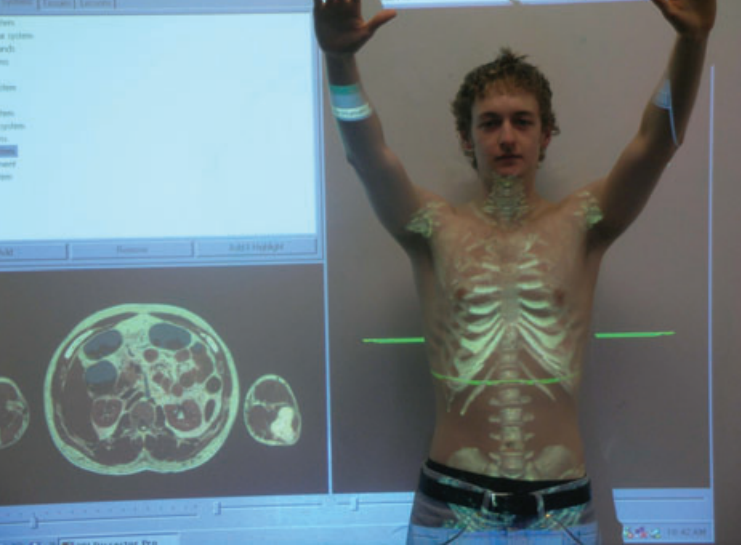

What lies beneath: the use of three-dimensional projection in living anatomy teaching

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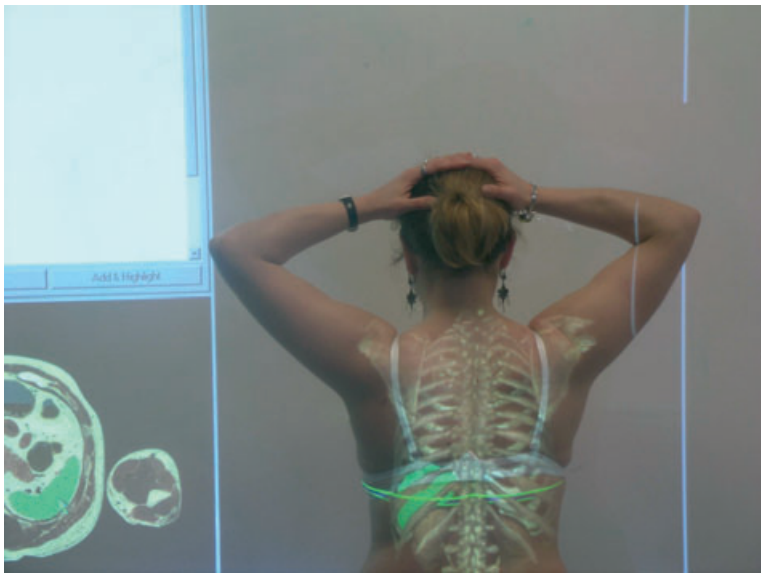
We have developed an interactive and lively anatomy teaching session

There is considerable debate about the best way of teaching anatomy, and which resources to use,[1,2] but there is a consensus that electronic representations of the body alone do not offer students a learning experience that enables them to understand completely the complex three-dimensional (3D) relationships within the human body.[3,4] These electronic resources, however, may be a useful adjunct to other resources employed in anatomical teaching. We have explored the use of one resource in particular, the VH Dissector™, Pro edition[5](VHD) and have developed an interactive and lively anatomy teaching session which, as well as being fun, delivers some powerful learning opportunities for both students and staff.

VH DISSECTOR™

The software allows the user to examine the anatomy of individual viscera, structures or entire

