A new system for digital image acquisition, storage and presentation in an accident and emergency department

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Abstract

***Objectives*—To develop a computer based storage system for clinical images—radiographs, photographs, ECGs, text—for use in teaching, training, reference and research within an accident and emergency (A&E) department. Exploration of methods to access and utilise the data stored in the archive.**

***Methods*—Implementation of a digital image archive using flatbed scanner and digital camera as capture devices. A sophisticated coding system based on ICD 10. Storage via an "intelligent" custom interface.**

***Results*—A practical solution to the problems of clinical image storage for teaching purposes.**

***Conclusions*—We have successfully developed a digital image capture and storage system, which provides an excellent teaching facility for a busy A&E department. We have revolutionised the practice of the "hand-over meeting".**

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The accident and emergency (A&E) department is uniquely placed in the hospital setting, treating a large and varied range of clinical conditions. Many patients present daily, often in the acute stages of illness or injury, often as yet untreated, and exhibiting florid signs and symptoms. This richness of case mix requires the A&E practitioner to be an excellent diagnostician. It also presents an unrivalled opportunity to assemble a library of resources with which to teach doctors, nurses and students the skills they require.

Most departments already have a substantial collection of slides, radiographs and other material but the acquisition and storage of clinical data for teaching purposes is often problematic. The first step in developing a system to enable material to be archived more effectively was to identify difficulties with current arrangements, and seek potential solutions.

Radiographs are difficult to copy during working hours, and almost impossible to copy out of hours. Duplication usually entails taking the original film to the radiology department's copier and incurs significant costs (currently between £6 and £10 per film). Interesting radiographs leave the A&E department when patients are admitted to other specialist units, or other hospitals. Ideally radiographs would be copied immediately, before leaving the department with the patient, and copying facilities would be available over 24 hours.

Photographs are extremely useful when correlated with other information and images, especially radiographs, but are infrequently taken. Disincentives include: difficult access to appropriate camera equipment, high threshold for taking pictures because of processing costs, long delay between taking picture and seeing final product (slide or print) and therefore difficulties collating photos with other data. The best solution would facilitate excellent camera availability, and the ability to store photographic images on file together with other clinical data—radiographs and history for example—almost immediately. A well indexed collection should allow a large quantity of data to be accessed according to a variety of useful criteria: for example, incident (for example, falls, road traffic accidents), types of investigation (for example, radiographs, ECGs), types of pathology, etc.

Departmental slide and radiographic collections that already exist are often rapidly depleted by accidental damage, "borrowing", and general dispersion into particular presentations. These problems could be overcome by using a storage medium that is non-degradable and easily duplicated to allow storage of multiple back up copies of data.

After a period of research into these issues a computer based system was developed and installed in the Accident and Emergency Department of Edinburgh Royal Infirmary. The following is a description of the general solution we have found to these problems, along with the equipment used to implement it. The system allows simple and rapid capture of radiographic, photographic and paper based material (for example, ECGs, blood results, illustrations and diagrams), in the A&E department and pre-hospital settings. This information is quickly and easily archived and retrieved by the senior and middle grade medical staff in the department using an interface that requires minimal computer literacy. Currently over 3000 images have been stored. These are accessed by nursing, medical and radiography staff to generate same day hand-over presentations, case reports, teaching packages and induction materials. This system is solely for teaching purposes and does not form a part of clinical record keeping.

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Image capture

Image capture is accomplished by two mechanisms. A flatbed scanner is the "workhorse" of the system. Recent improvements in technology mean that a flatbed scanner with a transparency hood for this type of system costs around the same as a good PC. Radiographic image scanning is a complex problem. Much has been written about the difficulties involved in generating digital images containing all of the information required for radiological scrutiny—while maintaining a manageable file size. In developing a system for the capture of teaching material—not for use as patient records or in primary diagnosis—we opted for a slightly less demanding standard. 12-bit scanning at a resolution of 240 dpi (800 dpi maximum) produces excellent digitised radiographic images, of suitable quality for most teaching purposes. The information in each image is sufficient to allow some post-scanning processing if required (for example, to compensate for over/under exposure in the original film), or to "zoom-in" on areas of interest. The final use of most of the radiograpahic images is in the production of presentations for on-screen view, or slide production. A few images are printed as hardcopy, and some may be submitted for publication in digital form.

With these factors in mind, we opted for JPEG (Joint Photographic Experts Group) as our final file format for storage. JPEG is an image storage format commonly used by publishers, on the internet and when working across computer platforms (for example, Windows, Macintosh, UNIX). It is designed for the storage of pictures (as against line drawings or text), which it compresses in a "lossy" fashion. This means that the JPEG format discards some information from the image during storage, but in a way that minimises the impact of this degradation on the human eye. The amount of image deterioration can be traded against compression ratio. Using maximum quality JPEG compression we can store information rich images with an average size of around 500k on disk—representing a 50% file size reduction.

The physical size of the radiographs to be scanned is an issue. We opted for an EPSON GT-12000 colour image scanner in part because of its large scanning area—310 mm × 437 mm. This accommodates all but the largest plain radiographic sheets (350 mm × 430 mm) where a small strip of image from a long edge of the film is ignored. In practice this has not caused a significant problem.

CT and MRI images are printed on even larger sheets, but here smaller areas of interest (for example, a single cut) can easily be defined and captured. Paper based images, ECGs, diagrams, etc, are scanned conventionally and compressed in a similar fashion. The scanner interface is a standard utility, controlled using a custom program that forms a part of our system. A selection of commonly scanned media types and sizes are pre-configured, permitting "one touch" scanning. Expert users are also able to obtain greater control if required, by using the EPSON utility that interfaces with Adobe Photoshop (a standard graphics manipulation program).

