Applied Learning of Anatomy and Physiology: Virtual Dissection Tables within Medical and Health Sciences Education

Satheesha Nambiar Periya, PhD[1]; Christian Moro, PhD[2]

Satheesha Nambiar Periya, PhD

[1] Associate Professor (2017), Department of Biomedical Sciences (Human Anatomy), College of Medicine, Gulf Medical University, Ajman, United Arab Emirates.
[2] Assistant Professor, Faculty of Health Sciences and Medicine, Bond University, Gold Coast, Queensland, Australia.

*Address Correspondence to author:
Christian Moro
Faculty of Health Sciences and Medicine,
Bond University, Gold Coast,
Queensland, Australia.
Tel: +61 7 55954775.
ORCID: 0000-0003-2190-8301
email: cmoro@bond.edu.au.

Received: July 16, 2018
Revision received: October 05, 2018
Accepted after revision: January 09, 2019
BKK Med J 2019;15(1): 121-127.
DOI: 10.31524/bkkmedj.2019.02.021
www.bangkokmedjournal.com

Abstract

Anatomy and physiology are core subjects in medical and health science programs which students often find relatively challenging compared to other disciplines. Although dissection of cadavers remains the main teaching method utilised to teach human anatomy, a range of interactive multimedia modules and virtual visualization software and devices have become available to supplement learning in these areas. Studying anatomy and physiology via three-dimensional (3D) visual models is becoming increasingly prevalent, as is the quality of instruction available through the use of virtual dissections. Virtual dissection tables are a recent entry to the options that medical and health science programs have when considering learning tools for their students. However, with the range of novel tools available, many educators find that choosing which new technologies to adopt in the classroom or teaching laboratories can become overly complicated, with the risk of some technologies becoming distracting or not always effective for their students. It is also difficult to find concise, evidence-based reviews of upcoming technology, making the onus on program leads to identify which technology or modern devices may be most suitable for learning within their institution, without ever having utilised many of the devices on offer. As such, this article aims to provide benefits and limitations of virtual dissection tables, outline the recent literature surrounding applications of this technology, and provide insights for institutions seeking to consider virtual dissection tables. This article focuses on informing educators towards possible use-cases for these devices to assist with considerations of which new technologies to consider for use medical and health science programs.

Keywords : learning anatomy, anatomage, virtual dissection table, traditional dissection, technology-enhanced education.

In recent decades, teaching of human anatomy has been reduced in medical curricula globally and replaced with clinical education; resulting in a potential decrease of human anatomical knowledge in newly-graduated doctors.[1-3] Historically large anatomy departments have commonly been converted into small entities of medical education groups or incorporated into surgical departments.[4] However, most medical institutions still utilise traditional teaching styles in anatomy and physiology teaching, such as cadaveric dissection where the main learning is traditionally guided by an educator.[5] In courses where dissection is not implemented, or commonly utilised, the human anatomy teaching and how it links to the subsequent physiology is pivotal to the curriculum for prospective clinicians.[6] In many medical schools nowadays, a mix of postgraduate and undergraduate students study in the same class, with traditional methods often not meeting the additional support required for undergraduate students new to university study.[7] Learning in human anatomy has been centred around dissection of cadavers for many decades, during which time the style of teaching gradually progressed with the implementation of prosected specimens, plastinated specimens, computer-based and web-based learning, multimedia learning and virtual anatomy software.[8-11]

Focusing on the addition of technology in anatomical courses, Ramsey-Stewart G, et al.,[12] conducted a study on senior medical students in Sydney and concluded that dissections should remain an integral component of medical education. In addition, Azer and Eizenberg[13]

concluded that utilising multimedia did not change student perceptions regarding usefulness of cadaveric dissections. Most learners also found that the cadaver dissection method increased their perception of learning additional anatomy through technology. Virgil Mathiowetz et al.,[14] compared anatomy laboratory teaching versus online anatomy software and observed that the students who attended anatomy laboratories scored higher than students who solely engaged with their online learning program. This was consistent with the observation of Custer and Michael,[15] that a virtual dissection table was a beneficial learning tool in the education of imaging science students. Winkelmann[16] reviewed fourteen studies comparing different teaching approaches including dissection, prosection and online computer- based teaching aids, finding that there was a lack of sufficient evidence to demonstrate one method's superiority over others in anatomical education.

