Implementing *Anatomic VisualizeR* Learning Modules in Anatomy Education

Donald D. Rigamonti[3], Ph.D., Howard J. Bryant[2], Ph.D., Osvaldo Bustos[3], M.D., Leon Moore[2], Ph.D., Helene M. Hoffman[1], Ph.D.

[1]University of California San Diego, School of Medicine
Uniformed Services University of the Health Sciences
[2]School of Medicine and [3]Graduate School of Nursing

Abstract

Anatomic VisualizeR is a virtual reality (VR)-based environment for teaching and learning of clinical anatomy initially developed by the University of California, San Diego (UCSD) School of Medicine under a grant from the Defense Advanced Research Projects Agency (DARPA). Currently, educational applications of *Anatomic VisualizeR* are being jointly explored by UCSD and the Uniformed Services University of the Health Sciences (USUHS) in Bethesda, Maryland with support from the Henry M. Jackson Foundation for the Advancement of Military Medicine.

Anatomic VisualizeR provides a virtual dissection room in which students and faculty can directly interact with three dimensional models and concurrently access supporting curricular materials. A broad range of virtual exploratory tools enables users to investigate structures in ways not possible in the real world. A partial list of options includes: link/unlink models, change opacity or size, dynamically create cross sectional views using a clipping plane, measure sizes and distances with a virtual ruler, mark structures with a flag, identify structures using a probe, and draw lines and simple objects using a SpaceDraw tool. Moreover, a student may choose to access additional information resources using *Anatomic VisualizeR*'s search tool.

Anatomic VisualizeR made its curricular debut outside UCSD in the Fall of 1999 when it was used for teaching of two graduate-level nursing neuroscience lectures. USUHS is currently running the only alpha version of *Anatomic VisualizeR* outside of the UCSD Learning Resource Center and will be jointly developing other VR-based anatomy/neuroscience lessons over the next year.

Keywords: Anatomy Education, *Anatomic VisualizeR*, Learning Modules, Neuroscience Education, Virtual Dissection, Virtual Exploratory Tools, Virtual Reality

Introduction

The Uniformed Services University School of Medicine, and the Graduate School of Nursing (GSN), founded in 1972 and 1992 respectively, is the only federally mandated site to train advanced health care practitioners in the nation. Although advanced classroom technologies, such as a stand alone Simulator Center and a Distance Learning Program are operational for the new millennium, the use of cyber-enhanced technologies highlighted in this paper began five years ago as new technologies, including the Visible Human Data Set, were incorporated in three courses in the GSN. The courses were Clinical Anatomy/Cell Biology, Neuroscience I and Neuroscience II. The use and results of these efforts are recorded for the Clinical Anatomy/Cell Biology course [1], and enhanced Neuroscience Program[2][3][4]. Improved spinal anesthetic intervention have been incorporated in the clinical setting[5]. Newer technology, including advanced software and virtual reality have been recently added to the curriculum.

Anatomic VisualizeR is a virtual reality (VR)-based environment for the teaching and learning of clinical anatomy initially developed by the University of California, San Diego (UCSD) School of Medicine under a grant from Defense Advanced Research Projects Agency (DARPA)[6][7][8] . Currently, the educational applications of *Anatomic VisualizeR* are being jointly explored by UCSD and the Uniformed Services University of the Health Sciences (USUHS) in Bethesda, Maryland with support from the Henry M. Jackson Foundation for the Advancement of Military Medicine.

Methods

Anatomic VisualizeR provides a virtual dissection room in which students and faculty can directly interact with three dimensional (3D) models (anatomic, schematic, etc.) and concurrently access supporting curricular materials (text, images, sound, video, etc.). A broad range of virtual exploratory tools enables users to investigate structures in ways not possible in the real world. The options include: link/unlink models, change opacity or size, dynamically create cross sectional views using a clipping plane, measure sizes and distances with a virtual ruler, mark structures with a flag, identify structures using a probe, and draw lines and simple objects using a SpaceDraw tool. Anatomic orientation can be maintained regardless of view or magnification, and anatomic position can be reestablished through other menubar options. Moreover, within any lesson and at any time, a student may choose to access additional information resources (e.g., correlative histology or pathology images, surgical videos, diagnostic studies) using *Anatomic VisualizeR*'s search tool.