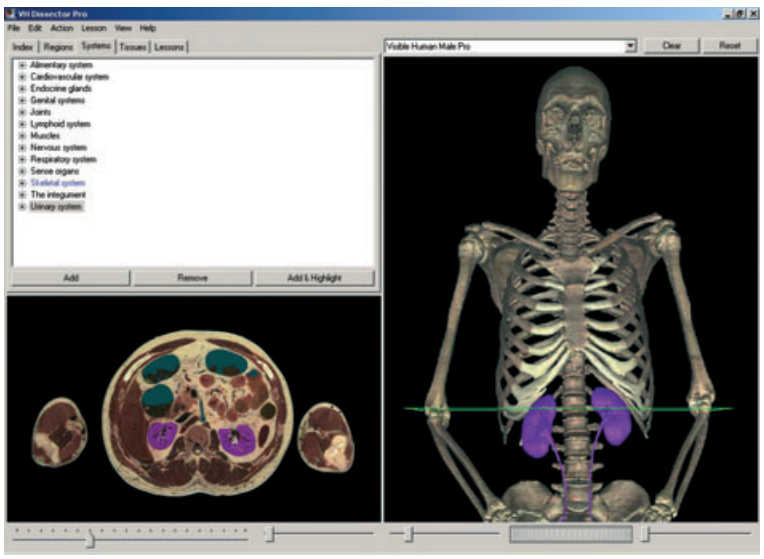


organ systems simultaneously in both 3D and 2D (two-dimensional) views (see Figure 1). With a mouse click, individual viscera or organ systems can be removed from the 3D view to reveal underlying structures and, of course, the individual body parts can then be put back in, to give a good view of the relationships between anatomical structures. In addition, structures can be selected and highlighted simultaneously in both transverse and 3D views, enabling the user to move repeatedly between the 3D and 2D representations. This is a powerful aid to understanding the relationships between anatomical structures and facilitating the development of a 3D mental map of the body. Modern diagnostic medicine relies routinely on the interpretation of 2D clinical images such as magnetic resonance imaging (MRI) and computed tomography (CT) scans; early mastery of these skills is important for undergraduates and can be facilitated using VHD software.

IMAGE PROJECTION

The fun part of the learning can be achieved by projecting 3D reconstructions of the body on to the surface of the living body itself (see Figures 2–5). Combined with palpation, this provides an innovative way of helping students to develop appropriate spatial relationships and views of the body. In principle, the same information could be gained by projecting the 3D reconstructions on to a conventional flat surface, but we have found that, in terms of learning, a valuable emotional impact is achieved when anatomical images are projected on to the body of a living individual, usually a student volunteer. With the room lights dimmed, the appearance of an ethereal projection of body structures on to the skin of a fellow student creates a powerful visual image, as illustrated by the following comment from a first-year undergraduate student: 'Whenever I see my own body now, in my mind, I see what's underneath my skin.'

