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The Role of 3D Imaging in Anatomy Education: A Survey-Based Evaluation

El Papel de las Imágenes 3D en la Enseñanza de la Anatomía: Una Evaluación Basada en Encuestas

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SUMMARY: The mental visualization of the shape and organization of different anatomical structures has a very important place in the learning process. This study aimed to evaluate the effectiveness of the spatial relationships between the cross sections of 3D anatomical images in the coronal, sagittal and horizontal planes in the learning process of students. These new educational materials in the digital age can help to better understand the localization of anatomical structures and to encourage students to use their time more effectively according to their learning speed and ability. Our study was conducted on second-year students (n=114) studying at Baskent University Faculty of Dentistry in the spring semester of the 2023-2024 academic year. Firstly, a preliminary questionnaire was administered to the students inquiring about the anatomical structures they had difficulty in understanding during the neuroanatomy course. These structures were then demonstrated to the students during the practical lesson using the 3D imaging method. After the training, students' opinions were evaluated using a questionnaire. More than 50 % of the students stated that the anatomy education given using the 3D imaging method at the end of the practical training facilitated the comprehension of the anatomical structures, and that it would be useful to include the method in the anatomy education process. According to the results of our study, we think that the 3D imaging technique has positive effects on the understanding of complex anatomical structures within the scope of anatomy education, and that it will support classical teaching methods.

KEY WORDS: Anatomy education; 3D imaging; Students.

INTRODUCTION

Anatomy education has an important place in basic medical courses and forms the basis of the courses in the clinical branches. In today's innovative and technological age, the traditional anatomy teaching model that has been used for years needs to be diversified with technology (Estai & Bunt, 2016). The development of technology in medical education has led to an increase in research into the effectiveness of different teaching methods in anatomy (Losco *et al*., 2017).

The mental representation of the shape and organization of different anatomical structures plays a very important role in the learning process (Pujol *et al*., 2016). In anatomy classes, neuroanatomy is a section in which students have difficulty in visualizing anatomical structures in their minds. Teaching neuroanatomy to students is known to be particularly challenging due to the complexity and interconnectedness of the central nervous system (Giles, 2010). Students should not only learn the anatomical structures, they should also understand their topographic anatomy, spatial anatomical relationships and clinical significance. In a study, it was found that inadequate teaching techniques and the challenging nature of neuroanatomy subjects caused neuroanatomy to be seen as difficult and even as neurophobia (Arantes *et al*., 2018). Over time, various computer-based applications have been designed using different medical imaging techniques to help students better understand these complex anatomical structures and the relationships between them (Pasricha *et al*., 2023). As a result of recent advances in technology, reduced teaching time, increased class sizes, increased costs of cadaver-based teaching, and difficulties in obtaining cadavers, computer-based teaching methods are increasingly being used in

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anatomy curricula to enhance student learning (Estevez *et al*., 2010). If we look at the literature, there are studies that have analyzed the positive effects of computer-assisted learning in the field of anatomy (Losco *et al*., 2017; Santos *et al*., 2021).

Three-dimensional (3D) medical imaging allows the structural visualisation of systems, organs, and tissues in human anatomy, providing both single and multi-dimensional image data about these structures. 3D Slicer, a computer-based program, is a free, open-source software application developed for medical image analysis and visualisation. 3D Slicer is a powerful visualisation tool that enables the exploration of imaging datasets in both two and three dimensions, and contains various general and specialized tools for the integration, processing, and multimodal analysis of functional and anatomical data (Fedorov *et al*., 2012).

In the present study, we conducted anatomy practical training using the 3D imaging method in addition to traditional teaching methods, utilizing the 3D Slicer program. The aim of our study is to evaluate, from the student's perspective, the use of 3D computed tomography (CT) and magnetic resonance imaging (MRI) based 3D images within the 3D Slicer program as an innovative teaching module for anatomy education.

MATERIAL AND METHOD

Study design. This cross-sectional study was conducted on second-year students (n=114) studying in Turkish and English programmes at the Faculty of Dentistry at Baskent University during the spring semester of the 2023-2024 academic year. All participants were informed about the study, which was approved by Baskent University Institutional Review Board and Ethics Committee (Project no: KA24/174). The study was carried out on a voluntary basis and conducted in accordance with the principles of the Declaration of Helsinki.

