An Internet-based Nuclear Medicine Teaching File

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Teaching file cases play an important role in the training of nuclear medicine residents; however, film-based teaching files have limitations, such as difficulty in accessing cases in a department with several remote clinical sites. The goal of this project was to develop a digital teaching file with the capability for local and remote (Internet) network access, with the additional requirements that viewing existing cases and addition of new cases be easy and simple. **Methods:** The teaching file software (TF-Web) utilizes applications developed for the World-Wide-Web in combination with locally developed programs for importing images, entering case information, indexing, searching, case selection and case editing. The time required to add cases to the TF-Web and to access existing cases from local and remote network sites as well as computer storage requirements were assessed. **Results:** Cases entered in TF-Web may be viewed either with or without diagnoses and may be accessed with acceptable speed (2–14 sec) from both local and remote network sites. A relatively complex case required 1.2 megabytes of storage, with lesser storage requirements for simpler cases. **Conclusion:** A digital teaching file has been developed that allows easy access from computers located both locally and elsewhere on the Internet. Digital storage requirements are reasonable, and, because of the unique nature of TF-Web, case storage may be distributed among multiple institutions.

Key Words: teaching files; computer networking; World-Wide-Web; Internet

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Conventional film-based teaching files are an important component of the residency training program in nuclear medicine. Cases are reviewed as unknowns in formal teaching conferences, and residents view individual cases at other times. Film-based teaching files, however, have several disadvantages:

1. They are difficult to access in a department with several disparate clinical sites.
2. Finding desired cases can be difficult despite the use of a standardized indexing system.
3. It is very difficult to show dynamic (cine) studies.
4. Loss of films (e.g., due to misfiling) can make teaching cases worthless.
5. Access is sufficiently slow that it is rare that the teaching file is used as a diagnostic aid during clinical interpretation.

In addition, access to the teaching file is quite limited (if not impossible) once residents complete the training program, preventing them from comparing new cases to ones encountered during their training program. In this project, a network-accessible electronic teaching file (TF-Web) was developed to overcome the limitations of a conventional film-based teaching file.

TF-Web utilizes a program called Mosaic* (*1–4*), an application available from the National Center for Supercomputer Applications (NCSA, University of Illinois, Urbana-Champaign, IL) that allows one to navigate through the Internet and take advantage of network resources using a point-and-click hypertext environment. Mosaic can be used for viewing a wide variety of network accessible images, including weather maps, reproductions from art museums, graphs from technical journals, and university campus maps. By navigating to appropriate locations in the network or "web" of participating sites, one can also use Mosaic to search many databases, such as those of the Human Genome Project, the National Institutes of Health grant information database and the Astrophysics Data System. This project combines the image display and search capabilities of Mosaic to create an Internet-based nuclear medicine teaching file.

METHODS

Software/Hardware Platforms

To allow the greatest flexibility while conserving computer resources, the teaching file was implemented using a World-Wide-Web (WWW) server (NCSA-HTTPd) coupled with remote networked WWW clients (e.g., NCSA-Mosaic); further details about these WWW applications may be found in the Discussion section. The HTTPd server was configured to run on a UNIX workstation (Personal DECstation 5000/25, Digital Equipment Corp.,

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*Since the original manuscript submission, Netscape (available from ftp-.netscape.com) has superseded Mosaic as the most commonly used World-Wide-Web program.

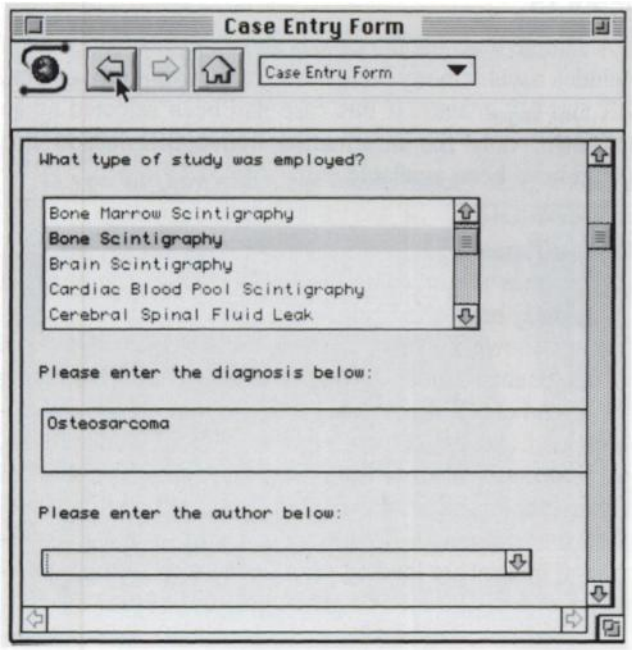

FIGURE 1. A portion of the Mosaic form used for entering teaching file cases. The form contains scrolling lists, text entry fields and pop-up menus to simplify data entry. Mosaic allows information to be entered from both local and remote sites.

