

ANATOMAGE TABLE

THE FUTURE OF ANATOMICAL EDUCATION AND MORE

Knowledge of anatomy is one of the cornerstones of modern medicine. The dissection of cadavers to learn human anatomy has been common practice in many countries in the world for centuries since Vesalius founded modern human anatomy in Padua during the sixteenth century.

Alas nowadays many doctors and surgeons feel their knowledge of anatomy is inadequate¹. Why is this so and what it is possible to do to revert this tendency is the first aim of this contribution?

Subsequently we will focus on additional benefits the presented solution provides specifically to surgeons' practice and we will end with what the near future is likely to bring to this area of medical training.

ANATOMICAL TEACHINGS DECLINE

All over the world Anatomy is regarded as one of the fundamental subjects to be learned by future doctors and health specialists as a whole.

Depending on the country, and often even depending on individual medical schools or universities, Anatomy might be taught through the use of cadaver dissection; or through lectures asking for mnemonic study of the regional districts of the body; or through more innovative and involving ways asking students to deal deductively with functional regions and interactions between structures, organs or systems. Some ask their students to dive fully, deep into the anatomy during their first years while others proceed over the years step-by-step, integrating the material other medical disciplines.

Given the importance anatomy has, everyone would think time devoted to it would grow or at least remain the same over the decades... All the contrary!

Devoting the same amount of time to prepare new doctors but having to deal with more specialised advanced topics and new medical subjects altogether, curricula have thinned the time devoted to basic sciences like anatomy to an all-time low. In some countries in the last century it has been reduced even by more than 40%.

This means students must learn the same amount of knowledge in less time; thus, they require assistance focusing on the right data and work outside of lecture hours, both at school or at home, without the presence of their professor.

A second huge problem is starting to manifest itself in countries where bodies — due to cultural mindsets, ethical beliefs, or the law itself — are becoming unavailable and creating a supply shortage for cadavers used in teaching.

Cadavers are considered a privilege to work with among students, teachers, and medical professionals. They are the most common method for teaching anatomy, so they must be distributed to a wide variety of health organisations². While institutions with established programs often have their own willied body donation (WDB) program, most schools have to act as third party beneficiaries to the more established institutions³. Despite the distribution of cadavers, not every health organisation is able to successfully obtain their own cadavers.

Managing a cadaver lab is costly and time consuming. Specialised equipment must be purchased and properly used to maximise the cadaver's practical lifespan. Once a cadaver is dissected it must be rigorously maintained with hazardous embalming chemicals and regularly monitored by trained professionals.

Furthermore, the required number of specialised employees, professors, and teaching assistants to assist and guide students during dissections is far too high to be financially feasible for many schools. These combined with the lab maintenance costs pressure schools to offer limited sessions on real cadavers for the most deserving students. It is no wonder then that students in other healthcare disciplines such as nursing, physical therapy, and allied health programs may feel there is an increased shortage of available cadaver resources. The result is a student-cadaver ratio that is incredibly high⁴ even as schools accept any cadaver available in an effort to make access to students viable.

Cadaver dissection, even where cadavers are readily available, still presents some common limitations that cannot be circumvented. The colour resemblance and consistency of tissues and organs is different in a dead body. Additionally, structures are fragile and, when examining a cadaver, visibility is localised to the exposed area of tissue. Rotating a cadaver is not a viable option, so students are left viewing only a portion of the organ or anatomical system. The body is only visible as it is, forfeiting the possibility of getting acquainted to the different structures and their relations as visible through imaging systems currently available.

Aids to cadavers must be implemented to further enhance the understanding of anatomical relationships and infrastructure. Unluckily complimentary tools currently in use are most of the time limited and faulty.

Physical models have a number of limitations that rank their use in anatomy education below both dissection and computer modelling⁵. Models are artistic recreations of an anatomical feature, which could mean that there is little accuracy to a life-size scale⁶. Some models can be taken apart, but only in predetermined areas⁶. Further, there is a lack of information from surrounding features: fasciae, adipose tissue, and connective tissue are all taken away⁶.

Through digital solutions students and instructors can create and share anatomy content equivalent to the information found in lectures⁷. Alas anatomy videos lack the interactivity that is associated with physical manipulation. Videos may provide an adequate amount of information, but the large variety of videos creates a problem: students spend more time searching for the right video than studying the material being presented⁸.

Apps present 3D models that are, again, just artistic renderings and often idealised. Medical anatomy apps were thus found to be limited by anatomical accuracy and conformation to an education standard⁵.