A virtual Study Guide supplies descriptive text and an organized presentation of key concepts, suggested exercises and exploratory actions, and flexible non-sequential access to a variety of lesson materials. Instructional activities, organized into learning modules, can be selected from a collection of previously developed learning modules or can be specially developed using the associated lesson authoring environment. Modules can be created for individual instruction, for presentation in large group settings, and for other curricular contexts which require understanding of 3D structures and complex spatial relationships.

The 3D polygonal models which constitute the nucleus of *Anatomic VisualizeR* are, in large part, based on the National Library of Medicine's Visible Human Project™ dataset[9]. These models were produced by Visible Productions of Fort Collins, Colorado and subsequently modified by a 3D medical illustrator at UCSD. Modifications were made to reduce the number of polygons. In addition to 70-90% decimation, careful editing of facets and adjusting of polygonal patterns were required to optimize application performance. Moreover, changes were made to make idiosyncratic structures represent those seen in a higher percentage of the general population. The creation of new anatomical structures as well as 3D conceptual schematics was also necessary.

Anatomic VisualizeR is still an experimental application, SGI-based, and available on a limited number of workstations. At USUHS, one work station is available for study or research by small groups of students or for presentation of lessons by projection in large classrooms. Workstation components include: a Silicon Graphics Octane Workstation 2 X 250 MHz MIPS R10000 CPUs, IMPACT, Channel Option Video Board, 256 MB RAM, IRIX64 rel 6.5, Ascension Flock of Birds Trackers, Fakespace Pinchgloves, Spacetec IMC Corporation Spaceball 3003 3D mouse, Stereographics CrystalEYES shutterglasses. With only one workstation available, its primary curricular use has been as a teaching/visualization tool in lecture format. At UCSD, *Anatomic VisualizeR* has been a part of the School of Medicine's Human Anatomy course since 1998 for the teaching of the sphenoid bone and the autonomic components of the cranial nerves. In 1999, a lecture on the anatomy of the human ear was also delivered to the UCSD medical students using this application. On each of these occasions, the corresponding *Anatomic VisualizeR*-based learning module was made available for individual and small group sessions on a voluntary basis and was utilized by 40-50% of the UCSD class.

Anatomic VisualizeR made its curricular debut outside UCSD in the Fall of 1999 when it was used for two, graduate-level, nursing-neuroscience lectures at the Uniformed Services University of the Health Sciences in Bethesda, Maryland [10]. USUHS is currently running the only alpha version of *Anatomic VisualizeR* outside of the Learning Resource Center. Five lessons are planned for presentation using *Anatomic VisualizeR*. These lessons will be: The Skull, Figure 1, The Ear, Figure 2, The Clinical Anatomy of the Thorax, Figure 3, and Clinical Anatomy of the Abdomen, Figure 4. A neuroscience lesson is currently under development. The Skull Lesson is described below as a prototype presentation.

Results

The traditional way to teach the skeleton of the head, or dry skull, to medical, nursing and other students is complicated for many reasons, the most conspicuous of them being:

a. The complex design of the human skull, as well as the small size and fragility of many of its contributing bones.

b. The overwhelming number of anatomical details, such as the peaks, valleys, prominences, depressions, craters, fossae, grooves, fissures, crevices, spicules, spines, canals, tunnels, passages, holes and foramina that characterize the normal human skull.

c. The limited number of dry skulls available to anatomy departments.

d. The need to circulate the same skull through the hands of multiple students and their instructors.

e. The difficulties in distinguishing normal details from abnormal occurrences from student-made artifacts (i.e. in their eagerness to learn, students accidentally yet routinely poke new holes through bony plates where holes do not normally exist).

f. The impossibility to disarticulate the skull at will in order to demonstrate the multiple communications that normally exist among major anatomical regions. For example, the pterygopalatine fossa, a major neurovascular distribution center, has on average of ten openings to allow its contents to pass in-and-out of the cranial cavity, nasal cavities, orbit, oral cavity, paranasal sinuses, infratemporal fossa, pharynx and soft palate.

