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Development and Utilization of a Web-Based Application as a Robust Radiology Teaching Tool (RadStax) for Medical Student Anatomy Teaching

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Abstract

Rationale and Objectives—The primary role of radiology in the preclinical setting is the use of imaging to improve students' understanding of anatomy. Many currently available Web-based anatomy programs include either suboptimal or overwhelming levels of detail for medical students. Our objective was to develop a user-friendly software program that anatomy instructors can completely tailor to match the desired level of detail for their curriculum, meets the unique needs of the first- and the second-year medical students, and is compatible with most Internet browsers and tablets.

Materials and Methods—RadStax is a Web-based application developed using free, open-source, ubiquitous software. RadStax was first introduced as an interactive resource for independent study and later incorporated into lectures. First- and second-year medical students were surveyed for quantitative feedback regarding their experience.

Results—RadStax was successfully introduced into our medical school curriculum. It allows the creation of learning modules with labeled multiplanar (MPR) image sets, basic anatomic information, and a self-assessment feature. The program received overwhelmingly positive

feedback from students. Of 115 students surveyed, 87.0% found it highly effective as a study tool and 85.2% reported high user satisfaction with the program.

Conclusions—RadStax is a novel application for instructors wishing to create an atlas of labeled MPR radiologic studies tailored to meet the specific needs their curriculum. Simple and focused, it provides an interactive experience for students similar to the practice of radiologists. This program is a robust anatomy teaching tool that effectively aids in educating the preclinical medical student.

Keywords

RadStax; medical student; software program; atlas; teaching tool

For many medical students, their first exposure to the field of radiology occurs in gross anatomy and related courses. The quality of this experience has long-term impact on medical students' competence in and opinions about radiology (1,2). The instructor's goal in this setting is not to teach clinical radiology but rather to use imaging to demonstrate anatomy and provide students with the basics of interpretation (3). Although a didactic approach is often necessary to disseminate key information within a limited time frame, clinical correlates and interactive experiences are preferred by students (4,5) and are thought to improve their understanding of anatomy (6,7). Digital technology can help create more interactive experiences in medical education (8), as evidenced by the increasing use of the iPad (Apple Inc., Cupertino, CA); however, there is often an underutilization of this technology in radiology courses (9). Although there are many applications and online radiology resources already available, such as E-anatomy (IMAIOS, Montpellier, France) or the Medical Resource Imaging Center (MIRC; RSNA, Oak Brook, IL), none is optimized for preclinical medical education (10,11). Lack of time and resources is a significant limitation for faculty who seek to provide the most rewarding educational experience possible (8,12).

After reviewing the currently available resources, we identified key characteristics of an ideal teaching tool that can be tailored to meet the specific needs of the preclinical anatomy or radiology instructor. The ideal resource would include 1) a fast and intuitive way to create labels for all anatomy of interest; 2) the incorporation of basic information about each labeled region of interest; 3) the ability to view all three planes of imaging simultaneously; 4) a guide bar for localization to facilitate three-dimensional (3D) understanding; 5) a search function; 6) the ability to be easily incorporated into lectures; 7) availability for independent study; and 8) a means for self-assessment. Therefore, the purpose of our endeavor was to develop a free, user-friendly, Web-based program for instructors to create an institution-specific tool compatible with both Web browsers and the iPad, which is becoming ubiquitous in the classroom.

In this article, we describe the development and use of RadStax (Fig 1), a Web-based JavaScript (JS) program developed using free, open-source, and ubiquitous software packages. Other specific topics discussed in this article include system requirements for the program, our initial experience with use, and future plans for development.

METHODS

Technical Development

RadStax is a free, open-source, JS program that is supported on the latest version of the Web browsers Safari (Apple Inc., Cupertino, CA) and Chrome (Google Inc, Mountain View, CA), which are free and available online. The program consists of a user version and a developer version. Both versions are accessed through a HyperText Markup Language (HTML) file that calls upon the JS programming. Supporting files include Cascading Style Sheets (CSS), Portable Network Graphics (PNG), Extensible Markup Language (XML), and Joint Photographic Experts Group (JPEG) files. The CSS and PNG files contain various graphic and interface application support functions. The XML files contain the label coordinates and related information for the structures. The images displayed from selected studies are in JPEG format. RadStax can be run from a local drive or uploaded to a server for remote access.