Maynard, MA) connected via ethernet to our hospital network, with subsequent connection via a microwave relay to an Internet gateway located several miles away on the Washington University main campus. A 600-megabyte hard drive was employed for storage of teaching-file related software and images. The teaching file can be accessed using WWW client applications running on several hardware platforms, including UNIX workstations, Apple Macintosh computers, and IBM-PC compatible computers. Display of images requires at least an 8-bit (256 color) monitor; dynamic formatting allows a variety of screen sizes, although a minimum of 640 × 480 pixels is preferred. Ethernet access from within our local network or via the Internet is required; such access can also be obtained (albeit more slowly) using a telephone modem connection.

Case Display

Once entered into the system, cases are stored in the WWW Hypertext Markup Language (HTML), which allows the client software to present the user with formatted text containing links to images and other text pages. Initial access is through a list of cases for each study type (e.g., bone scintigraphy), either with or without display of the diagnoses. After selection of the case, the viewer is presented with a brief history and the primary image set associated with the case. Additional image sets (if any) may be displayed by "clicking" corresponding links with the mouse. If the case was accessed as an "unknown," a link is available to display the full case with the patient diagnosis, findings, discussion and any follow-up information.

Customized Data Entry and Searching

Although it would be possible to enter each case by direct typing of the HTML code (including associated file links), such data entry would be laborious and would require the person entering the data to be knowledgeable regarding the details of HTML. To simplify data entry, a Mosaic-accessible form (Fig. 1) was designed that permits the user to enter information about the case; the form contains data fields as specified in Table 1. Upon submission, the data in the form are handed by the HTTPd server to a custom program written in the C language. This program then creates the known and unknown pages (with incorporation of the selected images), creates links to these pages and adds portions of the case information to a database. The contents of the data fields are retained in machine-readable format, allowing re-creation of the completed form for subsequent editing from a remote computer using Mosaic. Fields may be omitted if not relevant to a specific case or may be added later during the editing process as needed. Access to case addition and editing features are password protected, although viewers may add text to a "comments" page without use of a password. Cases are initially marked as "under construction" and are accessible for viewing and editing only from local workstations. Once cases are completed, they are marked "finished" and are available for remote access from sites outside of Washington University.

TABLE 1
Fields Used for Data Entry of Teaching File Cases

Institution (P)	Primary image file name (L)
Password (T)	Additional image(s): types (L,O)
ACR Anatomic field (P,S)	Additional image(s): filenames (L,O)
ACR Pathologic group (P,S)	Full history (T,O)
Scintigraphic study type (L,S)	Discussion (T,O)
Diagnosis (T,S)	Follow-up (T,O)
Patient name (T,H)	Follow-up image type (L,O)
Patient birthdate (T,H)	Follow-up image file (L,O)
Study date (T,H)	Differential Diagnosis (T,O)
Brief history (T)	References (T,O)
Case author (T)	Full American College of Radiology (ACR) Classification (L,O)
Case difficulty (P)	
Case quality (P)	Case completion state (R)

T = text field; L = scrolling list; P = pop-up menu; S = searchable; O = optional; H = hidden from TF-Web user; R = radio button.

Submission of images to TF-Web is accomplished directly from the workstation used for clinical interpretation. Transfer of images from our clinical display computers (UNIX workstations) to the WWW server was facilitated by our department-wide ethernet network. Once the images are displayed on the computer monitor, a rectangular portion of the screen may be selected using the mouse. The selected images are then automatically converted to GIF format and sent via network to a subdirectory on the server computer. Conversion is accomplished with the aid of the Extended Portable Bitmap Toolkit in the publicly available PBMPLUS program. Image submission and case entry may occur from any of our clinical sites. Once images have been submitted, the image file names are available for selection in the case entry form described above.

