

Browsing Software of the Visible Korean Data Used for Teaching Sectional Anatomy

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The interpretation of computed tomographs (CTs) and magnetic resonance images (MRIs) to diagnose clinical conditions requires basic knowledge of sectional anatomy. Sectional anatomy has traditionally been taught using sectioned cadavers, atlases, and/or computer software. The computer software commonly used for this subject is practical and efficient for students but could be more advanced. The objective of this research was to present browsing software developed from the Visible Korean images that can be used for teaching sectional anatomy. One thousand seven hundred and two sets of MRIs, CTs, and sectioned images (intervals, one millimeter) of a whole male cadaver were prepared. Over 900 structures in the sectioned images were outlined and then filled with different colors to elaborate each structure. Software was developed where four corresponding images could be displayed simultaneously; in addition, the structures in the image data could be readily recognized with the aid of the color-filled outlines. The software, distributed free of charge, could be a valuable tool to teach medical students. For example, sectional anatomy could be taught by showing the sectioned images with real color and high resolution. Students could then review the lecture by using the sectioned and color-filled images on their own computers. Students could also be evaluated using the same software. Furthermore, other investigators would be able to replace the images for more comprehensive sectional anatomy. *Anat Sci Educ* 4: 327–332. © 2011 American Association of Anatomists.

Key words: Visible Human Projects; cadaver; gross anatomy education; cross-sectional anatomy; radiology education; computer-assisted learning; computer software; user-computer interface

INTRODUCTION

Computed tomographs (CTs) and magnetic resonance images (MRIs) have made it possible to diagnose a myriad of diseases that, in the past, could only be diagnosed during surgery or autopsy (Gunderman and Wilson, 2005). However, the normal anatomical structures in CTs and MRIs are not

readily appreciated by medical students. Therefore, it has been attempted to reconstruct the original CTs and MRIs into colorized three-dimensional (3D) models that can be rotated and actively explored by students. The 3D models are superimposed on the axial, coronal, and sagittal planes of original CTs or MRIs. On the images, captions are added for structural identification (Trelease and Rosset, 2008; Nowinski et al., 2009; Tam, 2010).

On the other hand, easily obtainable stereoscopic plastic models of various body regions assist the interpretation of CTs and MRIs to some extent. An interesting teaching method has been described by Oh et al. (2009) in which medical students make clay models, section them, and compare cut surfaces to CTs and MRIs. This allows medical students to learn how cross-sectional two-dimensional (2D) images are created from 3D structures of human organs (Oh et al., 2009).

An alternative and reliable approach for learning normal structures in CTs and MRIs is sectional anatomy, a specialized field of anatomy using sections from cadavers. This approach is particularly useful, because the sections show

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true body colors without the restriction of image resolution. The inclusion of sectional anatomy training in medical school curricula has been shown to have a great impact on subsequent CT interpretation (de Barros et al., 2001). In another study, students showed strong preferences for the presentation of sections with their corresponding MRIs, because it helped the students interpret the MRIs (de Barros et al., 2001; Khalil et al., 2005).

To protect cadaver sections during handling in the anatomy laboratory, while also ensuring excellent visualization of the anatomic structures, each section can be cased in a display box made of transparent acrylic material (Zamarioli et al., 2010). Permanent specimens can also be made either by embedding them within a synthetic resin mixture (Hwang et al., 2006) or by plastination (Magiros et al., 1997; Weiglein, 1997; de Barros et al., 2001). The plastinated slices are often digitalized for more applications, such as computerized animation and 3D reconstruction (Lozanoff et al., 2003; Sora et al., 2008).

An innovative approach for producing sectional images is to mechanically remove thin slices of cadavers in sequence and digitize these surfaces. Such sectioned images, prepared through the Visible Human Projects in the United States, China, and Korea, have been published in atlases contributing to sectional anatomy (Spitzer and Whitlock, 1997; Zhang et al., 2004; Tang and Dai, 2006; Cho, 2009). But the printed images are static, nonexpandable, and nontransferable (Nowinski et al., 2009).

Computer-based teaching using these sectioned images has become popular for its educational benefits (Weidemann et al., 1997; Marker et al., 2010; Tam, 2010). In particular, sectioned images from the American Visible Human Project have been widely employed in educational software. For example, students can use a sliding bar in some software to fade-in sectioned images while fading-out MRIs, or vice versa (Khalil et al., 2008). More sophisticated software is the Voxel-Man (Gehrmann et al., 2006) and the VH Dissector (Spitzer and Scherzinger, 2006). These kinds of self-directed learning tools are beneficial to the student's initial schema that anatomical information influences radiologic diagnosis.