Because of the reasons summarized above, many medical and nursing schools resort to large plastic models to teach the intricacies of the skeleton of the head. Unfortunately, this gives the student a distorted idea of the true size of the structures in question, besides the fact that no plastic skull can faithfully reproduce the true three-dimensional, palpable and measurable anatomy of a real-life skull, let alone its unique feel. *Anatomic VisualizeR* radically changes the anatomical approach to learning the human skull by giving the student and/or faculty the ability to study, move in space, disassemble, manipulate and reassemble, at will, a virtual skull as many times as needed, without fear of altering any anatomical relationships, breaking off bony spicules, or otherwise creating abnormal passages between two or more continuous anatomical regions. Thus, anatomy students and faculty alike are enabled, as well as empowered, to study, learn and/or teach anatomy in new, creative ways that are clearly beyond what traditional methods of teaching can achieve with a dry skull. In a sense, it could be said that *Anatomic VisualizeR* puts the student "behind the wheel" of his or her own anatomical education.

Some of the outstanding features that make The Skull Lesson an effective learning and/or teaching tool include:

a. Students and faculty can interact with a three-dimensional skull model, either individually or as a group, repeatedly and at their convenience, without ever affecting the anatomical integrity of the model. Thus, subsequent student groups can use the same exact model as if no one before them had ever used it.

b. The bony face can be either disarticulated "in toto" from the cranium or bone-by-bone, and, in turn, all eight cranial bones and fourteen facial bones can be studied individually from all angles and different levels of gross anatomical magnification.

c. Individual bones can be highlighted to make them stand out from the surrounding bones, at times with unexpected results. This occurs when the student discovers, and actually visualizes the palatine bone's intricate contributions to otherwise seemingly disconnected anatomical regions, such as the floor of the orbit, the lateral wall of the nasal cavities, the roof of the mouth and the medial wall of the pterygopalatine fossa.

d. The detailed analysis of the keystone bone of the cranium, the sphenoid bone, is greatly facilitated by the ability to selectively remove it from the base of the cranium in order to manipulate it in space and "fly it around" the virtual dissection room to visualize its complex anatomy from above, below, in front, behind and from both sides. This procedure can be repeated with any of the bones that make up the skeleton of the head.

e. Great structural insights can be developed into the normal and abnormal anatomy of the skull by simply making any bony structure transparent, such as "looking into" the petrous pyramid of the temporal bone to allow the student to see the ossicular chain suspended in the middle ear. This is a difficult task in gross anatomy without the intervention of a experienced ear dissector.

f. Individual bony structures can be "flagged" in order to quiz students to enhance their understanding. Furthermore, anatomical details can be pointed out and identified with a built-in probe, regardless of their relative depth in the articulated skull, thus making disarticulation a moot point.

g. A virtual ruler can accurately measure distances between anatomical features, opening sizes or lengths of structures in question, thus providing another novel research tool.

h. By using a clipping plane, the student can create "cross-sectional views" of the skull at any angle in space, making it possible to explore in three dimensions anatomical regions that are a constant source of apprehension among students because of their complexities, such as the already-mentioned pterygopalatine fossa as well as the cerebellopontine angle, to name just a few.

i. The virtual insertion of certain soft tissues into the skull (i.e. internal carotid artery, dural sigmoid sinus, membranous labyrinth of the inner ear, etc) as well as the ability to relate them accurately to their neighboring osseous structures, add significant new dimensions to an already-powerful teaching tool.

j. In addition to all the features described above, *Anatomic VisualizeR* offers the student the opportunity to call up certain supporting learning materials while navigating the intricacies of the bony skull in three-dimensions. For instance, while studying the orbit, the student may wish to supplement the overall learning experience with pertinent clinical and/or pathologic informational resources such as, written text, audiovisual images, x-ray films, CT and/or MRI scans, diagnostic studies and/or video sequences of a surgical procedure under way. These can all be displayed side-by-side with the 3-D model under study.