In addition to allowing selection of cases from the known and unknown pages organized by study type, user selectable groups of known and unknown cases may be retrieved using a search menu. Fields that may be searched include case difficulty, case quality, study type, diagnosis and the primary portions of the American College of Radiology (ACR) numerical case index (*5*).

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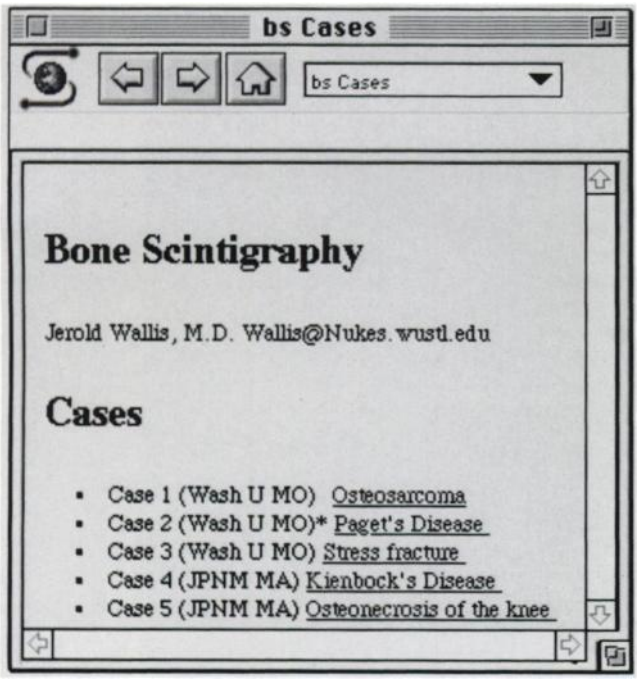

FIGURE 2. A portion of the case selection menu. Cases may be viewed by clicking with the mouse on the underlined words. If the cases had been accessed as "unknowns," a short history would have been displayed instead of each listed diagnoses. Cases marked JPNM MA are located in the teaching file at the Joint Program in Nuclear Medicine at Harvard Medical School (see text). Cases marked with "*" are under development and can be viewed only from local workstations.

Inclusion of Cases Located at Other Institutions

Cases from other institutions may be included in our teaching file using two methods, both of which require passwords at the time of case entry. If images are transmitted to our institution in GIF format, the remainder of the case entry may be performed from remote sites using Mosaic. The result is similar to local entry of a case, with images and text residing on our HTTPd server.

To distribute network load and storage requirements, however, it may be better for the case descriptions and images to remain at their original site. By use of a remote case indexing feature, cases located at other institutions with Mosaic servers may be searched and accessed from within TF-Web. Only the links and indexing information are retained locally. Remote cases are clearly marked as such during retrieval, with display of the name of the contributing institution (Fig. 2).

A summary of the software components of TF-Web and their functions is provided in the Appendix.

Evaluation

The performance of TF-Web was assessed using the metrics of: (a) time required to enter a simple teaching file case, (b) response time for viewing a case from several different computer platforms at local and distant network locations and (c) storage requirements for the teaching file cases. Evaluation of the effectiveness of teaching file cases as a learning tool is beyond the scope of this investigation.

RESULTS

A sample teaching file case is shown in Figure 3, which includes a whole-body bone scintigraph, plain radiographs, MR and CT images. If this case had been selected as an unknown, only the information above the dashed line would have been available.

Access Times

The times required for display of a case containing a whole-body bone scintigraph with associated case description are shown in Table 2; these times represent several measurements made during normal weekday working hours, and user's access time may vary depending on network load. Access is quite rapid from local workstations, and is acceptable from both local and remote networked personal computers. Access by modem is possible, especially for occasional use or for display in teaching conferences if images are loading prior to the start of the conference.

Case Entry

Addition of a simple case (nuclear medicine images only) with basic case information required approximately 10 min. Plain-film and CT images currently need to be transferred to our workstation through a film digitizer (Model FD-1S, Kodak Health Imaging Systems, Dallas); it is planned that these images will become available directly over the network in the near future. Obviously, creation of extensive case discussions and reference lists can require additional time that is independent of the digital or film-based nature of the teaching file. The flexible nature of TF-Web permits such additional text to be added at a later date; if desired, typing of dictated material may be performed by a secretary at any of our networked secretarial Macintosh computers. A portion of a sample case entry page is shown in Figure 1.