The process of creating a RadStax teaching resource can be broken down into four simple steps: 1) deciding on the anatomic structures most appropriate for the curriculum; 2) choosing ideal imaging studies to highlight these structures; 3) processing and importing image files; and 4) labeling structures.

1. Anatomy and radiology course directors identified structures of an appropriate level of detail for the first- and the second-year medical student lectures. A medical student entered these structures, along with related information, into a spreadsheet (Table 1) and converted the data into XML format. The RadStax developer interface uses this XML file to display the chosen structures as a list of label options.
2. Normal imaging studies of each anatomic region were selected by subspecialty attending radiologists who serve as lecturing faculty for the radiology component of the first- and second-year anatomy courses. Multiple imaging modalities were selected, including radiographs, computed tomography (CT), and magnetic resonance (MR) imaging. Our radiology records department appropriately deidentified all studies to ensure Health Insurance Portability and Accountability Act compliance.
3. Using the freeware digital imaging and communications in medicine (DICOM) viewer *OsiriX* (Pixmeo, Geneva, Switzerland), optimal slice thickness and window levels were selected for each study by radiology faculty. A medical student then processed the data set in the following manner: each view was cropped so the guide bar would sweep across the entire window; each stack of images was ordered to begin with the most superior; the most anterior; and the most right for the axial, coronal, and sagittal planes, respectively; the images were exported in JPEG format; and finally, an automated process resized the images to a maximum of 600 × 600 pixels and assigned a color profile to maximize compatibility.
4. All studies were labeled by a medical student and confirmed by a subspecialty attending radiologist. The developer version of the program (Fig 2) prepopulates

the structures identified earlier (now contained in the XML file) and allows for creation of new structures within the program, all of which can be modified or deleted at any time. Labels are either displayed over a point coordinate or anchored to the tail of an arrow, both of which are easily generated with an intuitive point-and-click graphic interface. Intermediate slices are automatically labeled in a vector format. Therefore, labels will track smoothly over the entire structure with as few coordinates defined as possible but still follow even the most tortuous vasculature. The work is saved by overwriting the existing XML file with new code that RadStax automatically generates, allowing the new labels and related information to be displayed in both the developer and the user versions of the program.

All files were uploaded to our institution's server, making the program available using either the Safari or the Chrome Web browser. In addition, an iPad application that ran RadStax was easily deployed and uses the browser in a way that allows for maximal utilization of screen real estate and provides a more focused experience.

Our code and a more detailed account of the technical steps involved are available on request to any instructor wishing to use RadStax at their institution.

Program Implementation and Assessment—RadStax was first implemented as a self-study resource for the class of 2015 during the neuroanatomy course (September to November 2012). It was introduced in lectures given by faculty and used in student-led review sessions before examinations. These students had previously used images taken from the MIRC as a resource to study anatomy and radiology. RadStax was then incorporated into the curriculum for the class of 2016 during the gross anatomy course (January to April 2013). MIRC was not offered to this class; therefore, they could not offer comparative evaluation.

First- and second-year medical students were the primary end users of RadStax. These students were surveyed regarding their use and assessment of the program. Ten-point Likert scale surveys were conducted on completion of each course in an educational setting as part of curriculum development. Participation was entirely voluntary, and it was explicitly stated that participation or nonparticipation would have no bearing on grading. The data were collected anonymously, and summary statistical analysis of the pooled data was performed (Table 2). No course director or faculty member had access to individual responses.

Institutional review board (IRB) review was not necessary for the development of RadStax. The fully deidentified images are displayed in a manner consistent with current educational practices and no research was conducted using this data. IRB review deemed the student survey research to be Exempt, Category 1.