Conclusions

Anatomy is, first and foremost, a visual science. Therefore, those students who have the ability to mentally evoke images at will, think in three dimensions, perceive different levels of depth with accuracy, and reason things out instead of memorizing them, have a clear advantage over those who cannot. From this perspective, *Anatomic VisualizeR* levels the playing field by giving each student, regardless of individual differences, the same opportunity to maximize his or her anatomic learning experience at his or her own pace and convenience. Through it all, the reproducibility, flexibility, accuracy, clarity, and lack of decay of anatomic images even after multiple uses by an unlimited number of students, along with a plethora of virtual exploratory tools readily available to the user, make *Anatomic VisualizeR* a technological breakthrough as well as a tool of choice to learn and/or teach gross and/or clinical anatomy in the 21st century.

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Figures

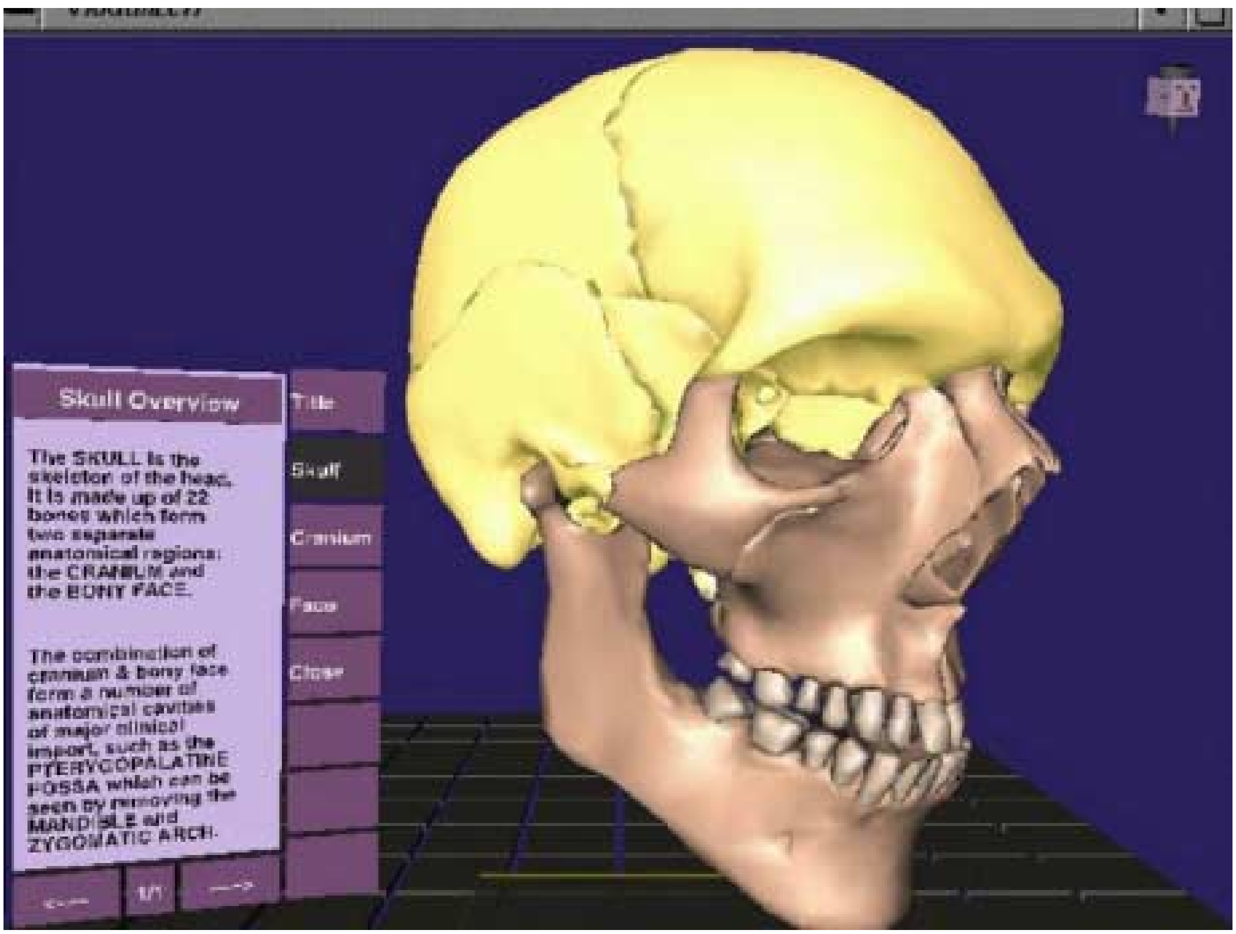

Figure 1. Frontolateral view of the male Visible Human Skull. The neurocranium is shown in

yellow and the facial skeleton is shown in brown.