All of these issues can explain why many doctors feel their anatomy knowledge is inadequate for the important tasks and responsibilities given to medical professionals. Is there any solution? Will there be? As we will show, technology can be a solution to all these limitations associated with the current teaching of anatomy.

INNOVATION AS THE SOLUTION

Technology, in the case at hand, can be a game changer and we believe it is already and it will be even more in the next few years⁹. Virtual dissection solutions, such the Anatomage Table can really make a difference, not to bypass real dissection altogether but to complement it, overcoming its current limits.

Anatomage started as a radiology imaging company in 2004. Anatomage recognised the need to complement cadaveric studies while working on visualising medical images to make them as real as possible. Anatomage pursued the concept of a virtual dissection table to improve diagnosis for the entire body. The solution came as the Anatomage Table, a virtual dissection table replicating a real cadaver bed and demonstrating all real patient data in a 1:1 life-size scale. Unlike cadavers, the Anatomage Table isn't restricted by legal regulations, so it is globally accessible. The Table presents a full 3D visualisation of real patient data that can be segmented and annotated. The Table creates a safe working environment for student interaction, by removing the need for hazardous materials that students are exposed to during cadaver dissection. The Table reduces recurring costs and prevents the need for expanding a cadaver lab.

The Anatomage Table provides the ability to manipulate a life-size virtual cadaver. Anatomage collected male and female cadaver data sets from the Visible Korean project and the Visible Human Project; cadavers in their 20s, 30s and 40s. Anatomage



established fully 3D volumetric visualisation of human cadavers by combining their software with the photographs of 0.2 mm axial slices of the cadavers. The virtual cadavers are more accurate than any other alternative and more searchable than a cadaver. The Table's interactive touchscreen is sensitive to multipoint touch for simple rotation and zoom gestures.

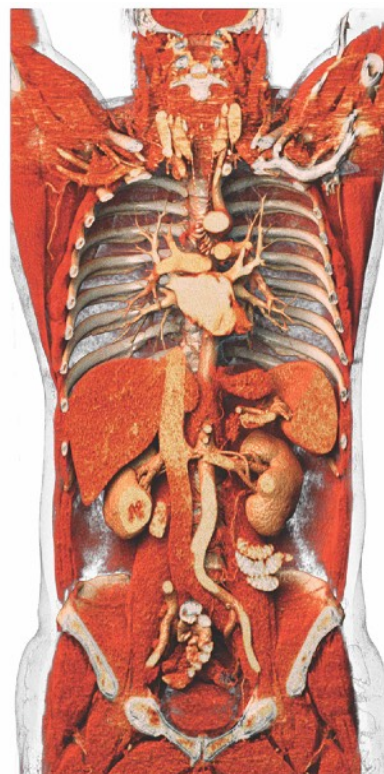
The 3D cadavers can be dissected for internal inspection. Different slice tools can be used to create either custom freehand incisions or clipping planes in the volume of the cadaver. Measurements of the visible image can be taken in a variety of ways.



The full body male and female cadavers are composed of real patient data, portraying tissue in true living colour, without the presence of any embalming chemicals. The full body cadavers have been systematically segmented and annotated. The cadavers can be peeled away structure by structure to demonstrate the various anatomical systems associated with the human body thereby creating a unique opportunity to display anatomical relationships that would otherwise be impossible to see with traditional cadavers.

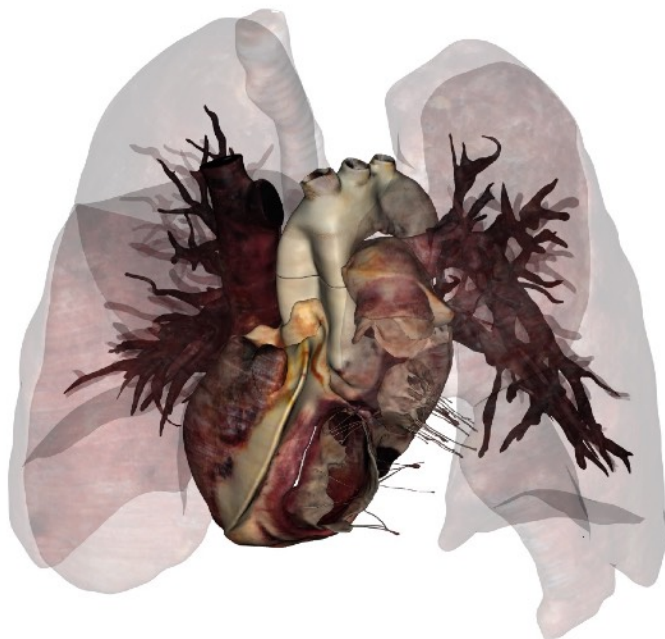
The Table imports files in the digital imaging and communications in medicine (DICOM) standard directly or through a Picture Archiving and Communication System (PACS). The Table software reads a series of DICOM files and directly renders the scan in 3D automatically. Uploaded files are reviewed in the same manner as the cadavers where the visible volume can be manipulated, rotated, and removed by the touch of a finger. The Table presents a DICOM file in a variety of different renderings, including photorealistic top class Ultra High Quality (UHQ) renderings, each designed to emphasise a different part of the scan. The original slice data from which the 3D rendering is composed, is always accessible on the Table.