Invention. Our study was conducted during the practical anatomy training after the completion of all theoretical neuroanatomy training given to dental students by the Anatomy Department of Baskent University. The 3D Slicer programme was used for the 3D imaging method during laboratory training.

The 3D Slicer software allows the import and export of images in the Digital Imaging and Communications in Medicine (DICOM) format and network transmission. DICOM is a digital data format standard developed for the storage, display and analysis of 2D and 3D scientific data from medical imaging devices (Fedorov *et al*., 2012). A magnetic resonance imaging of the brain (MRHead), which is included as sample data in the 3D Slicer programme, was used in the research. Initially, a pre-survey was conducted using Google Forms, asking students about the anatomical structures they found difficult to understand during the neuroanatomy course. Based on the questionnaire, the anatomical structures that students found most difficult to understand were identified (Appendix 1).

Appendix 1. Most challenging neuroanatomical structures identified by students.

Hypophysis
Sphenoid sinus
Cerebellar tonsil
Falx cerebri-tentorium cerebelli
Mesencephalon
Insula
Thalamus
Basal ganglia
Corpus callosum
Fornix
Septum pellucidum
Brain ventricles

During the two-hour laboratory session, 3D images displaying the sagittal, horizontal, and coronal planes simultaneously were projected onto the screens in the anatomy laboratory as part of the training. The anatomical structures that students had difficulty understanding were shown to them one by one on the MRHead image in the 3D Slicer program (Fig. 1).

Survey structure. The students' opinions on the use of the 3D imaging method were then assessed using a Google Form questionnaire. The students were motivated by the fact that they would make a significant contribution to improving the anatomy course's teaching methods. The questionnaire was original and developed by the researchers based on the literature. Its content was reviewed by an expert with 30 years of experience in teaching anatomy and another expert who previously developed a scale. In the first part of the questionnaire, students were asked about their age, gender, previous knowledge of 3D imaging and whether they had received training in this method. The second part of the questionnaire consisted of 8 questions about the use of 3D imaging methods in anatomy training. The questions were prepared as a 5-point Likert-type questionnaire with the options of strongly agree (5), agree (4), neither agree nor disagree (3), disagree (2), strongly disagree (1). In the last part of the questionnaire, the students were asked which of the anatomical structures shown to them were better understood after the 3D imaging method.