Early mastery of these skills is important for undergraduates

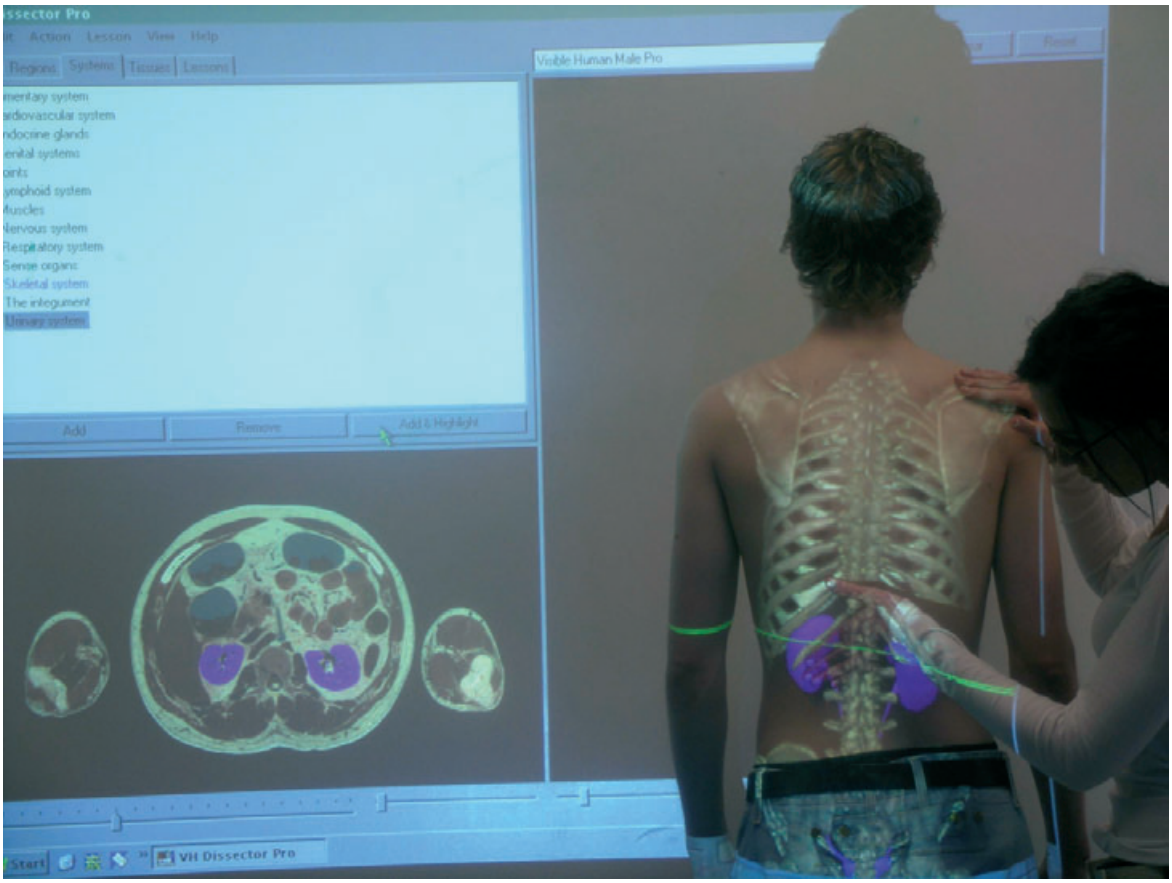


The primary teaching tool is the Virtual Human Dissector (VHD) program,[5] developed using resources from the Visible Human Project® (VHP). The VHP provides a complete, anatomically-detailed representation of normal male and female human bodies in transverse CT, MR and cryosection slices. Since its development, VHP has provided data for several anatomy teaching resources, ranging from simple labelled and unlabelled image databases,[6–8] digital atlases, 3D reconstructions, and animations.[9,10] Some noteworthy examples of projects are still in development – for example, 'The Vesalius Project' and 'The Voxel Man'.[11,12] More recent projects employing data from the VHP include the development of virtual models and virtual reality systems for training in surgery.[13–15]

The VHD program was constructed using the entire library of cryosections available from a male cadaver (sliced at 1 mm intervals); structures in each cryosection were outlined by hand and the data obtained were used to generate selectable 3D reconstructions of each structure.

A valuable emotional impact is achieved

It is best to have several students involved as life models



In the normal view, the VHD software allows the user to interface with three different windows. The main window shows a 3D reconstruction of the body and a moveable transverse plane of section or cursor line which can be scrolled up and down the body (see Figure 1). The second window shows the selected 2D cross-sectional image corresponding to the plane of section chosen at the level of the cursor line in the 3D view, and the third window shows a control panel that enables the user to navigate and operate the software. The 3D view also enables structures to be faded in and out of view as desired: the skin, for example, can be removed by fading it out of view.

COMBINING BODIES AND PROJECTED IMAGES

To project onto the living body effectively, we have found that it is possible to resize the 3D projection to match an individual's body size by using the subject's own bony landmarks as a guide (for example, the clavicles and suprasternal notch). We have found it best for students to be partially undressed during the course of these sessions. For male students, this involves being naked above the waist, or wearing shorts if structures below the waist are to be examined (see Figure 2). For female students, wearing bras or bikini tops proves acceptable to the majority of students, as does the wearing of shorts, if necessary. The presence of undergarments, however, can distract from the impact of the body projection (see Figure 3), and some educators may prefer to use a female life model naked from the waist up to maximise the impact of body projection to illustrate the anatomy of a living female.

Although the match will not be perfect, this can be a valuable training tool, particularly if the projection is associated with palpation. The students can see structures projected on to the body and at the same time feel any landmarks corresponding to these. It is especially useful where there are significant differences; for example, at the margins of the liver (see Figure 4).

EQUIPMENT

It is helpful to provide a large, portable, floor-level mirror to enable the student acting as a model to see the VHD projections on to him/herself. Equally, it is best to have several students involved as life models, so that all can share the experience of seeing images projected on to others and palpating them.

The equipment required is very straightforward, involving the software, a laptop computer (for ease of moving about the laboratory), and a portable data projector. A useful piece of

equipment is an adjustable wheeled stand, whose platform can be raised, lowered and tilted, making it easier to align the 3D images with the body of the individual on whom they projected. The 3D learning tool is available to students for private study, though not in the projected form.

PEER PHYSICAL EXAMINATION

Peer physical examination (PPE) is well tolerated in medical undergraduate classes and offers a number of advantages in the teaching of clinical skills.[16,17] PPE provides students with a safe environment in which to practice and master clinical skills prior to the patient encounter, and is less costly than the alternative of providing students with plastic models or simulated patients. Importantly, it also enables the student to experience for themselves the physical and emotional aspects of the clinical examination.[16]

In our experience, students engaged in PPE appear to quickly overcome any sensations of embarrassment, and welcome the novel experience of learning anatomy by using body projection. It has been reported that factors such as age, gender and religious background may have an impact on the willingness of students to take part in peer physical examination.[16] However, for a practical activity such as this, it is not compulsory for every student to act as a living model; it works just as well if only a small number of students volunteer, but these students must agree to be palpated by their peers in support of the learning objectives.