The Table also features a digital library containing an expansive array of pathological cases, as well as radiology reports. Comparative analysis cases, medical device demonstrations, animal scans, 4D examples, rare and otherwise inaccessible pathology cases are easily viewable and ready for dissection with the Anatomage Table.

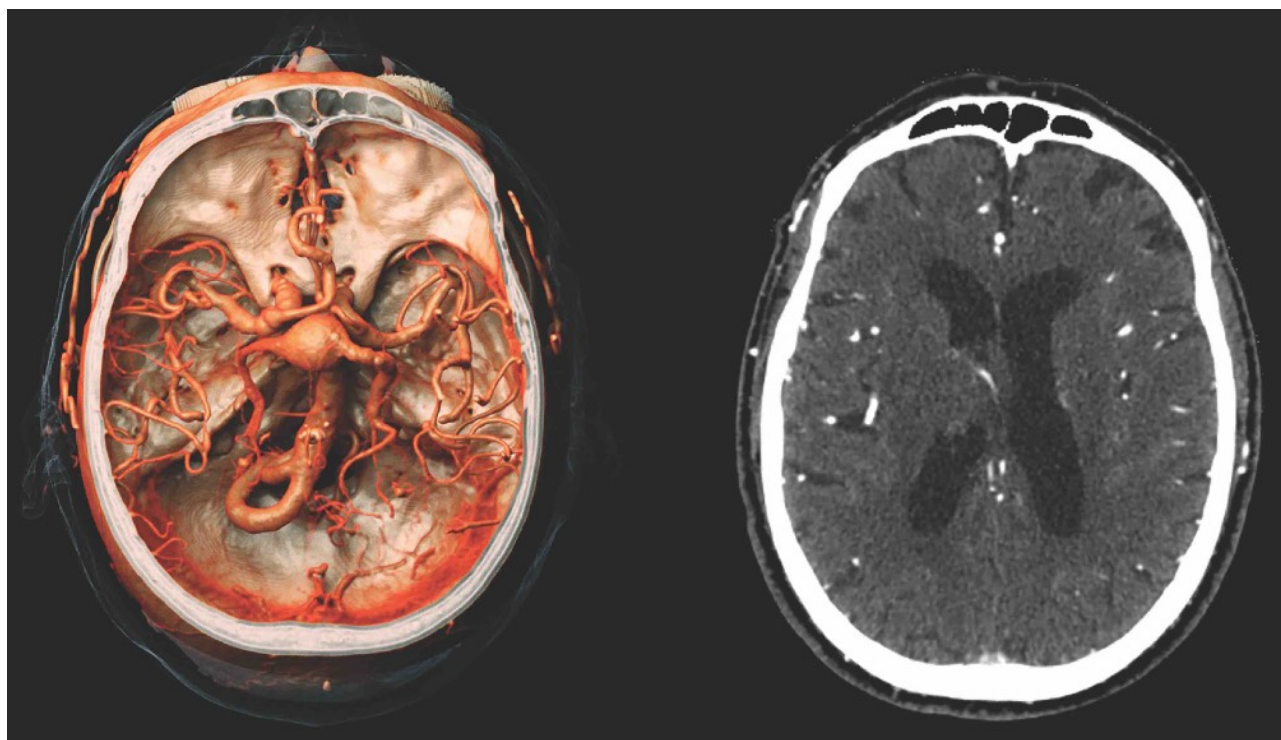


Institutions can also build their own library of case studies to create a unique curriculum to fill their own educational needs.