The way both anatomy and physiology have been taught has been greatly modified over recent years, leaving a degree of uncertainty concerning the overall goals of modern anatomy teaching.[4,17] One new technology that can assist with the learning experience in these subjects is the virtual dissection table. This article aims to provide a description of the functionality, modules and potential of virtual dissection tables, and to provide insights for schools seeking to adopt this technology within their anatomy curricula. The authors make no recommendations on whether any particular virtual dissection table itself, such as the Anatomage Table, is a suitable tool. Instead, this article focuses on informing educators on possible use-cases for the devices, to assist with their considerations towards which new technologies may be useful within medical and health science programs.

About the Anatomage Table, a commonly used virtual dissection device

One commonly utilised virtual dissection table in medical or health education departments is the Anatomage Table. This device depicts segmented human 3D anatomy as interactive life-size displays of 3D models. It renders visualizations of 3D anatomy and interactive perceptions with displayed visualizations of anatomy, as they would appear on an embalmed cadaver. It conveys anatomical details for virtual cadaver-based dissections and provides simulations that can be programmed when required. A life-sized perception of the full human body also provides learners with an ability to simulate surgical operations. The learner can stand beside the Anatomage Table and interact with the model, such as by rotating the virtual patient horizontally, or into a position that assists their desired learning objective. Finger gestures or a stylus can be used to interact with the table. The physical table is movable or can be locked into a fixed position. The Table has been developed based on the Invivo5 imaging software technology, allowing volume rendering, photographic rendering and 3D mesh rendering.[14,15] For more specific use of the Anatomage Table, 3D digital anatomy libraries with scans of pathology, clinical cases and routine medical examinations are accessible. Anatomage has medical imaging software approved by the FDA, which maintain compatibility with all CT or MRI data. Within these modules, identical to the anatomical simulations, the learner can zoom, rotate and cut the image using finger gestures.[14,15] Models can be edited, and image labels from anatomical structures imported, with the additional potential of users uploading patient scans into the system for examination. With finger gestures it can turn images, move the models, or alter viewpoints. Individual structures can be reconstituted in high-detailed 3D, culminating in anatomical imagery that can be explored by the student, or demonstrated to a small group of learners by the educator.

Use of the Anatomage Table as a virtual dissection device in teaching sessions

Cadavers represent the gold standard of teaching tools within the anatomical laboratory. However, due to supervisory, ethical, accessibility and financial constraints, student use of these models can become limited. As a supplement to structured anatomical laboratories, virtual dissection tables may suit some medical and health science schools wishing to extend their teaching to allow further individual student study, or additional interactivity. The Anatomage Table has both full body female and male anatomy, depicted from head to toe providing detail such as minute nerves and blood vessels at high resolutions. The regional anatomy includes the head and neck, upper and lower extremities, thorax, abdomen, pelvis and related structures (Figure 1). The images illustrate the anatomy of a cadaver by maintaining consistent colour and shape, and can be sectioned at various regions to exposing anatomical structures that allows learners to visualize soft tissues, skeletal tissues, muscles and organs. These tissues can be customised by virtually slicing, segmenting and layering, although it does lack the haptic feedback from doing this activity with cadaveric models. With the help of annotation icons that can be saved and viewed later, each learner can develop new methods for individualised study, and the educator can guide exploration through innovative programs, quizzes, and tests, as well as data from still photographs, or CT and MRI Scanners.

A virtual dissection table with imaging data may an alternative for student learning when the traditional cadaveric dissections are not available. Learners can incise the skin, remove soft tissue, section the body and isolate any organ with finger gestures. The learners repeat the dissection and can undo their action at any time, with cutting and sectioning allowed across most directions. One benefit often presented to support using virtual dissections in this way is that if a structure is accidently cut, it does not devaluate the experience in any way. However, it needs to be noted that although cadavers can often be sutured or repaired, and there are educational benefits for students making 'mistakes', which can be a great enhancement to genuine and authentic learning. In virtual dissections, all cuts can be removed or the body immediately reconstruct if required. For immediate comparisons, many virtual dissection tables allow the learner a simple method to compare two

ISSN 2287-0237 (online)/ 2287-9674 (print)

clinical presentations or cases side by side, and users can review pre- and post-surgery cases, measure tumour growths and correlate chest volumes between inhalation and exhalation. This is all without the requirement for chemicals, additional ventilation, freezers or other facilities, with no leakage, disposal needs, or embalming equipment required. As cadavers usually provide solely one case for each student, there is a far greater ability for variation in student experiences through virtual models. There are also no recurring acquisition costs since all content is reusable. Image data within a virtual environment can be modified and reused unlike a cadaver dissection. This allows a greater potential for each learner to gain a similar understanding of the anatomical relations, identification of difficult structures and will be able to assimilate various biological systems in the human body through virtualisations compared to cadaveric preparations (Figure 2).