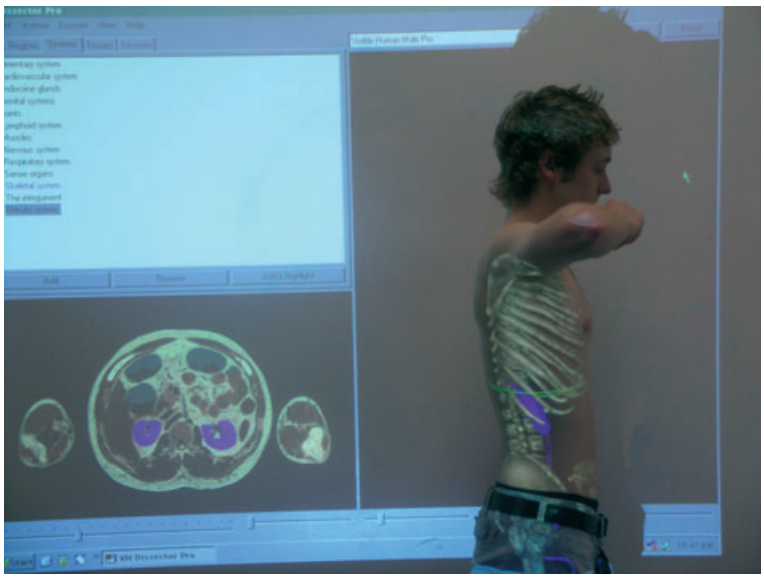
USING THE SOFTWARE

In using VHD, we have found it extremely valuable to be able to add and remove structures from view. For example, the heart or the liver can be seen in the context of the ribs alone, rather than after the ribs have been removed or spread in the cadaver to show the organs inside the body cavity (as seen in Figure 3). It is also possible to rotate the image at the same time as the living model is rotated, so that changing views of relationships can be obtained during the course of the session, including lateral and posterior views. Indeed, in contrast to gross cadaveric dissection, with VHD, lateral and posterior views are as easy to obtain as anterior views (see Figure 5). Thus the relationships of body parts, particularly in lateral views, are much more readily appreciated, since the student can see the underlying structures in the context of the body's surface.

A particularly helpful way of using the software is to scroll up and down through the transverse sections. Novice students often struggle to interpret anatomical information in transverse section (TS) and, in particular, find it difficult to identify to which of the vessels each enclosed space corresponds. This is a difficult skill to acquire, but is an important one, since clinical practice demands the routine interpretation of such anatomical representations. Scrolling up and down rapidly through the transverse sections reveals the nature of a structure and leads to an excellent understanding of 3D relationships. In practice, this understanding can best be achieved by following the changing profile of a single structure (for example, descending aorta to external and internal iliac arteries, or oesophagus to pylorus) in the 2D view as the cursor is scrolled up and down the body in the 3D view. This learning activity can be especially powerful when coupled with the use of the living body and plastic torso models, which can be handled and rotated to reinforce haptic feedback. What, at first glance, students may perceive to be incomprehensible, complex anatomy can be seen to be orderly and straightforward. Perhaps counter-intuitively, we have found that it is better to identify the structures by their arrangement in 3D space, as seen by scrolling up and down, rather than looking initially at their nature, as one would in cadaveric specimens (for example, the nature of the wall surrounding the vessel). Although this is a valuable guide when there is a need to distinguish between, for example, a vein and an artery, we have found it is best to allow the students to identify the target

Novice students often struggle to interpret anatomical information

We have found it is best to allow the students to identify the target structure first



VHD can go some way towards bridging the gap between novice and expert

structure first and then to look at the nature of the enclosing structures. This can then be generalised to other structures so that, once students have identified veins and arteries successfully, they will find it easier to identify other blood vessels.

CONCLUSION

Anatomy teachers have developed a conceptual 3D mental map of the body as a result of years of teaching anatomy, and can easily locate cross-sectional images within that mental map of the body. This is a skill that students commonly struggle with initially. VHD can go some way towards bridging the gap between novice and expert 3D conceptualisations of the body via simultaneous access to both 2D and 3D representations.

While not replacing other teaching methods entirely, this approach does provide some advantages that conventional projection, or even dissection, cannot offer: namely, the relative ease with which lateral and posterior views of anatomical structures may be obtained and, uniquely, it offers an overlapping contextualisation of the cadaveric anatomy usually only seen in the dissection room on to a living, breathing subject.

We are engaged in a programme of evaluation of the outcomes of 3D body projection, to determine its effect on student learning and to contribute to the debate surrounding best practice in anatomical teaching.

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