We thought that our project, Visible Korean, could play a part after intensive outlining and programming. The object of this research was to present browsing software of the Visible Korean data that could be used for teaching sectional anatomy. To achieve this goal, 1,702 sets of corresponding MRIs, CTs, and sectioned images (direction, horizontal; intervals, one millimeter) of a whole cadaver were chosen, and browsing software was developed for all of the images, on which more than 900 structures were readily identified from color-filled images.

EXPERIMENTAL PROCEDURES

MRIs, CTs, and sectioned images of the whole body were obtained from a male cadaver (age, 32 years old; height, 164 cm; body weight, 55 kg). A total of 1,702 pairs of horizontal MRIs and accompanying CTs (intervals, one millimeter; image size, 512×512 pixels; color depth, 8 bits grey; file format, TIFF) were used. Subsequently, 8,510 sectioned images (intervals, 0.2 mm; image size, $3,040 \times 2,008$ pixels; color depth, 24 bits color; file format, TIFF) were produced by serial sectioning of the same cadaver (Park et al., 2005a). Excessive margins of the sectioned images were cropped to reduce their size to $2,500 \times 1,425$ pixels. Among the sectioned images, every fifth image was selected to maintain 1,702 sectioned images with one-millimeter intervals (Table 1).

Table 1.

Features of 1,702 Sets of the Final Images in the Browsing Software

Images	Size	Color depth	File format	File size
MRIs	493 × 281	8 bits gray	JPEG	66 MB
CTs	493 × 281	8 bits gray	JPEG	39 MB
Sectioned images	1,000 × 570	24 bits color	JPEG	228 MB
Color-filled images	1,000 × 570	8 bits color	BMP	2,765 MB
Total				3,098 MB

All intervals between images are 1 mm.

Structures in the sectioned images were outlined on Photoshop CS3 version 10 (Adobe Systems, Inc., San Jose, CA) to elaborate 1,702 outlined images (intervals, one millimeter; image size, $2,500 \times 1,425$ pixels; file format, Photoshop data). Initially, 13 basic structures such as skin and bones were delineated (Park et al., 2005b). Subsequently, as many components in the whole body as possible were demarcated over several years to obtain the outlined images of 937 structures.

The same number of colors was selected to distinguish 937 outlined structures: red, green, and blue values (0–255) of the colors were decided not to be similar between adjacent structures. With Photoshop, all outlines of each structure were automatically filled with a specific color to prepare 1,702 color-filled images (size, $2,500 \times 1,425$ pixels; color depth, 8 bits color; file format, TIFF). In a text file (color.txt), the following details about every color-filled structure were summarized: structure name, numbers of uppermost and lowermost images, and red, green, blue values constituting the color (Table 2).

The resolution and margins of the MRIs, CTs, sectioned images, and color-filled images were regulated so that all of the images matched one another. The size ($2,500 \times 1,425$ pixels) of the sectioned and color-filled images was reduced to $1,000 \times 570$ pixels (1.75:1). As a result, the pixel size was converted from 0.2 to 0.5 mm, and the file size was decreased. For the images to correspond with one another, the margins of MRIs and CTs were cut off; as a result, the image size (512×512 pixels) of the MRIs and CTs was decreased to 493×281 pixels (1.75:1). The file format (TIFF) of the MRIs, CTs, and sectioned images were changed to the JPEG format, (Carmichael and Pawlina, 2000). The color-filled images were converted to bit map (BMP) files to maintain the precise red, green, and blue values. Consequently, the file size of all images was decreased to 3,098 MB (Table 1).

A software was developed to browse 1,702 sets of the MRIs, CTs, sectioned images, and initial color-filled images of 13 structures; the C# language of Microsoft Visual Studio .NET 2003 (Microsoft Corporation, Redmond, WA) was

Table 2.

Examples of Color-Filled Structures and Their Characteristics

Structure name	Uppermost image	Lowermost image	Red value	Green value	Blue value
Cranium without mandible	35	1,010	222	204	227
Parietal bone	35	620	199	209	230
Skin	0	8,505	112	89	15

used for this purpose. The software was composed of program files and data files from the entire set of images. The latter would eventually be replaced with new data files that were color-filled images of the 937 structures.

RESULTS

The browsing software developed in this study was made freely available from the homepage of the Department of Anatomy at Ajou University School of Medicine (Anatomy, 2011). The setup file (size, 374 MB) could be downloaded without charge or registration. Installation of the setup file resulted in automatic production of the main folder including “viewer of VKH.exe,” color.txt, and config.txt as well as four subfolders containing MRIs, CTs, sectioned images, and color-filled images (Table 1). If no longer needed, entire folders and files could be erased by the uninstallation procedure. The viewer of Visible Korean Human (VKH.exe) was executed to start the browsing software, consisting of a tool bar for selecting images (left side) and a set of four images (right side; Fig. 1A). Among the four images, the main image was displayed larger than the other three images, which could be replaced with other images by dragging the mouse. The color-filled images involved 13 outlined structures (Fig. 1B).