Figure 1: The Anatomage Table (upper left image) and representations of the virtual human cadaveric modules, detailing the skeletal and muscular system.

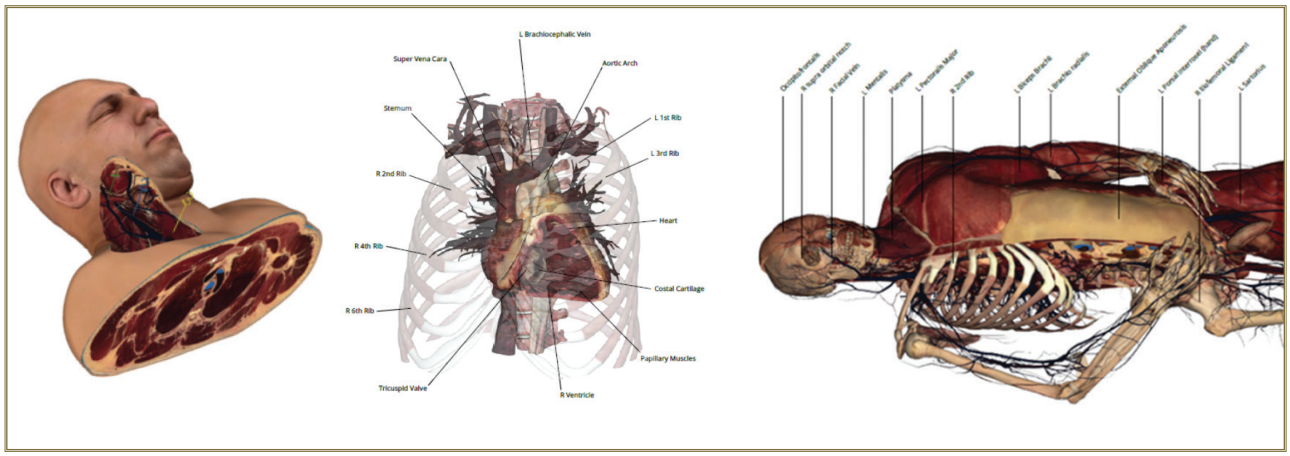

Figure 2: Examples of dissections performed with the Anatomage Table. Note the potential to annotate names of each feature, organ or body part of interest on top of the model provided.

ISSN 2287-0237 (online)/ 2287-9674 (print)

Use of virtual dissection tables in small group learning

In small group learning activities limited to around 12 students, an instructor should be able to comfortably stand on one side to direct a lesson viewing images, resolving clinical diagnoses, or relating features and structures to physiology. In medical education, a virtual dissection table could be used to simulate a patient on a table, as the size and appearance may be appropriate in some lesson styles. The device could also be incorporated into assignments and assessment activities, where learners may wish to analyse anatomy concepts, create annotations, export images and provide written comments on a 3D visualised model. In this way, the table offers a potential supplement to traditional cadaver dissections with real life patient colours and shapes. Each system of the body or anatomical structure can be isolated and viewed separately with its segmentation features. An institution can also upload data from a CT scan to the virtual dissection table and allow students to revise this alongside a virtual 3D rendered model at the same time.

Use of virtual dissection tables in lectures

The virtual dissection tables are large, heavy and bulky and may be difficult to move between anatomy teaching rooms and lecture theatres. However, if accessible, the device could be integrated into lectures and provide live demonstrations. Most virtual dissection tables can now connect to projectors, so can be used directly during lectures with previously prepared sets of lessons. Educators can create and demonstrate experiments or provide experiential-based sessions in a different or unique way. Video clips and screenshots can be saved and shared with students and integrated into lesson plans, and images extracted from using the Anatomage Table are depicted in Figure 3.