RESULTS

Technical Product

We created a radiology atlas of “normal” imaging for the entire body using multiple imaging modalities; including CT, MR, and plain film (Figs 1, 3, and 4). Studies are labeled in multiple planes (Fig 5), which focus on the anatomy most relevant to first- and second-year

medical students. Labels can be toggled on and off (Fig 6). If a labeled region of interest is selected, that label will be highlighted in red, associated structures will be highlighted in green, and basic information about the selected structure will be displayed in the top left corner (Fig 1). The multiplanar (MPR) capability with a guide bar allows for accurate 3D localization either by scrolling through the smaller viewers or by clicking anywhere on the main viewer, which will cause the smaller viewers to automatically jump to the appropriate slices (Fig 3a). The quiz mode converts all labels into randomly generated numbers and hides the navigation menu on the left until the user clicks on the “Key” button displaying answers for the entire series under the “Index” drop-down tab (Figs 4a and 4b).

There are embedded links throughout the program so that the user can find specific structures more easily. The “Structures” drop-down tab displays an alphabetical list of structures that are labeled in the main viewer. Clicking on those links will select the corresponding structures in that slice. The “Index” drop-down tab contains an alphabetical list of every labeled structure in the loaded study. Clicking on one of these links will cause the main viewer to jump to a slice containing that labeled structure. Alternatively, the user can jump to a slice containing a labeled structure by clicking on the “Find structure” link located in the top right corner of the “Description” drop-down tab (Fig 3a). This “Description” tab is renamed as the selected structure. The green links in the tab correlate with the green labels. Clicking on the green links will load information about associated structures without jumping to another slice. This provides a way for users to view information about structures that may be in another slice or even another study.

Two series of modules were created in sequential order for our neuroanatomy and general anatomy courses. These modules are located in the study browser found at the top of the window (Fig 1 and 4a). To maximize screen real estate, the study browser can be collapsed and hidden from view, and there is also a full-screen function (Fig 3b).

Implementation

RadStax was first offered to students as an optional self-study tool during the fall neuroanatomy course. It was subsequently offered to students in the spring general anatomy course, at which time various faculty members began incorporating it into their lectures. In both settings, a 5-minute RadStax demonstration was given at the beginning of the first lecture of each course, and students were provided an instruction manual. Students could use the program in their studying whenever and however they preferred.

Survey Results

The voluntary survey was completed by 60 of 106 (57%) second-year medical students and 55 of 102 (53.9%) first-year medical students. The survey questions and responses in aggregate are presented in Table 2.

The most highly rated features included continuous labeling (94.8%), an MPR interface (83.1%), and the use of multiple imaging modalities (83.6%). Students rated RadStax to be both an effective (84.7%) and an efficient (79.5%) study tool. Overall, students were satisfied with their RadStax experience (85.2%).

DISCUSSION

This article describes the technical development and implementation of RadStax; a novel, Web-based, tablet-compatible, interactive, free JS program that uses imaging as an adjunct teaching tool to improve the understanding of anatomy by medical students. The purpose was to develop a dynamic atlas of normal anatomy labeled with an appropriate level of detail for preclinical medical students, which was easily accessible and intuitive to use. Our survey results demonstrate widespread satisfaction by the students who used the application.

Medical students face unique challenges when first introduced to anatomy and radiology. They are in the process of learning the basic anatomy, and many struggle with the spatial reasoning skills needed for orientation and comprehension of the 3D space in imaging. Providing students with labeled cross-sectional images is an excellent way to introduce the relevant anatomy; however, this is usually done within the context of a slide presentation and remains constrained by its medium. Typically, a small number of images from an otherwise complete study are labeled and presented such that the relevant anatomic structures are appropriately showcased. Presenting the full set of images would be prohibitively burdensome in a slide presentation. Unfortunately, this approach leads students to memorize the slides by rote instead of developing a true understanding of the landscape of the human body.

One way to facilitate a more dynamic presentation is to create a series of slides that gives the effect of scrolling through a single plane of imaging. Another is to embed a video within a presentation. Although both these approaches offer advantages over displaying a static image, there are limitations. Primarily, presenting a single plane of imaging that is not cross referenced makes it difficult for students to orient themselves to the view and predict which direction the instructor is scrolling. Another limitation is that creating such dynamic slides or videos may be technically difficult and time consuming for faculty. Additional barriers to incorporating these presentations into a lecture include the various technological challenges that often arise when using cross-platform software.