Currently our TF-Web database contains both local cases and several cases located at the Joint Program in Nuclear Medicine (JPNM) at Harvard Medical School; these remote cases were developed independently as part of a separate teaching file project, but may be accessed and searched as if they were part of our local case collection (Fig. 2). Storage of the case shown in Figure 3 requires 56K bytes for the 300 × 400 pixel whole-body bone scintigraph (reduced from 240K bytes as a result of conversion from a 16-bit to an 8-bit image and the "loss-less" compression of the GIF image format); the selected portions of the digitized radiographs and CT and MR examinations add an additional 57K bytes, again utilizing image compression. When combined with the space required by the text and HTML forms associated with the case, a total of 1.24 megabytes are needed for this relatively complex case.

The search feature can access both local cases and external cases which have been added to our teaching file. The ease with which teaching file cases may be searched is demonstrated in Figure 4.

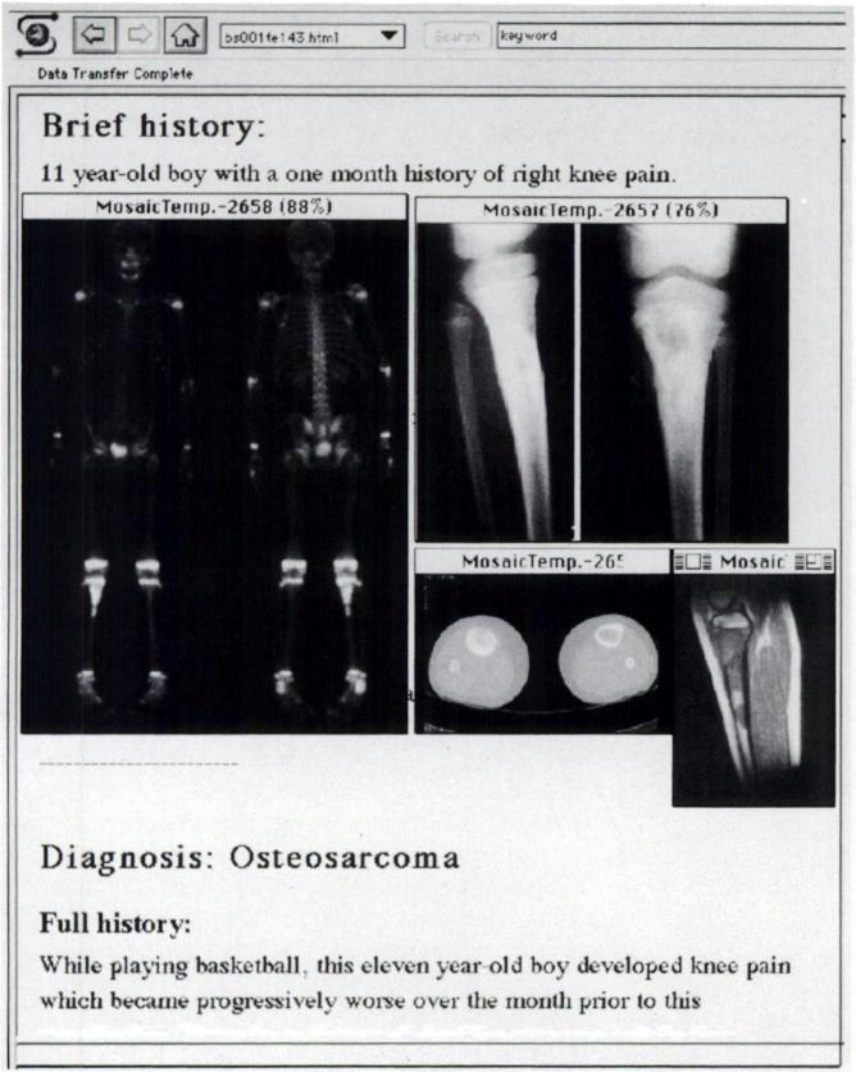

FIGURE 3. Sample teaching file case. The images were reduced in size for this illustration, and additional history and discussion would be available by scrolling the window. If accessed as an "unknown," only the brief history and the bone scintigraphy are initially displayed; the additional images and the diagnosis are revealed when the user clicks on the corresponding "links."