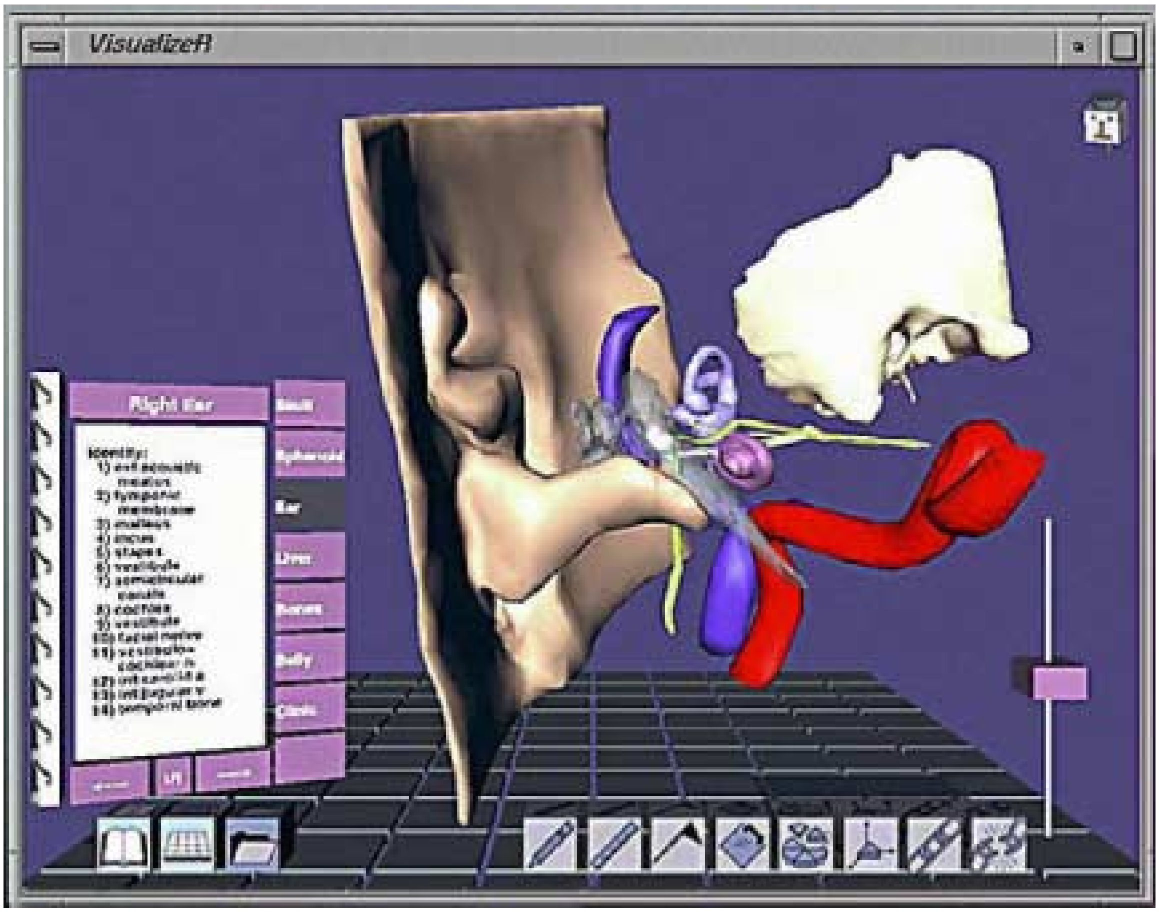

Figure 2. Right ear from Visible Human showing the VIII nerve, vestibular apparatus and cochlea. The temporal bone, internal carotid artery and sinuses are rendered.