RadStax is an interactive resource promoting active learning built specifically to address the teaching and learning challenges described previously. A novel, Web-based, JS program developed using free open-source software packages, RadStax offers MPR cross-referenced imaging on the same screen. RadStax also provides an efficient way to continuously label regions of interest, allows for the inclusion of descriptions of the labeled structures, and offers a mechanism for self-assessment with a quiz function, all of which can be tailored to meet the unique needs of any curriculum.

Although student satisfaction does not always lead to improved knowledge, our survey results suggest that RadStax is a value-adding educational program. All of our objectives were completed and received a favorable student response. In some cases, our survey results may actually underrepresent positive feedback because the lowest score also represented "Did not use." The two questions that are most likely to have been affected are those regarding the usefulness of the structure descriptions and the quiz function.

Limitations of RadStax in its current state include the following: First, although much of the workflow has been automated in a variety of ways, loading new studies into the program requires users to edit HTML and XML files. A second-year medical student with no previous experience in software programming primarily did this work; however, some may be reluctant to invest time in learning basic HTML and XML programming. Second, it remains somewhat cumbersome to update multiple studies that have already been labeled. We plan to develop an ancillary program that can apply the appropriate changes to a batch of files to minimize manual data entry. Third, exporting JPEG files from the DICOM format means the data are no longer truly volumetric. Although the guide bars are generally an excellent approximation of position, there is some discrepancy that cannot be avoided, especially when dealing with MR studies that use oblique planes to best demonstrate the anatomy. A method of customizing the guide bar display is being investigated for future versions. Fourth, some anatomic structures (ie, lobes of the lung) are better illustrated by regional shading, an option that is not currently available as with the labeling tool. Finally, this software is only supported on Safari and Google Chrome; however, as they are free, easily obtained via download, and run on either Mac OSX or Microsoft Windows, these two Web browsers alone provide a platform for ubiquitous use of RadStax.

Although the goal of using imaging to teach anatomy is not to make every medical student into a radiologist, the preclinical experience may have lasting effects on his or her competence in and opinions about radiology (1, 2). The radiology component of an anatomy course presents a unique, early opportunity to train all future physicians in the effective and efficient use of medical imaging (3). This exposure may also lead to the consideration of radiology as a specialty choice. We believe that more easily accessible and intuitive educational methods yield better results, and the literature supports the need for the development of focused educational programs such as RadStax (4–8, 10–12).

In conclusion, RadStax represents a novel Web-based software program that uses interactive anatomic imaging data sets to teach anatomy to preclinical medical students. Enabling medical students to gain a more comprehensive 3D working knowledge of the human body during this critical period of education may have a positive impact on future patient care. Going forward, we hope RadStax will be a valuable teaching tool across all 4 years of the medical school curriculum, teaching “normal” in the preclinical years and “abnormal” during clinical rotations.

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Figure 1.

Screenshot of RadStax, an interactive Web-based program for viewing imaging studies that allows 1) a fast and intuitive way to create labels for all anatomy of interest; 2) the incorporation of basic information about each labeled region of interest; 3) the ability to view all three planes of imaging simultaneously; 4) a guide bar for localization to facilitate 3D understanding; 5) a search function; 6) the ability to be easily incorporated into lectures; 7) availability for independent study; and 8) a means for self-assessment.

Figure 2.

Screenshot of the RadStax developer program. The studies load similarly; however, there are “STRUCTURE” and “ROI” tabs that allow for an intuitive and user-friendly way to create labels. The “STRUCTURE” tab allows for creation of new labels or selection of pre-populated data imported from the spreadsheet. These structures may then be edited or deleted directly within the program. The “ROI” tab will automatically generate coordinates after the developer selects the desired label type and clicks on the structure’s location in the main viewer. ROI, region of interest.

Figure 3.

Screenshot demonstrating the use of magnetic resonance, 3D localization capabilities, and full-screen mode. In addition to being able to scroll through all three viewers, clicking on the main viewer automatically loads the appropriate slices in the other two viewers allowing for 3D localization (a). Full-screen mode provides the maximum viewer size and is indicated in the top left corner (b).

