A Preliminary Report of the Virtual Craniofacial Center: Development of Internet-/Intranet-Based Care Coordination of Pediatric Craniofacial Patients

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The authors present preliminary information regarding the development of an Internet-based Virtual Craniofacial Center that provides access to a patient database with visual and textual data. Patients are photographed by digital camera with standardized images. Through a Web site linked to a remote database, patient demographics, management data, reports, and acquired digital photographic images are stored and retrieved. The database can be used to sort and to present data as desired by multiple specialists. Confidentiality is maintained by unique identification numbers and password access to the server for craniofacial team members. The current system uses economical equipment (i.e., digital camera, personal computer with modem, and access to a remote Windows NT-based server), using data that can be entered in a variety of cross-platform personal computer systems and transmitted on a wide range of bandwidths—from a relatively low-bandwidth (28.8 KB per second) modem to a high-speed T-3 line connection. Long-term goals include archival data storage and analysis, as well as the development of multicenter telemedicine links for active craniofacial centers.

Goodwin MD, Otake LR, Persing JA, et al. A preliminary report of the virtual craniofacial center: development of internet-/intranet-based care coordination of pediatric craniofacial patients. Ann Plast Surg 2001;46:511–516

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Received Dec 18, 2000. Accepted for publication Dec 18, 2000.

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Optimum delivery of care for pediatric patients with craniofacial anomalies relies on communication between specialists. Whether care is delivered in a multidisciplinary or interdisciplinary manner, adequate communication depends on the timely review of data and consultative opinions. The advent of managed care has led to restrictions in the nature and number of consultations, as well as increasing time constraints on specialists. This has begun to encroach on the capacity of the craniofacial team to deliberate over treatment options for these children. However, at the same time technology applications with regard to the transfer of visual as well as textual data have become increasingly powerful, cost-effective, and easy to use.

We demonstrate the development of an Internet-based Virtual Craniofacial Center (VCC) that provides access to a patient database with visual and textual data (Fig 1). In addition, we present the use of digital photography as a means of acquiring and storing visual data. The purpose is to facilitate communication between specialists and to permit remote access to patient data.

Computerized Telemedicine

Computerized telemedicine has been implemented for some time in several surgical specialties.[1–4] Radiology and pathology have already embraced telemedicine with digital imaging to facilitate communication between physicians. Increasing power and speed combined with decreasing costs have led to the commonplace use of computers with Internet or intranet access in the physician's office. This tool is valuable for specialists as a means of communication, organization, data storage, and education. The Internet's potential as a mode for teleconsultation continues to grow as the technology advances.

Several studies evaluating the early efforts in telemedicine have generally found it to be clinically feasible.[5,6] Otake and colleagues[4] used a low-bandwidth system to enhance the efficiency and efficacy of an intermittent surgical program