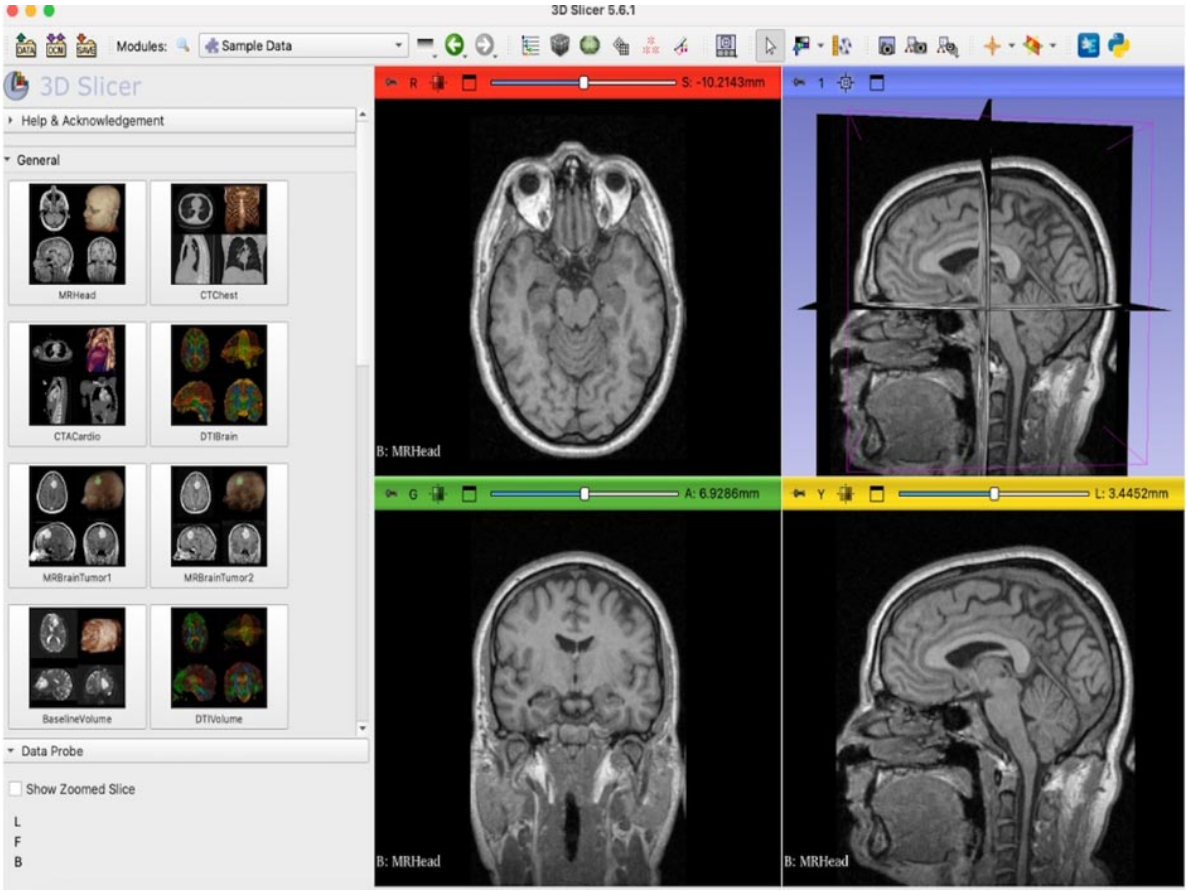

Fig. 1. The 3D Slicer program.

Statistical analysis. Statistical analysis was performed using Microsoft Excel (SPSS version 25.0). Means ± SD were used when presenting quantitative variables. Frequencies and percentages were used for categorical variables.

RESULTS

Our study was conducted with the voluntary participation of 114 students, 42.1 % (n=48) of whom were studying in the English programme of Dentistry and 57.9 % (n=66) of whom were studying in the Turkish programme of Dentistry. Of the participants, 72.8 % (n=83) were female and 27.2 % (n=31) were male students. 62.3 % of the students stated that they had no prior knowledge about the 3D imaging method, and 78.9 % stated that they had not received anatomy education using 3D imaging methods before.

Students' opinions on the use of 3D imaging methods in anatomy education are presented in Table I.

The proportion of students who strongly agreed with the statements 'The 3D imaging method is more effective in understanding the localisation of complex anatomical structures', 'The 3D imaging method should be used in practical anatomy education', 'I think that the 3D imaging method should be integrated into theoretical anatomy lessons', 'I think that the 3D imaging method will be beneficial to my clinical training' and 'I think that the use of the 3D imaging method will improve my success in practical anatomy exams' was found to be more than 50 % (57 %; 58.8 %; 52.6 %; 60.5 %; 52.6 % respectively).

The comprehension rates of anatomical structures by students with the 3-dimensional imaging method are presented in Figure 2.

Our results show that students had a high rate of comprehension of the anatomical points determined by the 3D imaging method, while the brain ventricles, fornix and thalamus structures were the anatomical structures with the best comprehension rate by the students (77 %; 70.2 %; 67.5 % respectively).

Table I. Students' opinions on 3D imaging method.

	Strongly disagree n (%)	Disagree n (%)	Neither agree nor disagree n (%)	Agree n (%)	Strongly agree n (%)
The 3D imaging method is more effective in understanding the localisation of complex anatomical structures.	4 (3.5)	3 (2.6)	5 (4.4)	37 (32.5)	65 (57)
The 3D imaging method should be used in practical anatomy education.	4 (3.5)	3 (2.6)	5 (4.4)	35 (30.7)	67 (58.8)
I think that the 3D imaging method should be integrated into theoretical anatomy lessons.	8 (7)	2 (1.8)	8 (7)	36 (31.6)	60 (52.6)
I would like to use the 3D imaging method as my study material.	5 (4.4)	5 (4.4)	20 (17.5)	33 (28.9)	51(44.7)
I think that the 3D imaging method will be beneficial to my clinical training.	5 (4.4)	3 (2.6)	7 (6.1)	30 (26.3)	69 (60.5)
I think that the use of the 3D imaging method will improve my success in practical anatomy exams.	3 (2.6)	4 (3.5)	16 (14)	31 (27.,2)	60 (52.6)
I think the 3D imaging method is time-consuming and confusing.	42 (36.8)	25 (21.9)	19 (16.7)	20 (17.5)	8 (7)