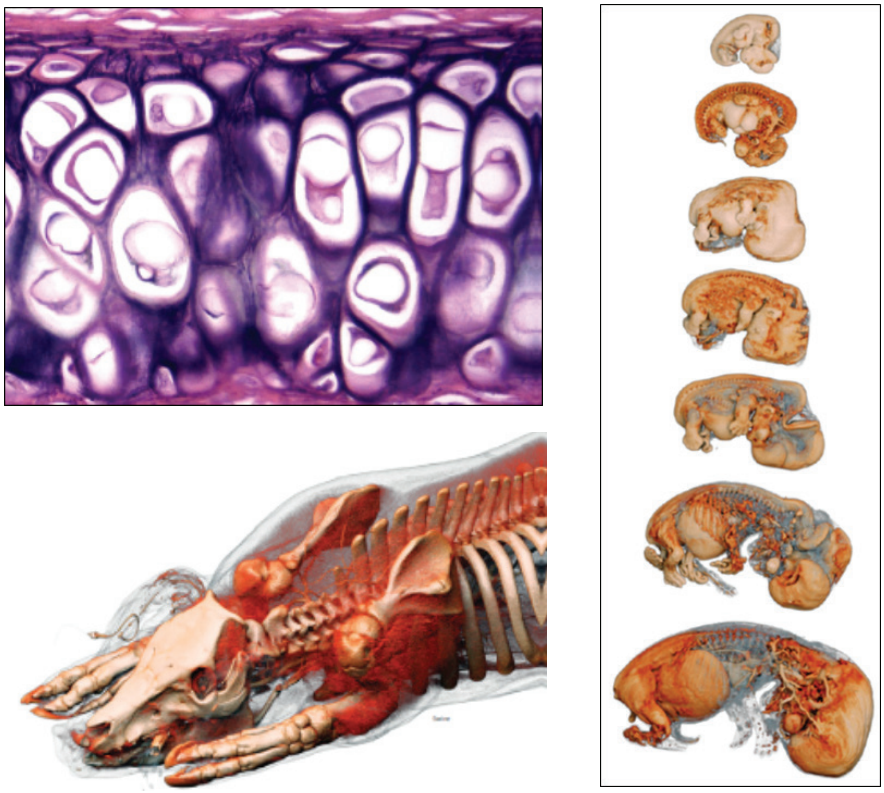

Figure 3: Depictions of images within the Anatomage Table software which may have a potential use in lectures, such as detailing cells, animal models, or developmental anatomy, such as illustrating the development of a foetus.

The use of virtual dissection tables in clinics or hospitals

Virtual dissection tables may be useful as a part of surgical case reviews, consultations, radiology or research through the input of magnetic resonance image (MRI) or computed tomography (CT) scans. In the hospital setting this could provide new options for clinicians when conducting consultations or educating patients (Figure 4). For example, it is possible to capture an image of a patient with an exposed abdominal cavity and display this on the table within the clinic. Patients can view their personal anatomy in 3D colour and navigate the imagery on the screen. As a pathological and procedural training tool, it has a digital library that incorporates pathological examples to for students or junior doctors studying pathology. Many virtual dissection tables can also overlay 3D models onto images of a patient, thus allowing a life-size simulation. This, and other uses of 3D rendered models used in the place of 2D scan presentations is becoming

ISSN 2287-0237 (online)/ 2287-9674 (print)

commonplace,7 and as the applications of these 3D anatomical models increases, a virtual dissection table is well-suited for assisting with life-sized spatial understanding of the human body. In the field of forensic and archaeological sciences, the Anatomage Table had a role in the investigation of Pharaoh Tutankhamun's cause of death in August 2012 and was subsequently documented by Fuji TV, PBS and in a Scientific American article on virtual autopsies in 2013.[18] The anatomy of different animals can be compared for research in veterinary science and the user can upload veterinary scans for teaching animal anatomy, such incorporating full-body cat and dog images. For example, the latest Anatomage Table software has also added 4D scans to visualize heart beats and respiration, which may be useful in a range of teaching practices or virtual autopsies.[19] Additionally, models of different ages can be presented to the learners, whereas cadaveric dissection most commonly involves examinations of elderly people. This allows students using virtual dissection tables the ability to investigate models of different ages, which is useful for learners wishing to identify variations in the skeletal system during ageing or development.[20]