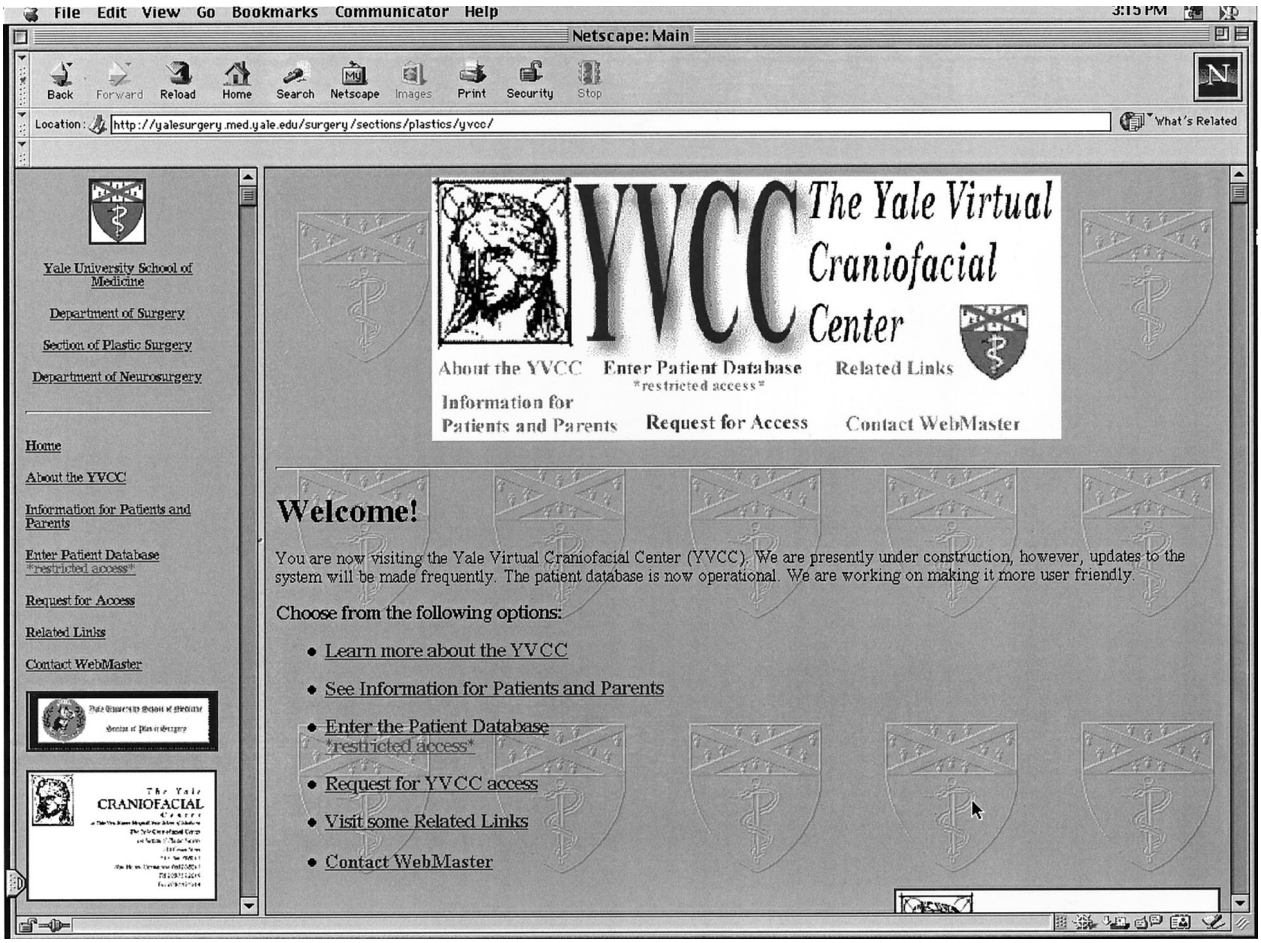

Fig 1. Home page of Yale's Virtual Craniofacial Center Web site.

in a remote area. However, few studies have demonstrated cost-effectiveness of telemedicine. Wooton and associates[6] concluded that teledermatology is not cost-effective except for circumstances involving long-distance travel and secondary-to-tertiary consulting. Given that established craniofacial centers are few and far apart, management of craniofacial patients is often subject to these circumstances. In addition, computerized telemedicine is a relatively new concept, and optimum efficiency may not always be achieved because of its novelty. As with any new technology there is an investment cost and learning curve for users. Furthermore, costs saved from implementing digital photography in place of standard photography can potentially offset initial investment costs. We contend that computerized telemedicine can be clinically feasible and cost-effective once it is fully integrated into the management of craniofacial patients.

Digital Photography

Digitalization of photographic data facilitates its incorporation into telecommunication applications. Although there are alternatives such as scanners and traditional 35-mm cameras, we have chosen digital cameras as our primary means of data collection because they are easy to use, allow immediate image retrieval, and are potentially cost-effective. The images are saved automatically as JPEG (Joint Photographic Experts Group) files. These files are compressed, allowing for easy transmission through low-bandwidth lines while preserving excellent image quality.[7]

Several centers for plastic surgery have already converted from standard photographic data storage to digital image collection.[8,9] Wirthlin and coworkers[2] found that wound evaluation on the basis of viewing digital images is comparable

with standard wound examination and renders similar diagnoses. Roth and colleagues[10] found that the feasibility of distance wound consultation using digitized photographic images was consistent with standard 35-mm slide images. Craniofacial centers generally use 35-mm slides and photographs to facilitate management of their patients. Therefore, we propose to use digital images of craniofacial patients as an adjunct to traditional patient management.