DISCUSSION

Computer-Based Teaching Files

Digital teaching files have several advantages over their film-based counterparts. Network access permits use at multiple sites, both within an institution and across multiple institutions. Loss of teaching file cases due to misfiling of films is prevented, and the digital teaching file is easily backed-up on tape. Because of the small size of nuclear medicine images and the ready access to the imaging data in digital form, nuclear medicine is particularly well suited for creating a digital teaching file. The rapid indexing and search/retrieval times of a digital teaching file permit use of

TABLE 2
Time Needed to Access a Sample Teaching File Case

Computer	Client application	Network link (distance)	Time (sec)
DECstation 5000/200	NCSA Mosaic 2.4	Ethernet (local)	2
Mac Quadra 610	NCSA Mosaic 1.03	Ethernet (local)	5
Mac PowerPC 6100AV	NCSA Mosaic 2.00A2	Ethernet (local)	7–8*
IBM PC 486/66	NCSA Mosaic 2.0A4	Ethernet (1 block away)	7–9
Mac PowerPC 6100AV	NCSA Mosaic 2.00A2	Ethernet/Internet (1000 miles)	7–14*
Mac Centris 650	NCSA Mosaic 1.03	14.4K modem (PPP protocol) connection (15 miles)	48–52

*Speed expected to increase with release of an optimized version of the software designed for the PowerPC.

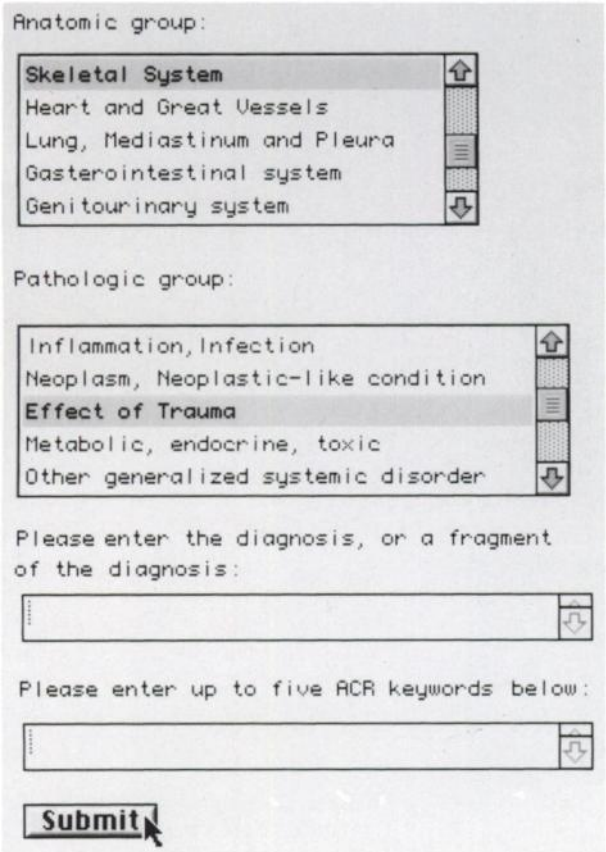

FIGURE 4. A portion of the teaching file search form. The user has elected to search for effects of trauma on the skeletal system (e.g., fractures) by selecting these items from the major groups in the ACR classification scheme. Alternately, text from the diagnosis or full ACR classification may be searched. Although not illustrated here, it is possible to limit the search based on other criteria, such as difficulty level.

the file as an "electronic atlas" for comparison with clinical cases. The ability to manipulate image brightness and contrast is useful, especially for cardiac images. Display of dynamic or gated images as a movie (a feature that we will be adding to TF-Web in the near future) is useful in gated cardiac imaging, gastrointestinal bleeding studies and hepatobiliary imaging. Finally, incorporation of the best cases from multiple institutions enhances the quality of the images used as teaching aids for residents.

Disadvantages of a digital teaching file primarily relate to the mode of presentation. Display to even small groups of people requires using a large monitor or expensive projection equipment. On the other hand, creation of high-quality slides is easier than from film, with the ability to add annotations and output to a film recorder.

A desirable feature of a digital teaching file is the capability for network access from remote sites. Many published efforts' in the development of digital teaching aids have focused on the creation of digital textbooks or atlases that may be accessed from a single computer (*6–14*). Other work has allowed network access within a single institution's local network (*15–17*) or PACS system (*18–20*), but those systems have not been designed for widespread network use. In the case of network access, images in the digital teaching file may reside in a dedicated storage area or may be accessed upon demand from the clinical area of a PACS system. The latter has the advantage of most closely modeling the setting of clinical interpretation, but requires substantial online storage. Placement of selected images from a study into a dedicated teaching file storage area, as was done here, requires less storage and may facilitate more rapid case review.