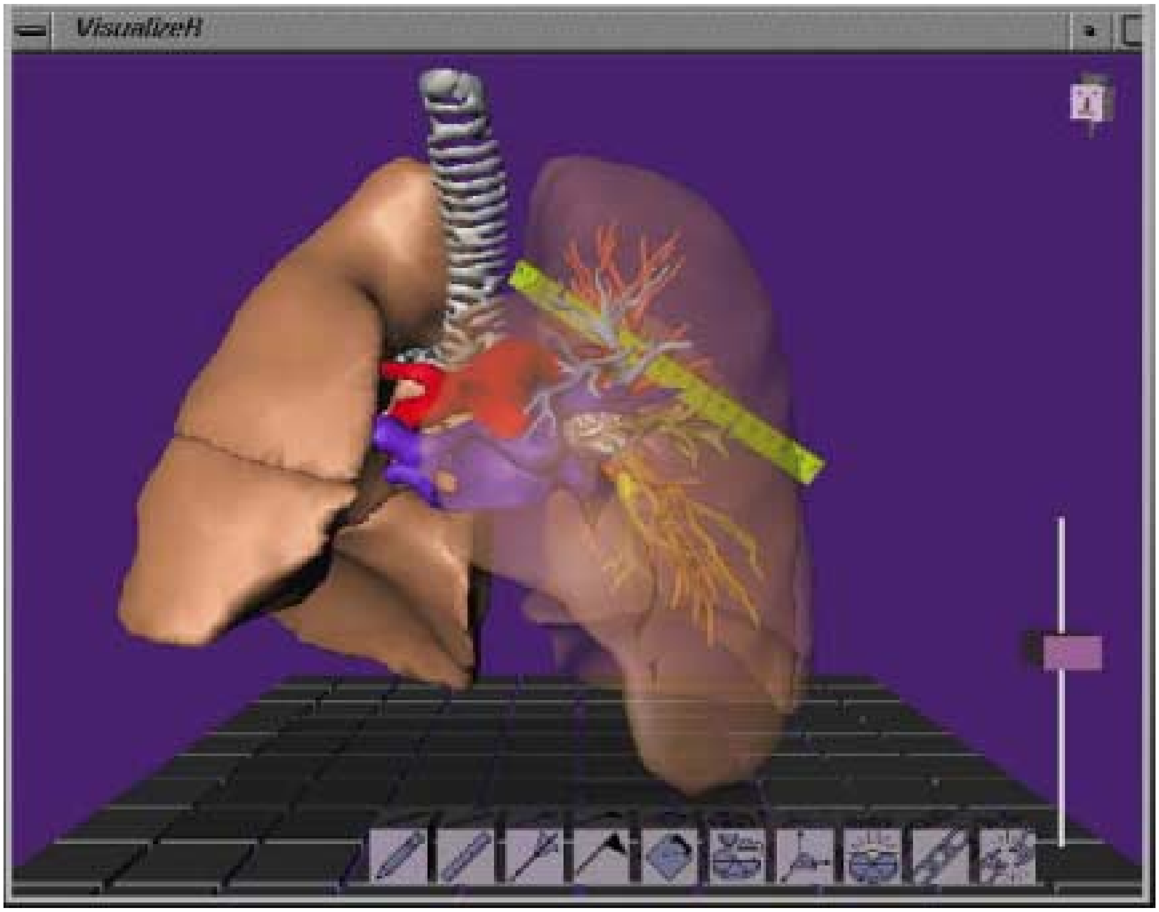

Figure 3. Lungs, tracheobronchial tree and pulmonary vessels. The left lung is transparent to allow viewing and measurement.