Equipment and Methods

The current system that our center has chosen includes economical equipment using data that can be entered in a variety of cross-platform personal computer (PC) systems. The PCs located at our center are the Dell (Dell Co., Austin, TX) series computers typically running with Pentium III or Celeron processors ranging from 500 to 733 MHz. Cost per PC usually ranges from $1,500 to $2,000.

Most commercially available digital cameras are suitable for visual data collection. We have chosen the Sony (Sony Co. of America, New York, NY) Mavica Series model MVCD83 that contains the standard high-speed (4×) diskette drive. The diskette drive is advantageous to the media cards offered on other digital cameras because it allows one to exchange quickly between diskettes that can be used for storage and to transfer data easily to the PC. The camera allows various levels of resolution, as large as 1,216 × 912 pixels. We found 640 × 425 pixels with fine resolution sufficiently clear for standard visualization of Web-based images. The JPEG files require 40 to 90 KB disk space. This permits storage of 15 to 25 images per diskette, depending on the composition of the photograph. Currently, the cost for this camera is approximately $700.

The Internet connection is through Yale University's T-3 line connected network. T-3 lines refer to high-speed phone connections that support data transmission rates of approximately 43 Mb per second. Other commercially available Internet providers that work through telephone line modems, cable connections, or digital subscriber lines are sufficient. The Web site is stored on Yale University's server and the database is stored on a remote commercial Microsoft Windows NT 4.0 (Microsoft, Redmond, WA) server. We use Interland's Feature Plus (Interland, Atlanta, GA) program with 300 MB hard-disk storage, and it costs approximately $50 per month.

Construction of the Web site was facilitated by use of a commercially available Web site editor, Microsoft FrontPage (Microsoft, Redmond, WA) (1998). There were minimal adjustments to the design, requiring a basic knowledge of Hypertext Markup Language. The database was accessed via scripts written in Cold Fusion (Allaire, Inc., Newton, MA) with data managed on Microsoft Access (Microsoft, Redmond, WA) (1997).

Security of Patient Data

When transmitting patient data over the Internet, every effort must be made to protect the information from intruders and "hackers." Before collecting patient data, consent was obtained from Yale University's Human Investigations Committee. In addition, written consent was obtained from each patient's guardian before any information was placed on the database. In addition, the opening page of the patient database provides instructions that stress the importance of data security to the user.

Within the Web site and database we have incorporated several features that restrict access to patient data, including individualized identification numbers and passwords. The Windows NT server has a redundant firewall that excludes all queries to the database except authorized transactions. All transmissions of patient data are through secure socket layer (SSL) encryption. SSL encryption uses RSA public key cryptography (provided by RSA Data Security Inc.) for authentication and encryption. Public key encryption is a technique that uses a pair of asymmetrical keys for encryption and decryption. This includes a widely distributed public key and a secret private key. Data encrypted by the public key can only be decrypted by the private key. Conversely, data encrypted by the private key can only be decrypted by the public key. This asymmetry is what makes public key cryptography so useful.[11]

Furthermore, database activity is monitored

frequently. If unauthorized activity takes place, efforts will be made to strengthen security at that level. The event of a breach in patient data security is highly unlikely. The standards that we use are equivalent to the e-commerce companies with large monetary transactions taking place on-line.

Our Experience

During a 7-month interval, patients followed in the Yale Craniofacial Center were photographed by digital camera. The digital images and additional information including demographics, diagnosis, and treatment were uploaded to the database through the VCC Web site (Fig 2). Currently, the Web site contains data for more than 100 patients. The database is organized alphabetically according to the patient's last name. There is a search feature that allows patients to be organized by various specifications including name, physician, diagnosis, etc.