Figure 4.

Screenshot of the use of plain films and quiz mode. Clicking on the “Quiz” button automatically closes the navigation window and randomly generates numbers for each label (a). Clicking on the “Key” button opens the navigation window and displays the answer key under the Index drop-down menu (b).

Figure 5.

Screenshot of labels in axial, coronal, and sagittal views. Labels are only displayed in the main viewer. Clicking on the “Axial,” “Coronal,” and “Sagittal” buttons will load the desired series of images and their labels (a, b, and c; respectively).

Figure 6. Screenshot of labels toggled on (a) and off (b). Instead of altering the Joint Photographic Experts Group images, the labels are displayed in an overlay fashion using an Extensible Markup Language file. This feature is especially beneficial when regions of interest are very small or in close proximity.

TABLE 1

Sample Spreadsheet

Set Name	Formal Name	Common Names	Structure Description
Vascular	Basilar artery	BA, vessel, artery	Origin: confluence of vertebral artery at the junction of the pons and medulla oblongata branches: anterior inferior cerebellar artery and pontine arteries Terminal branches: superior cerebellar artery and posterior cerebral artery
Viscera	Common bile duct	CBD, Vater	Origin: the common bile duct is formed from the confluence of the cystic duct and common hepatic duct Drains to: joins the main pancreatic duct to form the ampulla of Vater
Bone	Coracoid process	CP	Superior to the glenoid cavity, this anterolateral projection of the scapula gives rise to the attachment of three muscles: coracobrachialis, short head of the biceps, and pectoralis minor.
Nerve	Facial nerve	FN, CN VII, nerve, inner ear	Arises from the pons. Controls muscles of facial expression, conveys taste from anterior 2/3 tongue. Supplies preganglionic parasympathetic fibers to submandibular and lacrimal glands
Muscle	Flexor hallucis longus	FHL	Proximal attachment: the inferior two-thirds of the posterior surface of the fibula and the inferior part of the interosseous membrane Distal attachment: the base of the distal phalanx of the great toe
Level	Functional segment 1	FS1, liver, portal vein, hepatic, division, divisions, FS, FD1, FD	The caudate lobe found in the posterior part of the liver
Gland	Pituitary gland	PGI, hypophysis	Rests in the hypophysial fossa. Composed of the anterior pituitary and posterior pituitary
Space	Rectouterine pouch	RuP, Douglas	Separates the body of the uterus and the supravaginal cervix from the sigmoid colon
Connective tissue	Thecal sac	ThSac	A membrane of dura mater that surrounds the spinal cord and cauda equina and is filled with cerebrospinal fluid

Sample of the information entered into a spreadsheet and then converted into XML format. The columns "Set Name" and "Common Names" were created with a future version in mind, which will provide a text search function.

TABLE 2

Survey of First- and Second-Year Medical Students Who Used RadStax

	First-Year Students; N = 55	Second-Year Students; N = 60	Combined percentage; N = 115
How helpful was it to see all three planes of imaging simultaneously (with a guide in the other two windows)?	8.42/10	8.20/10	83.1
How helpful was it to be able to scroll through all three planes of imaging simultaneously?	8.37/10	8.11/10	82.4
How helpful was it to have the label follow structures while scrolling through the main window?	9.25/10	9.71/10	94.8
How useful was the quiz function?	7.08/10	8.07/10	75.8
How useful were the descriptions associated with labeled structures?	6.73/10	7.47/10	71.0
How helpful was it to have multiple modalities of the same study?	8.45/10	8.27/10	83.6
Overall, did you find RadStax to be an EFFECTIVE study resource?	8.47/10	8.47/10	84.7
Overall, did you find RadStax to be an EFFICIENT study resource?	7.73/10	8.16/10	79.5
Overall, how satisfied were you with RadStax?	7.93/10	8.42/10	81.8

Medical students were asked to participate in a voluntary and anonymous electronic survey. Subjects responded on a 10-point scale ranging from (1) "Not helpful/Did not use" to (10) "Extremely helpful." The data mean is displayed.