The color-filled images of 13 structures were replaced with those of 937 structures. At the same homepage, an update file (size, 24 MB) could also be obtained. The update file was uncompressed to yield the new set of color-filled images, color.txt and config.txt, which then replaced the previous set in

the subfolder and main folder. The browsing software then enabled users to see the color-filled images including the 937 outlined structures (Fig. 1C).

The software showed four images that could be simultaneously browsed in real time. Neighboring images could be continuously displayed by clicking software tools. The user was also able to select the images either by using the scroll bar or by typing an image number into the program. At any time, four images corresponding to each other were visualized (Fig. 1). This browsing was performed in real time because the image resolution was reduced and the image files, except for the color-filled images, were saved as JPEG files with a reduced file size (Table 1).

The software images showed the names of the outlined structures. If the user located the mouse pointer on a structure in the color-filled images, the structure name was shown as the tool tip text beside the mouse pointer (Fig. 2A). This was possible by referring to both the color-filled images and color.txt file (Table 2). The structures’ names could also be seen in the sectioned images (Fig. 2B), such that the color-filled images corresponded to the sectioned images. The labeling function was more essential for identifying the 937 outlined structures than for recognizing the 13 outlined structures.

DISCUSSION

Two-dimensional sectional anatomy can only be taught to medical students with a corresponding knowledge of 3D



Figure 1.

Screen captures of browsing software, the “Viewer of VKH” are shown in three different display options of the abdomen. A: Image of enlarged section with natural captured colors; B: option with the color-filled image delineating only 13 structures in the human body; C: advanced option with the color-filled image delineating 937 structures in the body.

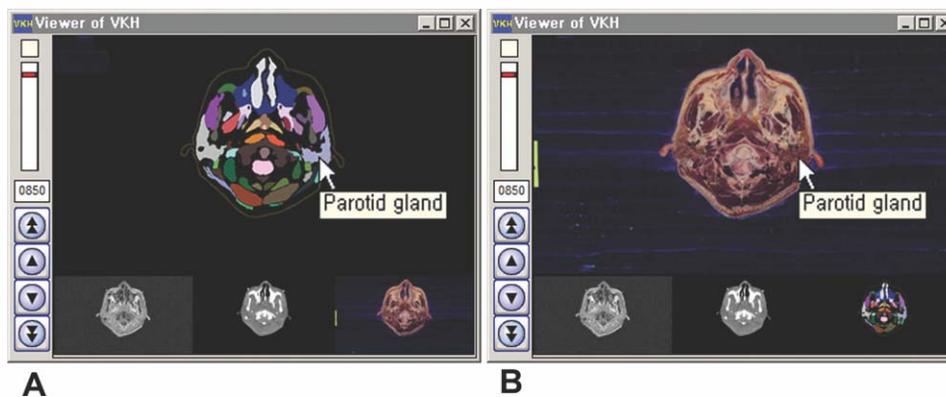


Figure 2.

Screen captures of browsing software, the “Viewer of VKH” are shown in two different display options of the head. Name of the structure is displayed when the mouse pointer flies over a specific structure. A: Color-filled image; B: sectioned image.

gross anatomy. In other words, only students familiar with regional anatomy from cadaver dissection can understand sectional anatomy. Acquisition of knowledge of sectional anatomy also enables students to review macroscopic anatomy and prepares them for the interpretation of CTs and MRIs in future clinical training (Khalil et al., 2005, 2008).

In a sectional anatomy class, numerous structures are difficult to present. This is often due to the fact that students can distinguish fewer structures in sectional planes than in a dissected, palpable cadaver. Given in advance, a list of anatomical structures to be discussed during lecture may help students better understand the material. It is generally preferable to follow a particular pathway in each system. For example, the digestive system is explained by tracing the course of a food bolus through the gastrointestinal tract in horizontal sections from the head to the perineum. Likewise, the respiratory system is introduced by tracing the airway, the urinary system by the passage of urine, the male reproductive system by the path of sperm, and the cardiovascular system by the route taken by the blood. A supplementary regional approach is also required. For instance, the topographic anatomy of the axilla is elucidated by observing the positional relationships of the musculoskeletal system, vascular system, lymphoid system (including lymph nodes), and nervous system in cross-sections.