The Anatamage Table's virtual cadavers address the limitations of cadavers by providing a unique experience for students to gain an appreciation of anatomical relationships throughout the body. In comparison to the localised viewing regions of a cadaver, the Anatamage Table enables a full 3D view of tissue, veins, organs, and anatomical systems. With the Table, any anatomical structure can be easily viewed separately or in relation to any other structure¹⁰. And the Anatamage Table's data can be accessed as many times as needed during frontal lectures, laboratories, self or tutor-aided reviews, group case studies and more.



The integration of radiology into any curriculum has never been easier than with the Anatamage Table^{11,12}. Instructors can assign students a scan for them to study, and teach pathology with the 3D rendering and original scan data simultaneously. By gaining early exposure to clinical images, students become more accustomed to understanding the value and purpose of CT imaging in patient diagnosis.



Same or similar software running on the Anatomage Table is also used in other educational or clinical products: the Anatomage Wall and Concourse.

While the Wall allows the user to visualise at once on 4 different big size screens (65") the same dataset from different points of view or through different renderings; Concourse is an addition to the Anatomage Table that let the user install Table content on a normal workstation and permits users to interact, via the web, with quizzes and tasks assigned by the instructor.

The innovation brought by the Anatomage Table, Wall, and Concourse still presents a few challenges. First, datasets are limited to 4 human bodies, 2 males and 2 females. Given those data are fully real, it is needed to expand the number of cadavers included in the Anatomage Table. The task is daunting since the acquisition of additional bodies is difficult from ethical, legal, and technical points of view; however it is certainly solvable and achievable in a few years' time. Another challenge is posed by the intrinsic 2-dimensional nature of a screen: data are 3D but are still being represented on a 2D surface. Lastly, there is no feeling of touching a real body, just a glass.

Despite this the technology is ready and needs no other steps to already be fully useful^{13,14}. As proof, nearly 1000 Tables have already been delivered all over the world with growing interests from educational institutions, clinics, simulation centres, museums, and the media. Documentaries have been filmed by the BBC, CBC, Japanese Fuji TV, PBS, and STV among others and the Table has even appeared in TV shows like Bones or Grey's Anatomy.

A SOLUTION THAT OPENS NEW SCENERIES

The Anatomage Table is also recognised as a medical device both in US and EU. Why is that so? Its use seems to be strictly educational. The reason is simple: once surgeons started using it to train their residents they found out additional possible uses of the device — clinical uses.

Since the Anatomage Table is able to open any DICOM dataset and directly visualise it in clear 3D renderings, a possible use is to review one's own data and proceed with pre- and post-operation briefings like Mayo Clinic, among others, is already doing¹⁵. Through the Anatomage Table it is possible to easily recognise the best path to follow for the surgery, limiting patient discomfort and heightening safety, or even identify, before actual surgery, if a different surgical approach is more favourable.

Patient communication becomes easier than ever with 3D imaging so easily available. Physicians can help the patient better understand the pathology and the proposed solution to take a real informed decision.

Another interesting development has been, given the realistic UHQ renderings, the use of CT and MR to teach anatomy through living patients data and not cadaver ones.

WHAT ABOUT TOMORROW?

Up to now we've talked about a technology already present even if brand new. What are the next steps we are envisioning?

As already stated, anatomical variations must be accounted for: studying anatomy on real data is the best option but each of us is different and each cadaver has died for different reasons; thus part of its anatomy is pathological. The technology we're discussing needs more cadavers to be acquired.

Same applies to the imaging library: more cases have to be added to let everyone be able to visualise data from rare pathologies and traumas, children, fetuses and embryos and many more. Histology is already a part of the library but that too must be expanded to let students instantly correlate macro and micro anatomy of every different tissue.

3D modelling and segmenting is always getting better and more accurate and same applies to labelling.

All of these steps are software related. What about the hardware? The truth is, it is not of the utmost importance: software is ready for any hardware to come.

Virtual reality headsets can be merged with the Table with little effort to obtain a real 3D visualisation of the human body. The problem will be letting hundreds of students in a classroom to access simultaneously at the data. One person access at a time (as it would be with current virtual reality systems) is just not applicable to teaching.

Force feedback gloves can be set up so that each anatomical structure will give a realistic feeling when touched.

Augmented reality eyepieces can be used to overlay imaging of the patient over his or her actual body; anatomical structures will then be automatically recognised on the patient's body through already on the market machine learning algorithms coupled with image recognition on the expansive set of imaging and cadavers data present in the Table.

The Anatomage Table is ready for new hardware that is currently being developed, it's just a matter of a few years.

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