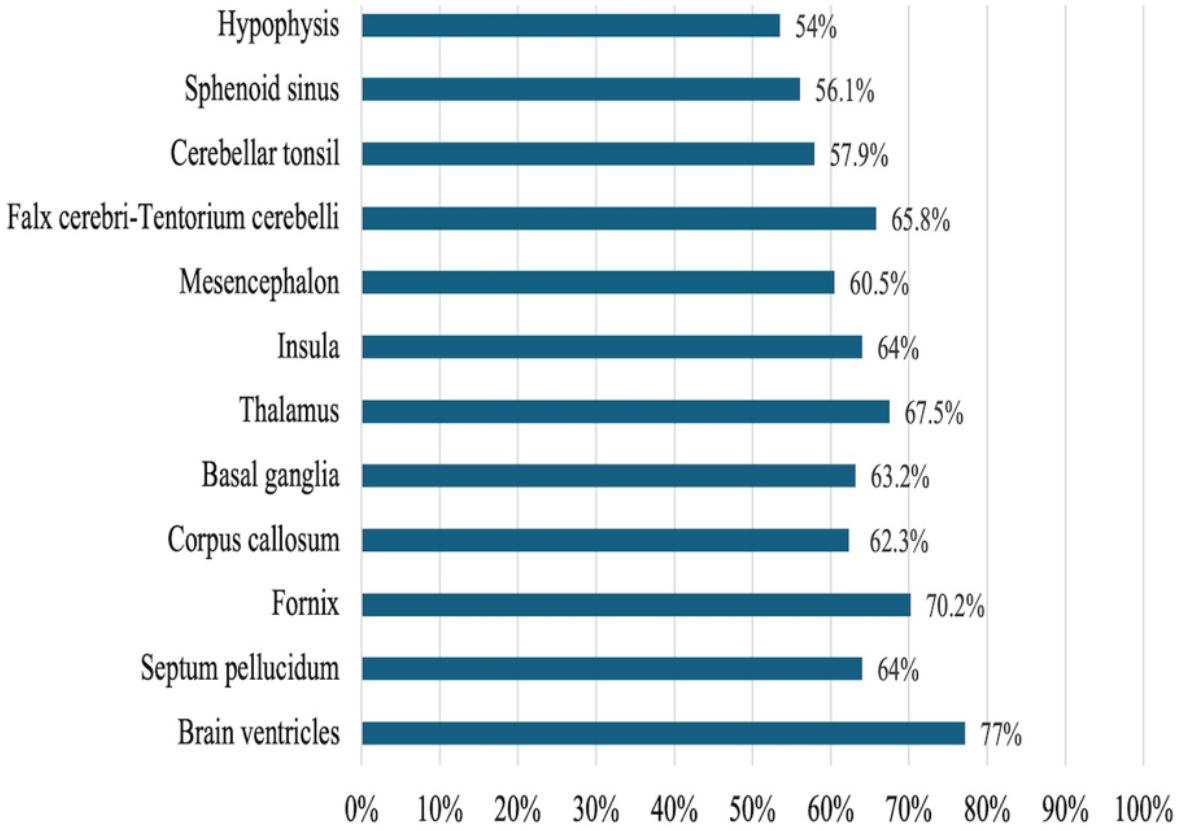

Fig. 2. The comprehension rates of anatomical structures by students.

DISCUSSION

In the present study, we aimed to evaluate the effectiveness and potential benefits of education by integrating 3D imaging technologies into learning processes in anatomy education by collecting student opinions. We used 3D imaging in the neuroanatomy board, which is one of the most difficult subjects for students. In a study by Cay

& Bakirci (2018) investigating the views of dental staff on anatomy education, 90 % of dentists reported that, in their professional lives, they mostly used what they had learned from their neuroanatomy courses. Anatomy education is a fundamental aspect of the training of students and healthcare professionals and it plays an essential role in ensuring safe clinical practice, particularly in surgery (Turney, 2007). The results of the study showed that 86.8 % of students (26.3 % agreed, 60.5 % strongly agreed) believed that 3D imaging would benefit their clinical training.