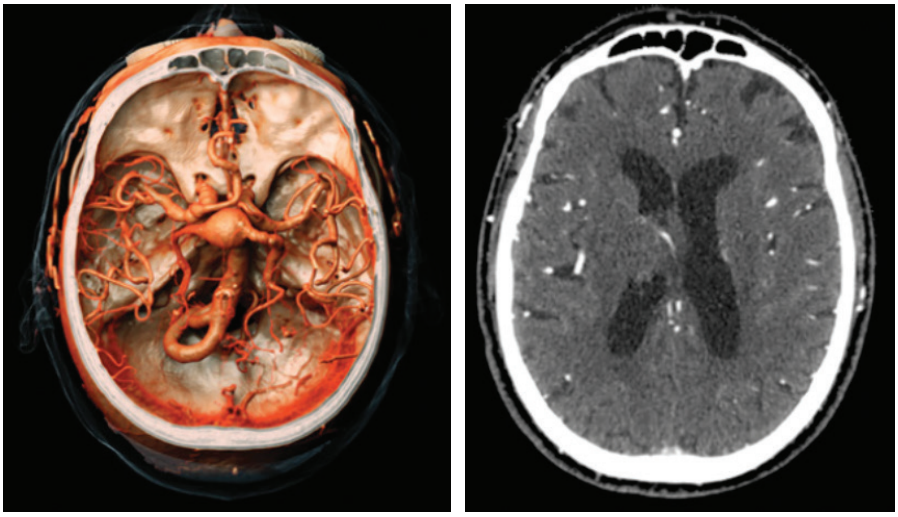

Figure 4: Depictions of scans side-by-side with virtual imagery of the structures, taken from the Anatomage Table.

The potential for using virtual dissection tables in research

Researchers relating to teaching methods, case reviews, patient education, or hospital teamwork may find use in integrating virtual dissection tables within their investigations. Different researchers can interact with images, presentations and data simultaneously. Research on hollow organs, such as the gastrointestinal tract or the urinary bladder,[21-23] may benefit from using the 3D models or objects as training tools for new students. The ability to import files from patient MRI or CT scans gives early-career researchers, in particular, the ability to inspect research data or patient information through the life-sized rendering. The finger-gesture interactivity may assist in identifying comparisons between scans, or unique anatomical variations and features when compared to using a mouse-and-keyboard approach. Other research has been conducted on student perceptions of learning anatomy, such as within a Doctor of Chiropractic program, where students using the Anatomage table for musculoskeletal anatomy performed higher on examinations than students using plastic models or cadavers. This study identified other variables between the cohorts, and as such, research is required to confirm the conclusions, although this presents an interesting area for future studies.[24]

Limitations of virtual dissection tables

There is limited data to suggest that virtual dissection tables are a suitable complete replacement for cadaveric studies. In programs such as medicine, which rely on cadaveric studies to teach students human anatomy, real and genuine cadavers are a primary and important tool for medicine. Cadavers allow a unique view into anatomical variation, provide hands-on kinaesthetic and tactile feedback, and expose students to a real-world experience. The uses outlined in this article provide options for methods solely to supplement cadaveric work, rather than act as replacement. However, the opportunity of using a virtual dissection table in combination with cadaveric dissections may present an opportunity for educators wishing to supplement learning in anatomy and physiology. An additional limitation is that the technical acumen of individual learners may be different. A student who is used to studying anatomy through a tablet device or digital form of learning, may be more experienced in the gestures, insights and content utilised within the virtual dissection table software. This therefore results in the potential for different students to have varied degrees of success in learning from this device. Additionally, the tables themselves are relatively large and bulky, and its usage and storage may require a dedicated space.

Regular servicing, updates and maintenance are also required, and during this time the table cannot be used by educators or students. As such, it is highly recommended that prior to adopting new technologies or devices to supplement learning, curriculum leads and educators consider the uses, benefits and limitation of each resource carefully.

The literature surrounding virtual dissection tables

According to Drake et al.,[5,25] dissection helps in the identification of structures along with tactile information on tissue texture, and the reduction of applied hours of clinical anatomy within medical curricula over recent decades is of concern. Anatomical dissection provides kinaesthetic aspects of learning through the 3D visualization of structures. Once any structure is cut or damaged during dissection, it cannot be reconstructed hence, dissection is irreversible in nature. Through these features, virtual dissection tables are becoming versatile teaching tools within many university medical and health science curricula. Although virtual models, such as those used within virtual and augmented reality[9,10] or cadaveric dissections are highly useful teaching tools, in a classroom environment, the virtual dissecting tables allows students the ability to undergo both teacher-directed learning, individual exploration or self-directed learning.[26] The virtual dissection tables allows students to isolate different structures in 3D form, dissect, reconstruct, zoom in and out, transecting them to acknowledge the anatomical knowledge. Rosenzweig et al.,[27] reported that pausing, rewinding and revisiting different structure and systems by creating pre-settings in the virtual dissection table is a unique feature that helps to provide further personalization to the learners.