Another method of distribution of digital images is via CD-ROM, as used in the PET tutorial published by UCLA (*21*), but this method is machine-specific and does not allow for easy incremental growth. Videodisks, such as those used for the ACR learning project, have also been used for distribution of radiographic teaching material (*22–24*). These are similar to CD-ROM but store data in lower-resolution analog images to achieve greater storage capacity and faster data transfer time.

A few institutions have begun to create prototype Mosaic-based teaching files, including a nuclear medicine teaching file at the Joint Program in Nuclear Medicine, a collection of "nice cases" accessible on LUNIS at Loyola University and a radiology teaching file at the University of Washington. None of these, however, currently offer case search capability, and they likely use manual typing of HTML links and more laborious methods of importing images than that used in the TF-Web. The flexible case entry system we have developed will minimize the effort of case creation, allowing the primary focus to be on the content of the teaching file case. Perhaps the most ambitious effort utilizing Mosaic for teaching is the Virtual Hospital at the University of Iowa (*25*), which includes a preliminary version of an electronic textbook of medicine, complete with radiographs. On the other hand, this project also does not offer the search capability of the TF-Web and does not allow viewing of cases both with and without the diagnoses.

It is critical that the case material in the digital teaching file be of high quality. TF-Web provides for quality control during data entry through a local "holding area" for newly entered cases. After online editing and approval by senior physicians, cases become available for wider network distribution. To allow continued quality control, viewers may add comments to specific cases by clicking on an "add comments" link; these comments may be viewed both by TF-Web users and by the staff maintaining the teaching database by using a corresponding "view comments" link.

Mosaic as a Network Tool

Mosaic is an outgrowth of the World-Wide-Web project developed by Tim Berners-Lee at the European Particle Physics Laboratory (CERN) that was designed to enhance communication among physics researchers. Versions of Mosaic have been written by NCSA for Macintosh, IBM/Windows and UNIX workstations.

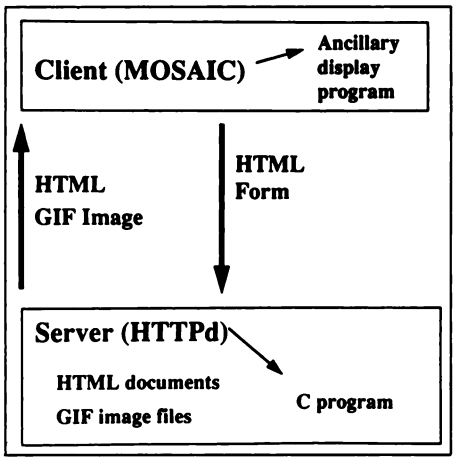

FIGURE 5. Teaching file cases (consisting of GIF images and HTML documents) are stored on the server computer (lower box). Upon request, they are sent over the network (bold arrows) to the client computer (upper box) where the case is viewed. Simple viewing of GIF images may be done within from within Mosaic, and gray scale manipulation or cine display of image sets can be performed after automatic transfer of data to ancillary display applications. Data entered through forms are processed by application-specific programs (e.g., C programs) residing on the server.

Upon launching Mosaic from a computer with access to the Internet, the program automatically establishes communication with a user-designated "Home Page." On this page, one is presented with what appears to be a text document, perhaps with some graphics included as well. Some of the words in the document will be underlined; these are "links" to access other information. These links could be set to jump to another document on the same computer or to a document on a different computer on the Internet anywhere in the world.

Mosaic is actually the "client" half of a client-server pair. It is capable of displaying documents sent to it by a server in a English-like language called HTML. Formatting of the text of the document is done locally; HTML includes designations to mark text for display in various ways: as the title of a page, in bold face, etc. When a link is present, the HTML code includes an address or "uniform resource locator" (URL), which lets Mosaic know where to look for information should you click on that link. An example of a URL address is "http://gamma.wustl.edu/tf/home.html," which says to look on the gamma computer at Washington University, St. Louis in the tf directory for the document called home.html, which is the "home page" for this teaching file. Mosaic may also make use of other network tools such as FTP, Archie and WAIS; a summary of network tools directed to the nuclear medicine physician is available (*26*).