The software prepared in this study is an improvement over previously available tools traditionally used in teaching sectional anatomy. A whole cadaver can be serially sectioned using an electric band saw to produce slices and permanent specimens including plastinated sections (Magiros et al., 1997; Lozanoff et al., 2003; Sora et al., 2008). However, it is impossible to manufacture slices of the whole body that are thin enough for students to trace such tiny structures as the ductus deferens. In addition, the cadaver sections or their permanent specimens can be damaged or lost. Moreover, they are not always accessible (Cook, 1997; Weiglein, 1997; Hwang et al., 2006; Gould et al., 2008). In a photo atlas of sectional anatomy, thin structures (e.g., a coronary artery) in contiguous sections are very difficult to follow due to a limited number of views. Although anatomical structures are labeled in the atlas, the extent of each structure, graspable only

after segmentation, is not presented (Spitzer and Whitlock, 1997; Zhang et al., 2004; Tang and Dai, 2006; Cho, 2009). Computer software developed to show sectioned images such as the Visible Human Project data is usually not free of charge and can have an insufficient number of anatomical structures outlined. Among them, on-line software is difficult to browse in real time (Toh et al., 1996; Jastrow and Vollrath, 2003; Kim et al., 2003; Gehrman et al., 2006; Spitzer and Scherzinger, 2006).

Our up-to-date browsing software is expected to resolve the shortcomings of prior educational materials. This software has been used for teaching sectional anatomy for three years at our institution. The following executions are recommended on the basis of our experience.

First, the lecture on sectional anatomy is carried out by showing the sectioned images of the software, installed on the classroom computer. Introducing the individual systems or explaining the nearby structures’ relationships are attempted by visualizing the sectioned images with improved quality (Park et al., 2005a). The lecturer can easily browse the adjoining images either at 1-mm intervals with the computer keyboard “↑” and “↓” buttons or at 10-mm intervals using the “Page Up” and “Page Down” buttons. The software can successively display neighboring images, which is almost real time because it operates off-line on the computer.

Second, students can review the lecture using the same software. The software in this study can be downloaded and installed in every student’s personal computer. The student can browse the sectioned images on desired levels using multiple inputs of the software (Fig. 1). Placing the mouse pointer over the segmented structures displays their names, which is a very powerful tool for studying sectional anatomy individually (Fig. 2).

Third, students are evaluated using the software. To use the software for testing, question numbers instead of structure names are displayed (Fig. 3); this can be altered in the color.txt file, by simply replacing the structure names with the question numbers (Table 2). For strict examination, the names of the surrounding structures are erased, but some names can be retained for clues. The computer test on the school computers is facilitated by offering students the levels



Figure 3.

Screen captures of browsing software, the “Viewer of VKH” in the assessment mode. Question number is displayed when the mouse pointer flies over a specific structure. The answer to Question 1 on both sections is gluteus maximus muscle.

(numbers of uppermost and lowermost images in Table 2) of the structures in question, such that students may find the test questions quickly. Nevertheless, the lecturer may prefer the conventional tag examination to the mentioned computer test. In this case, the sectioned images, contained in subfolder of this software, can be printed out in colors and used for the tag examination.

Fourth, the color-filled images in the software can be updated to teach more comprehensive sectional anatomy. Initially, only 13 structures were identified (Fig. 1B); subsequently, 937 structures have been outlined (Fig. 1C). However, even 937 structures may be insufficient. For example, additional brain components could be segmented for teaching details of neuroanatomy. Any developer can provide additional segmentation based on the sectioned images in this software (Table 1). The enhanced color-filled images accompanied by new color.txt file (Table 2) will be substituted for the old files as per the unique needs of the developer. Unfortunately, color-filled images in the software have some errors, which is unavoidable due to the number of delineations. If errors are found, the images can be revised by any developer. With regard to the revision, we suggest the developers share the data with other users, including ourselves.

Fifth, whole images of entirely different subjects can be loaded in the software. Our research team finished the sectioning of a whole female cadaver; the female structures are being outlined in the same manner as discussed above. When completed, the male data in the existing software will be replaced by the female images so as to study the female reproductive system. Furthermore, other sectioned images of cadavers in the United States and China can be added to the software (Spitzer and Scherzinger, 2006; Zhang et al., 2006; Tang et al., 2010). In the meantime, the quality of the CTs and MRIs of the cadaver in this software is not excellent. In other laboratories, CTs and MRIs of living persons exemplifying different pathologies, or who are otherwise normal, can be scanned and segmented to revise the software, which hopefully will be beneficial to radiology classes. During data replacement, it is not necessary to fill all four folders with image files. For example, the software can perform with only two folders (CTs and color-filled images) completed. Such flexibility might be useful for various teaching needs.

The Visible Korean project was started to develop software for medical education. It seemed that only 3D models, constructed from the original 2D images, could be used for the software (Shin et al., 2009, 2011; Jang et al., 2011). However, 2D images were found to be practically useful for the novel software package described in this report. The browsing software equipped with various functions for the sectional anatomy is available with no constraint on time or place. Medical students’ responses to this software have been favorable. However, the educational value compared with previous methods requires further objective study. The software could also be an exhibit in a science museum to demonstrate the structure of the human body to common people including children.

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