Quentin-Baxter and Dewhurst[28] suggested that the simulation based on computer or software programs offers a bulk of sustaining and emphasizing information to learners, and they can work with them at their own speed. Additionally, Downie and Meadows[29] reported that students who are provided with a substitute to dissection, such as through utilising artificial models, charts and pictures, exhibited no significant differences in their performance on the written examinations compared to those students who studied solely through dissections. Custer and Michael[15] conducted a study on medical imaging students in regards to utilization of the Anatomage Table observed that the students appreciated studying using the device and suggested that it would be a helpful and efficient technology to incorporate into health professions. In this study, 94% of students agreed with the fact that they felt benefit from the use of Anatomage virtual dissection Table when studying anatomy. Almost 88% of students further described that they found a positive influence of the Anatomage virtual dissection Table on the overall classroom experience.

Chan et al.,[30] studied the efficacy in learning human anatomy and medical imaging with the Anatomage Table and compared with prosections. The results indicated that differences between the total scores for the Anatomage Table and the prosection group were not statistically significant. Similarly, between the two groups the differences in the total diagnostic medical imaging scores were also not statistically significant. Although instruction based on the Anatomage Table scored higher on identifying relative anatomical locations and imaging planes, these differences were not statistically significant. Anand and Singel8 conducted a comparative study of learning with the Anatomage Table and traditional dissection in neuroanatomy and reported that 90% of the students felt that the Anatomage virtual dissection Table helped them to visualize relations of different parts better. The majority of these students (79%) agreed that the Anatomage virtual dissection Table enhanced their learning experience and 75% agreed that the use of the Table required less time to understand structures. Almost 84% of students were in favour of including the Anatomage virtual dissection Table in the regular curriculum.

Conclusion

Virtual dissection tables are a novel technology-enhanced learning and teaching tool that facilitates 3D visualization of structures and their relations. Learning outcomes with these tables was thought to be comparable to traditional dissections in neuroanatomy, and learning was also augmented by allowing students independent and extended times with the models. It could be included in medical undergraduate curriculum as a teaching tool to facilitate learning and better spatial understanding of anatomy. However, further research is required to explore the synergistic learning effects of virtual dissection tables, prosection and other learning methods and materials as this could be of great benefit.

Acknowledgements

Images of software and anatomical visualisations authorised for use by Anatomage Inc, San Jose, CA.

Conflict of Interest

The authors declare no conflict of interest. The authors receive no payments, financial support or funding from Anatomage, its affiliated companies or any manufacturer of virtual dissection tables. Neither author receives any benefit from the publication of this article. Neither author is affiliated in any way with any maker of virtual dissection tables or their embedded software, and there is no financial interest or personal relationship with any third party whose interests could be influenced by the article's content.

References

1. Turney BW. Anatomy in a modern medical curriculum. *Ann R Coll Surg Engl* 2017;89(2):104-7.
2. Ahern J. Clinician involvement in the teaching of anatomy to medical students. *AMJ* 2015; 8(7): 247-8.

