challenges and Future Directions

However, there are still several educational and institutional challenges to its implementation, despite the growing acceptance of the clinically oriented anatomy teaching. Medical schools vary widely in their curriculum structure, hours of teaching, and access to cadaveric resources and educational technologies. This variability influences the degree of clinical integration that can be achieved, and frequently produces variation in students' anatomical competence at graduation[5,12]. Furthermore, the increased demands on curricula often compel anatomy educators to find a balance between comprehensive anatomical content and the limited time available in undergraduate medical programs, which necessitates careful prioritization of learning outcomes[11,17]. Resource limitations pose a

major obstacle, especially in institutions with limited access to cadavers, anatomy labs, advanced imaging resources, or immersive educational technologies[5,8]. Faculty shortages and the additional burden of curriculum integration further complicate implementation. Thus, successful clinically oriented anatomy teaching requires not only educational innovation but also sustained institutional support, faculty development, interdisciplinary collaboration and adequate infrastructure[42,43].

Investment in anatomy educators is equally important, as effective integration requires teachers who are familiar with both anatomical sciences and contemporary educational principles[14]. A further continuing challenge is to make sure that educational innovations are taken up on the basis of evidence and not of novelty. As virtual reality, artificial intelligence, simulation, adaptive learning platforms and digital resources continue to expand the range of educational possibilities, their long-term educational effectiveness remains an area of continued investigation[15,30]. Therefore, future curriculum development needs to focus on identifying the most appropriate mix of traditional and innovative teaching methods, recognizing that no single instructional strategy is effective for all educational settings. Careful alignment of learning objectives, teaching methods and assessment will be important to maximise educational outcomes[27].

Future research should go beyond short-term improvements in examination performance to assess long-term retention of knowledge, clinical reasoning, procedural competence and preparedness for clinical practice[8]. Multicentre studies with standardized educational outcomes would provide more robust evidence on the effectiveness of clinically oriented anatomy teaching in different educational settings. Moreover, further research is required to gain a better understanding of the integration of emerging technologies, competency-based curricula and interprofessional education without losing the underpinnings of the traditional anatomy education[40]. Overall, the future of anatomy education lies not in replacing established modes of teaching but in the successful integration of evidence-based educational methods that foster anatomical understanding, clinical application and lifelong learning[44,45]. A balanced curriculum that combines cadaveric learning, active educational approaches, technological innovation and clinically relevant assessment is likely to remain the most effective model for preparing future healthcare professionals[2,6,15].

Conclusion

Teaching clinically oriented anatomy is an important development in undergraduate medical education as it integrates the basic anatomical sciences with clinical application throughout the entire learning process. Contemporary curricula are shifting away from the idea of anatomy as a standalone preclinical subject, and embracing contextual learning, clinical reasoning, active

student engagement, technology-enhanced education and competency-based assessment to enhance the relevance and application of anatomical knowledge.

So far, there appears to be no one method of instruction that can satisfy all educational goals in anatomy. Rather, the most effective curricula integrate cadaveric dissection and prosections with clinical case discussions, active learning, medical imaging, digital technologies and clinically aligned assessment in a multimodal approach. This type of integration encourages deeper learning, long term retention, clinical reasoning and prepares students for later clinical training.

As anatomy education continues to evolve, future curriculum development should continue to be driven by educational evidence rather than technological innovation alone. To produce competent, reflective and clinically prepared medical graduates we need to build on the strengths of traditional teaching of anatomy, whilst judiciously incorporating modern educational techniques. The ongoing collaboration between anatomists, clinicians, medical educators and educational researchers will further improve the role of anatomy as a core component of undergraduate medical education.

Conflicts of interest

The authors declare no conflicts of interest.

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