We have not yet abandoned the traditional form of patient data management (i.e., patient files and notes). Current efforts to assess efficacy of patient data management through Web-based systems are ongoing and represent schema to be studied. While such studies are ongoing, patient data are collected and stored in traditional formats, in parallel. However, we think that with further experience with newer forms of data storage and retrieval, along with improvements in efficiency, this will likely be our primary means of patient data management.

Long-Term Goals

Our intention is to continue the growth and development of this system of patient data management, eventually replacing the current modal-

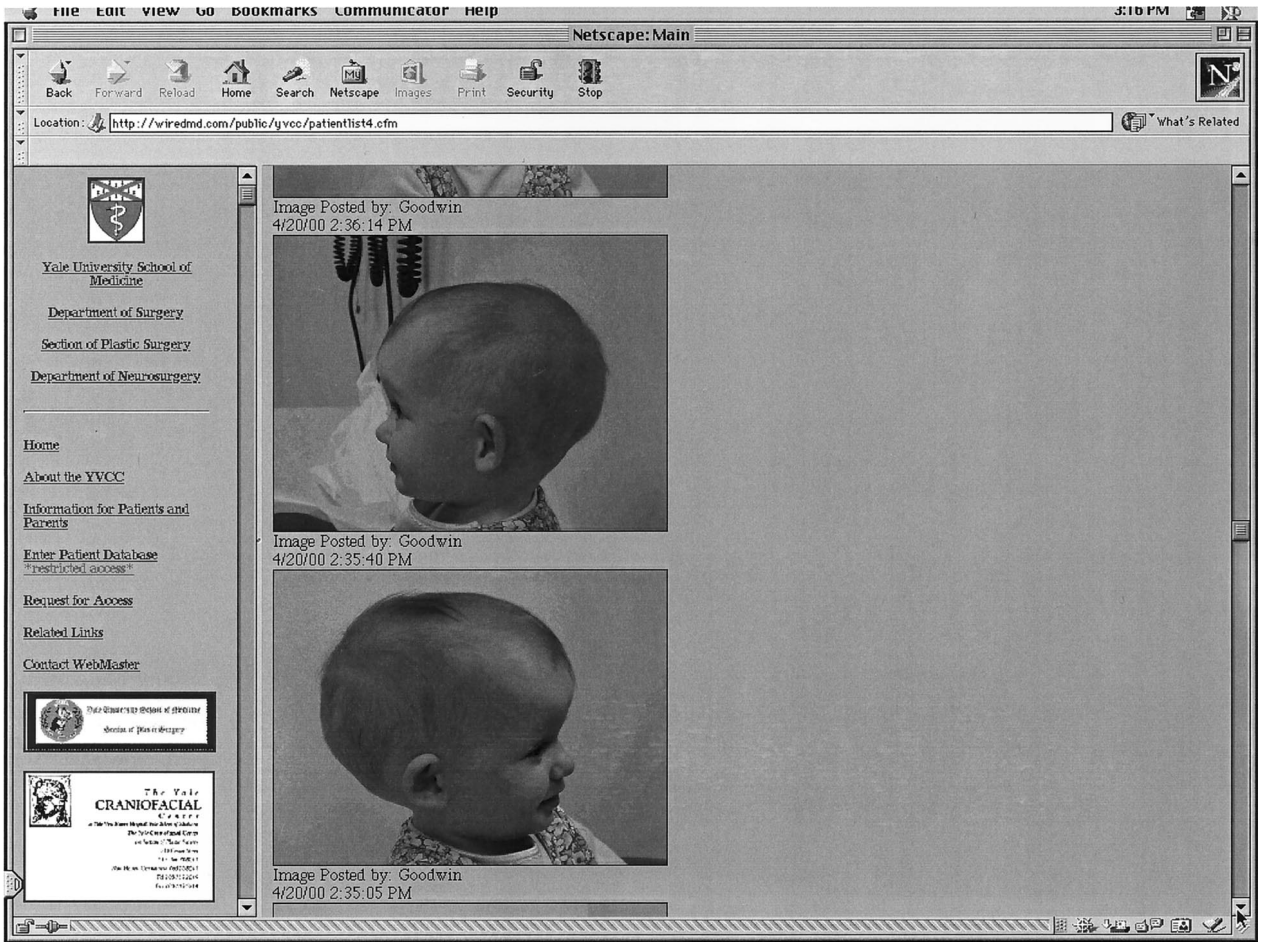

Fig 2. Uploaded images of a patient in the Virtual Craniofacial Center database.

ities. As members of the craniofacial center become more comfortable with this system, its efficiency will ultimately be realized. The Web site is continually evolving to become more user friendly and increasingly powerful as a tool for patient management.