3. Periya SN. Teaching human anatomy in the medical curriculum: a trend review. *Int J Adv Res* 2017;5(4):445-48.
4. Hildebrandt S. Lessons to be learned from the history of anatomical teaching in the United States: The example of the University of Michigan. *Anat Sci Educ* 2010;3:202-12.
5. Drake RL, McBride JM, Lachman N, et al. Medical education in the anatomical sciences: The winds of change continue to blow. *Anat Sci Educ* 2009;2(6):253-9.
6. McLachlan JC, Patten D. Anatomy teaching: Ghosts of the past, present and future. *Med Educ* 2006;40(3):243-53.
7. Moro C, McLean M. Supporting Students' Transition to University and Problem-Based Learning. *Med Scie Educ* 2017;27(2):353-61.
8. Anand MK, Singel TC. A comparative study of learning with Anatomage virtual dissection table versus traditional dissection method in neuroanatomy. *Indian J Clin Anato Physio* 2017;4(2):177-80.
9. Moro C, Štromberga Z, Raikos A, et al. The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *Anat Sci Educ* 2017;10(6):549-59.
10. Moro C, Stromberga, Z, Stirling, A. Virtualisation devices for student learning: comparison between desktop-based (Oculus Rift) and mobile-based (Gear VR) virtual reality in medical and health science education. *AJET* 2017;33(6):1-10.
11. Kuehn BM. Virtual and Augmented Reality Put a Twist on Medical Education. *JAMA* 2018;319(8):756-8.
12. Ramsey-Stewart G, Burgess AW, Hill DA. Back to the future: teaching anatomy by whole-body dissection. *Med J Aust* 2010;193(11-12):668-71.
13. Azer S, Eizenberg N. Do we need dissection in an integrated problem-based learning medical course? Perceptions of first- and second-year students. *Surg Radiol Anat* 2007;29(2):173-80.
14. Mathiowetz V, Yu CH, Quake-Rapp C. Comparison of a gross anatomy laboratory to online anatomy software for teaching anatomy. *Anat Sci Educ* 2016;9(1):52-9.
15. Custer T, Michael K. The Utilization of the Anatomage Virtual Dissection Table in the Education of Imaging Science Students. *J Tomogr Simul* 2015;1:102.
16. Winkelmann A. Anatomical dissection as a teaching method in medical school: a review of the evidence. *Med Educ* 2007;41(1):15-22.
17. Birt J, Stromberga Z, Cowling M, et al. Mobile mixed reality for experiential learning and simulation in medical and health sciences education. *Information* 2018;9(2):31.
18. Scientific American. Expertise insights illumination. 2017. (Accessed at January 4,2018 at https://www.scientificamerican.com/article/virtues-of-the-virtual-autopsy.).
19. Becker GJ.Virtues of virtual autopsy. *J Am Coll Radiol* 2005;2 (4):376-78.
20. Moro C, Covino J. Nutrition and growth: Assessing the impact of regional nutritional intake on childhood development and metacarpal parameters. *Anat Cell Biol* 2018;51(1):31-40.
21. Moro C, Edwards L, Chess-Williams R. 5-HT2A receptor enhancement of contractile activity of the porcine urothelium and lamina propria. *Int J Urol*;2016;23:946-51. doi: 10.1111/iju.13172
22. Moro C, Chess-Williams R. Non-adrenergic, non-cholinergic, non-purinergic contractions of the urothelium/lamina propria of the pig bladder. *Auton Autacoid Pharmacol*, 2012;32:53-9. doi:10.1111/aap.12000.
23. Moro C, Leeds C, Chess-Williams, R. Contractile activity of the bladder urothelium/lamina propria and its regulation by nitric oxide. *Eur J Pharmcol* 2012;674(2-3):445-9. doi: 10.1016/j.ejphar.2011.11.020.
24. Afsharpour S, Gonsalves A, Hosek R, et al. Analysis of immediate student outcomes following a change in gross anatomy laboratory teaching methodology. *J Chiropr Educ* 2018;32(2):98-106. doi:10.7899/JCE-17-7.
25. Drake RL, Lowrie DJ Jr, Prewitt CM. Survey of gross anatomy, microscopic anatomy, neuroscience, and embryology courses in medical school curricula in the United States. *Anat Rec* 2002;269 (2):118-22.
26. Periya SN, Sebihi A. Self-Directed learning in modern education: a trend review and perspectives of Gulf Medical University model, United Arab Emirates. *Int J Eco Busi* 2017;5 (5):5-9.
27. Rosenzweig M, MacEachern M, Masters C. The Anatomage table: an innovative approach to anatomy education. 2017. (Accessed at January 4, 2018 at http://hdl.handle.net/2027.42/136885).
28. Quentin-Baxter M, Dewhurst D. An interactive computer-based alternative to performing a rat dissection in the classroom. *J Biol Educ* 1992;26(1):27-33.
29. Downie R, Meadows J. Experience with a dissection opt-out scheme in university level biology. *J Biol Educ* 1995;29 (3):187-94.
30. Chan I, D'Eon M, Haggag H, et al. The Effectiveness of Learning Anatomy and Medical Imaging Using the Anatomage Table Compared with Prosections. Conference Paper May 2015: Joint Congress on Medical Imaging and Radiation Sciences, At Montreal, QC.