The HTTPd server, also supplied by NSCA, provides the other half of the client-server pair. HTML documents and images reside on the server computer, awaiting requests for transmission over the network. To minimize network load, the link between the client and server is established only long enough to download the requested information to the client computer and then the network link is dismissed.

As illustrated in Figure 5, both the client and the server may also have "helper applications" to assist in data display and processing. Mosaic is preset to pass certain types of data to other local applications when it receives data of that type—for example, images can be displayed within Mosaic or handed to a graphics application and "cine" movies and sounds files are handed to their respective "player" applications. Additionally, data may be entered using current versions of Mosaic with use of online "forms" containing pop-up menus, scrolling lists and boxes for entry of free text. Upon submission to the HTTPd server, the information in the form is passed to another data-handler program, the name of which is specified in the form. This program is typically written by the person setting up the HTTPd server, and may be designed for any function, including adding the supplied information to a database. For the TF-Web, many such programs were written to perform the functions of adding and editing teaching file cases, renaming images and performing the searching functions.

Mosaic is available directly from NCSA using FTP access from ftp.ncsa.uiuc.edu. One logs in with user name "anonymous" with your E-mail address as the password. Knowledge of FTP commands (ls, cd, image, get) is required; information about these commands should be available from anyone familiar with UNIX workstations. World-Wide Web client applications written by other programming groups are also available, and may be used instead of Mosaic for accessing TF-Web and other WWW servers. The URL for the Mallinckrodt Institute of Radiology Nuclear Medicine home page is http://gamma.wustl.edu—from there one can reach TF-Web as well as the Society of Nuclear Medicine Computer and Instrumentation Council home page, which has links to other radiology sites.

Internet access can be difficult for physicians not affiliated with academic medical centers. Such users usually connect to the Internet through a modem telephone link to a commercial provider; such connections can be expensive, although the cost has been declining as these services become more available. While the transfer time for text over a modem connection is rapid, optional display of images is rather slow. In the future, acceptable Internet access should become practical for any physician with a modem and a personal computer, and it is likely that direct Internet connection to homes and businesses will be established in a few years.

CONCLUSION

TF-Web succeeds in its goal of providing an easy-to-use network-based digital teaching file. It contains many features that will enhance its teaching value, including the ability to view images both as unknown cases and with accompanying diagnosis and discussion, to present images

from multiple imaging modalities and to search for cases by a variety of parameters. Selection of cases by level of difficulty make it usable at any level of medical training, and the ability to access TF-Web from Macintosh computers, IBM compatible computers and Unix workstations located anywhere on the Internet will increase its utilization. The ease of entering cases using online case forms with automatic generation of HTML codes should facilitate rapid growth of TF-Web. Finally, the potential for multi-institutional contributions to the teaching file will result in high-quality teaching cases being distributed among many participating centers while increasing the total number of cases available to all users.

APPENDIX

TF-Web Modules: Components and Function Descriptions

Below is a list of the software modules which were written to create the digital teaching file; these modules use the display and server features of the NCSA World-Wide-Web applications (Mosaic and HTTPd).

Case Entry System:

Forms for entering TF cases.

A program (cgi-bin post-query handler) written in the "C" language which takes the information contained in the TF entry form and creates the case by:

- Making an "unknown" and a "known" page in proper HTML syntax, with inclusion of only appropriate parts for that case (e.g., if there are no references cited, it will omit the subhead "References"),
- Assigning appropriate names for these pages,
- Renaming the image files to correspond to the assigned case name,
- Inclusion of links to the images from the known/unknown pages,
- Modification of the corresponding study type page to include links to the new case and,
- Addition of selected information to a searchable index.

Case Editing System:

A program that takes the previously entered information and recreates a partially completed form so that the user can add to or modify previously entered information.

A "C" program (cgi-bin post-query handler) that accepts the edited case information and replaces/updates the "known" and "unknown" case pages, as well as updating the searchable index.

Image Transport System:

A program that captures the selected portion of the screen as an X-windows screen dump, automatically converts it to a GIF file (by funneling it through the PBMPLUS portable pixmap converter) and automatically moves the GIF file to the workstation on which the TF-Web server resides.

Search Engine:

An HTML form that allows the user to enter the search criteria.

A program (UNIX shell script) that performs the search and "writes" a custom HTML page with links to the cases that resulted from the search.

Cases:

Known and unknown case pages with links to images.

Organizational pages based upon study type (e.g., renal scintigraphy), which provide links to cases.

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