Currently, the patient data on the VCC includes textual data and digital photographs. However, there is potential to expand the interface to incorporate radiographs, audio and video clips, and access to chart notes. This will require greater memory for storage and more powerful equipment, but will undoubtedly be made more feasible as technology progresses.

We are integrating a section to the Web site that provides information for patients and their parents. Patients and their families can refer to our Web site for answers to common questions about their various conditions. In addition, the section includes links to other craniofacial centers and information sources.

Before using this technology to make treatment decisions, we wish to be confident that its application makes a positive impact on patient care. We are beginning a controlled study to assess feasibility and cost-effectiveness. This will be performed by comparing prospectively bedside examination of these disorders by on-site craniofacial team members with the evaluations of off-site team members viewing digital images of the patients. We hypothesize that agreements between craniofacial team members evaluating the patients in person will be similar to those evaluating the patients by use of the VCC. Current results are too preliminary to report.

Conclusion

In this age of the Internet, communication between individuals is easier than ever. One can send many forms of data over large distances nearly instantaneously. In addition, digital photography has revolutionized image retrieval and archiving by circumventing the need for film processing. By combining these two recent advances in technology, physicians are now able to share visual and textual data quickly, easily, and inexpensively. It is imperative that management of craniofacial patients evolves as technology improves to ensure that these patients receive collaborative, multidisciplinary treatment. To our knowledge, this is the first Internet/intranet database developed for managing visual and textual data of craniofacial patients designed to facilitate communication among specialists. This system allows team members to participate from either a distance geographically or in time, allowing appropriate data or photographs to be entered or reviewed, and consultative opinions to be rendered or shared from remote locations. Although face-to-face examination of patients remains an important component of patient care, craniofacial teams may realize the utility of telemedicine in facilitating patient management.

Presented at the 17th annual meeting of the Northeastern Society of Plastic Surgeons; Hotel Omni Mont–Royal, Montreal, Quebec; Sep 14–16, 2000.

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Open Discussion

Henry M. Spinelli, MD (New York, NY): That was a nice paper. What is the biggest negative aspect of virtual telemedicine as applied to craniofacial surgery? As a corollary, are you an advocate of eliminating the physical examination as a traditional thing? I can see this extrapolating out.

Mr Goodwin: I am definitely not an advocate of eliminating patient contact. This is designed to be an adjunct to care at those times when the patient isn't there or when there are other physicians who may not be at a team meeting. I think the biggest fear, of course, is patient security, and we make every effort to make certain that the data are secure. The biggest drawback is that it cannot replace doctor–patient contact. The data are only as good as the pictures taken by the doctor or the photographer.

James W. May, Jr, MD (Boston, MA): I am not a craniofacial surgeon by any stretch, but one thing I am curious about is your scientific method. My understanding was that you had one surgeon examine the patient and a different surgeon analyze the patient based on your virtual center. Doesn't that make the assumption that if the two surgeons had both examined the patient directly, they would have come to the same conclusion about a treatment plan? If I am confused, please enlighten me.

Mr Goodwin: More than two surgeons are involved. We would have at least two on-site surgeons seeing the patient, and the agreements would be compared. In addition, an off-site surgeon using the visual images would be compared. So if the two on-site surgeons agreed and there was disagreement with the off-site surgeon, that would be understandable. If there were disagreements between the on-site surgeons, then it would be understandable that there would be disagreement between the on-site and off-site surgeons.

Dr May: But aren't you saying that all of the surgeons ought to agree?

Mr Goodwin: Well, it would be ideal if we had large numbers to validate this. At this point we don't.