Traditional methods of teaching anatomy are usually based on cadaveric dissection, lectures, textbook-based learning, two-dimensional models and drawings. (Losco *et al*., 2017; Chen *et al*., 2020). However, recent advances in technology have paved the way for more interactive and visually enriched approaches in anatomy education (Adnan & Xiao, 2023). In this context, advanced software tools such as 3D Slicer have emerged as important resources that enhance the learning experience by providing more effective and visually engaging ways to study anatomy (Zhang *et al*., 2024). The data collected in this study shows that 29 % of students agreed, and 44.7 %strongly agreed with the statement 'I would like to use the 3D imaging method as my study material', which implies that the use of 3D imaging as a learning tool is viewed positively by students.

Modern imaging techniques offer a valuable opportunity to complement traditional approaches to teaching anatomy. Particularly as basic science teaching time decreases and funding for cadavers decreases, alternative methods to help students better understand the structures, orientation and relationships of the body becomes more necessary (Pujol *et al*., 2016). Our research showed that 89.5 % of students (30.7 % agreed, 58.8 % strongly agreed) supported the use of 3D imaging in practical anatomy lessons and 82.6 % (31.6 % agreed, 52.6 % strongly agreed) supported its integration into theoretical anatomy lessons.

Students have free access to 3D anatomy platforms as part of their academic resources. In our study, 37.7 % of students reported having prior knowledge of 3D imaging methods. This suggests that students who are familiar with these techniques tend to prefer using such platforms as course materials. We believe this preference is driven by their interest in utilizing accessible, free tools to enhance their learning experience.

Although cadaver dissection is the foundation of anatomy education, it may not be sufficient to teach about certain parts of the body, such as the nervous and skeletal systems (Papa & Vaccarezza, 2013). Medical imaging alongside traditional dissection promotes a better understanding of anatomical spatial relationships, increases dissection efficiency and stimulates students' interest in gross anatomy (Reeves *et al*., 2004). Many studies have shown that 3D teaching methods facilitate the understanding of complex structures and improve the spatial perception of anatomical structures compared to textbooks and traditional 2D learning methods (Huang *et al*., 2010; Moro *et al*., 2017). In this context, software such as 3D Slicer, a practical and free application that facilitates 3D visualisation of 2D images such as CT, MR and ultrasound scans has become a valuable tool in helping students to better interpret and understand anatomical structures (Fedorov *et al*. 2012; Pujol *et al*., 2016; Zhang *et al*., 2024).

Medical imaging offers several key advantages: it closely aligns with the future practice of physicians, represents living anatomy, utilizes digital technologies, and provides a wide variety of learning resources. Several studies have investigated students' perceptions of anatomy courses, including imaging anatomy, through questionnaires. According to the results of these studies, 3D imaging anatomy significantly increases students' interest in gross anatomy and enhances their understanding of anatomical concepts (Rengier *et al*., 2009; Grignon *et al*., 2016; Heptonstall *et al*., 2016). Our study demonstrated that students found 3D imaging to be effective in both understanding the localization of complex anatomical structures (32.5 % agreed and 57 % strongly agreed) and arousing their curiosity about anatomical structures (30.7 % agreed and 38.6 % strongly agreed).

A survey of students' views on anatomy education by Uygur *et al*. (2013) found that the majority of students stated that the number of models used in practical anatomy courses was low and the amount of time spent on the model was insufficient. 36.8 % of students strongly disagreed and 22 % of students disagreed with the statement 'I think the 3D imaging method is time-consuming and confusing'. Anatomy education based on radiological data allows students to learn about anatomical structures from real images and to distinguish any existing variations from normal structures before proceeding to clinical training (Pujol *et al*., 2016). In a study conducted by Arı *et al*., on students' opinions on anatomy education, 92.1 % of the students stated that teaching aids other than cadavers should be used in practical anatomy courses (Arı & S¸endemir, 2003). In this study, 30.7 % of participants agreed, and 58.8 % strongly agreed with the statement 'The 3D imaging method should be used in practical anatomy education'. Overall, it is generally concluded that medical imaging significantly enhances the quality and efficiency of anatomy education (Machado *et al*., 2013; May *et al*., 2013; Grignon *et al*., 2016).