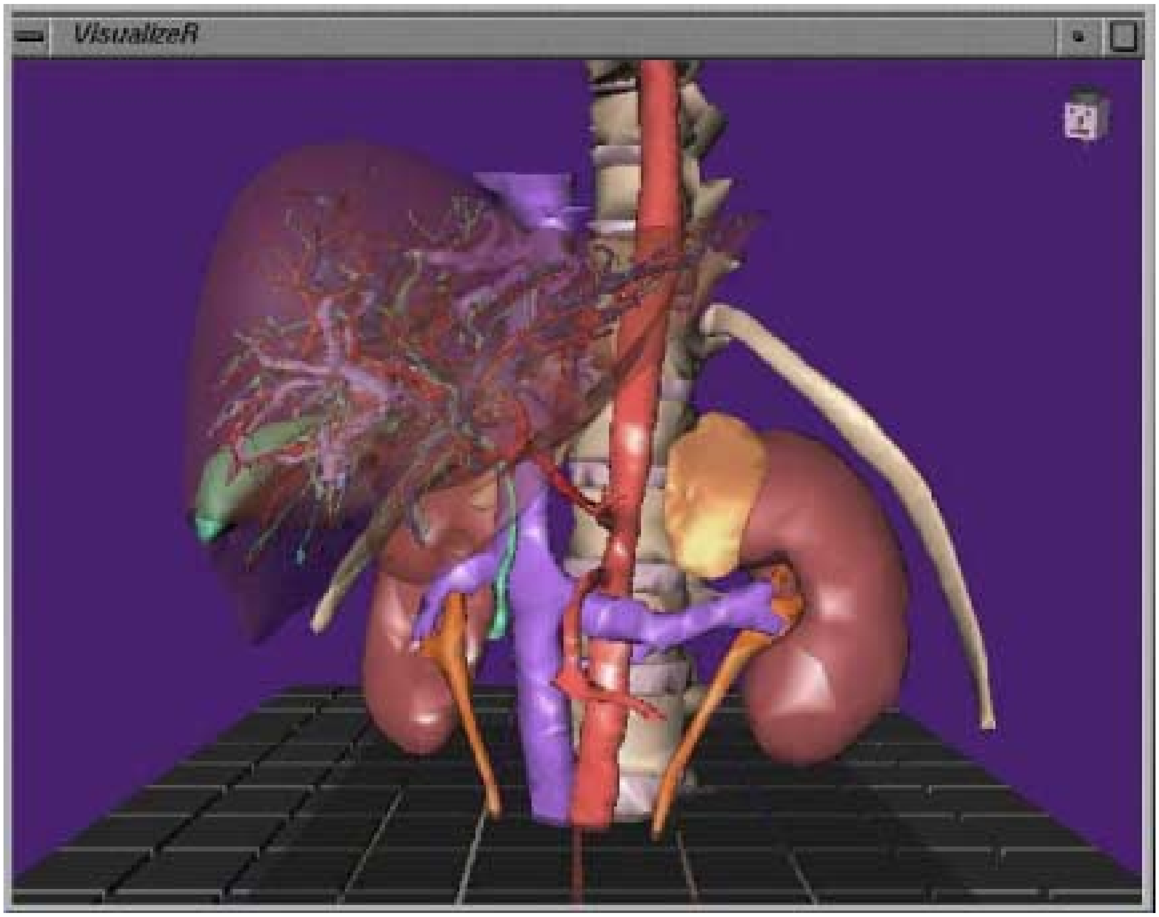

Figure 4. Abdominal structures from the Visible Human include the hepatic and renal systems. The great vessels, vertebrae and floating ribs are rendered.