Positive results are emphasized in several objective studies based on improvements in students' performance on exams or specific tests before and after medical imaging in anatomy education (Phillips *et al*., 2012; Grignon *et al*., 2016). Kish *et al.* (2013) found that students enrolled in the computer-assisted anatomy course showed a significant improvement in their oral anatomy exams, suggesting that computer-assisted learning can play a key role in improving performance in the anatomy curriculum. The results of the study indicated that 27.2 % of students agreed and 52.6 % of students strongly agreed with the statement 'I think that the use of the 3D imaging method will improve my success in practical anatomy exams'. We believe that the integration of innovative 3D technology systems into anatomy education, alongside traditional teaching methods, will be valuable in enhancing both the learning and teaching processes.

This study has a few limitations. Firstly, it was conducted solely within the Faculty of Dentistry and was limited to the student population of Baskent University. Secondly, the results are based solely on the responses of students who participated in the survey. It is also assumed that participants answered the survey honestly. Lastly, the survey instrument used had not been previously validated.

Many studies have investigated the importance of using technology in learning anatomy; however, there is a lack of the understanding of, as well as a lack of research into, how students engage with and learn from the use of technology, particularly 3D images, in their educational processes. This study highlights the positive impact of integrating 3D imaging technologies into anatomy education, particularly in neuroanatomy, a challenging subject for students. Our findings suggest that 3D imaging enhances students' understanding of complex anatomical structures, stimulates their curiosity, and supports their learning at an individual pace. The significant student interest in using 3D imaging as a study tool demonstrates its potential to complement traditional methods such as cadaver dissection and textbook-based learning. Moreover, students' positive responses to the integration of 3D imaging into both practical and theoretical anatomy lessons indicate the growing value of these technologies in anatomy education. As anatomy education evolves, 3D imaging provides an interactive, engaging, and effective way to visualize anatomical structures, offering advantages that traditional 2D and cadaver-based methods may lack. Additionally, these methods meet with the needs of modern medical practice, where digital imaging technologies play a critical role in healthcare.

In conclusion, the use of 3D imaging is beneficial not only in enhancing students' anatomical knowledge but also in improving their overall learning experience. It is also expected that this approach will help anatomy educators to communicate complex concepts more effectively and optimize teaching strategies through the use of visual tools. Future studies are needed to further explore the long-term benefits and optimal integration strategies of 3D imaging in anatomy education.

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RESUMEN: La visualización mental de la forma y la organización de diferentes estructuras anatómicas desempeña un papel fundamental en el proceso de aprendizaje. Este estudio tuvo como objetivo evaluar la eficacia de las relaciones espaciales entre las secciones transversales de imágenes anatómicas 3D en los planos coronal, sagital y horizontal en el proceso de aprendizaje de los estudiantes. Estos nuevos materiales educativos en la era digital pueden ayudar a comprender mejor la localización de las estructuras anatómicas y animar a los estudiantes a utilizar su tiempo de forma más eficaz según su ritmo y capacidad de aprendizaje. Nuestro estudio se realizó con estudiantes de segundo año (n=114) de la Facultad de Odontología de la Universidad de Baskent durante el semestre de primavera del curso académico 2023-2024. En primer lugar, se administró un cuestionario preliminar a los estudiantes para preguntarles sobre las estructuras anatómicas difíciles de comprender durante el curso de neuroanatomía. Posteriormente, se les mostraron estas estructuras durante la clase práctica utilizando el método de imágenes 3D. Tras la formación, se evaluó la opinión de los estudiantes mediante un cuestionario. Más del 50 % de los estudiantes afirmó que la formación anatómica impartida mediante el método de imágenes 3D al final de la formación práctica facilitó la comprensión de las estructuras anatómicas y que sería útil incluir este método en el proceso de formación anatómica. Según los resultados de nuestro estudio, consideramos que la técnica de imágenes 3D tiene efectos positivos en la comprensión de estructuras anatómicas complejas en el ámbito de la enseñanza de la anatomía y que complementará los métodos de enseñanza clásicos.

PALABRAS CLAVE: Enseñanza de la anatomía; Imágenes 3D; Estudiantes.

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