The second method of image input is from digital camera. Digital photography has only recently become an affordable tool in this context. We were keen to ensure adequate image resolution and colour rendition providing pictures of useful quality. Our two cameras—both Epson PhotoPC 700—have a resolution of 1024 × 768 (XGA). The cameras are compact and robust, with built in lens protection that makes them suitable for use in the hazardous environment of a busy A&E department. Removable card memory (Compact Flash) technology is fast and simple to download. We decided on a deliberate memory size limitation to encourage regular downloading of images from the camera after 33 high resolution colour photos. We purchased two identical cameras, ensuring excellent availability of equipment, and a back up system. Standard AA sized rechargeable batteries are used, and are the only consumables in the camera set up. The negligible running cost of digital photography means that operators can use a much lower threshold for taking pictures than with a conventional camera. Photos can be reviewed on the spot, and re-taken if necessary to get the best results. Images can be immediately downloaded and stored along with scanned radiographs and other information about an individual case. Autofocus and auto exposure mean "point and press" ease of use.

Storage

Images from the scanner or camera are stored in a single archive on a personal computer (an Apple Macintosh G3 PowerPC). A vitally important aspect of the storage system is that images are categorised consistently. Coding must be standard, comprehensive and robust. We have developed a system using the World Health Organisation International Statistical Classification of Diseases 10th Revision (ICD 10).[1] ICD 10 provides a means of coding not only disease process/injury, but also the precipitating events/aetiology. Images are also coded according to time and date captured, user involved, and a selection of other tags that enable powerful cross referencing and search options. Individuals are able to add their own personal project labels to particular images. We have implemented a variety of devices to facilitate image coding. If time is short, a user can capture (download/scan) images and leave them tagged with only a minimum label—then come back later to complete coding. Keyword searching the ICD 10 database, and "smart" prompting assist the user in ascribing codes to a particular image. Image retrieval is similarly flexible, with images accessible according to ICD 10 coding, media (for example, radiograph or photograph) type of pathology, user identification, etc. Images that make up a particular case (at scene photos, radiographs, ECGs, blood gas results and CT scans from a major trauma for example) are linked and can be retrieved as a set.

We have used a custom built application to facilitate ICD 10 tagging, picture cropping, rotation and anonymisation. To maintain maximum flexibility in storage tagged, images are stored as standard JPEG files. The image store can then be searched using any one of a host of standard "off the peg" image sorting applications (we use iView Multimedia[2]). The images can therefore be stored and backed up on CD-ROM as JPEG files (about 1200 images per CD)—readable using any standard graphics package and platform independent. The database itself remains quite small in size despite containing the information to allow rapid retrieval of a huge number of images. Once the required images have been identified, the user can download them onto floppy disk or Zip cartridge, for further use (to be made into slides for example).

Presentation of images

We have found many uses for the 3000 or so images that are currently stored in our system. Images can be easily manipulated using standard presentation software, for example, Microsoft PowerPoint. "Slide shows" produced using this type of application can then be displayed on screen for small audience use or projected from the computer using an LCD projector for larger groups. It takes registrars in the department about 30 minutes to assemble the images collected during a shift into a presentation of 6–12 slides to show during the handover meeting. More conventionally, the PowerPoint file is easily converted to traditional slides. Iomega ZIP cartridges provide a convenient vehicle for file transfer. For "one-off" printing, an inkjet printer produces "photo quality" glossy prints. Acetate slides for overhead projection can also be produced using the system, but this works best with line diagrams, drawings or ECGs. It is a simple matter to e-mail small numbers of image files to colleagues further afield when an exchange of information is required. Submitting images electronically for publication is simple and has also been accomplished using our system.[3]

Security and patient confidentiality

It is important that all images relating to patient data stored on the system are anonymised to preserve confidentiality. This has become a more widespread concern after the publication of the Caldicott Guidelines.[4] Anonymising (or de-identifying) images involves:

- Removal of all names, dates and patient identification numbers.
- Images where patients are recognisable (for example, digital photographs showing the face, or vehicle registration numbers) should be modified to preserve anonymity by pixelation or blanking out parts of the picture (for example, eyes).

This process is performed initially by the person capturing the image, then re-checked before images move from an initial 'buffer' area to the main departmental collection. The system itself is kept in a secure room. Access to equipment is carefully restricted to senior medical staff, who agree to an explicit written policy governing the use of the system and images contained on it.

Discussion

A&E departments are not typical of most clinical units. There are no ward rounds, little in the way of intra-departmental case conferencing and limited follow up of patients. Cases seen by an individual can be used for opportunistic teaching "at the bedside" but are then usually lost in terms of further educational value in the A&E department.

Hand-over meetings are a valuable part of the day, providing an excellent chance for education and discussion of interesting, instructional or difficult cases. Unfortunately these meetings can be extremely arid, as case presentations are commonly limited to verbal deliveries with supporting clinical images being the exception.

The image management system we have developed offers a significant step forward in teaching and case review. In the 18 months that we have been using the system linked to a computer data projector in the area of the department used for hand-over meetings, we have presented material collected on the image database during the previous shift. Some of these presentations have taken the form of full case or topic reviews, but even the addition of a single photograph, ECG or radiograph can greatly stimulate interest and facilitate communication. Weekly trauma review meetings are conducted using data collected by our trauma audit research nurse, which often includes follow up information and postoperative radiographs along with accident scene pictures and imaging from the initial resuscitation.

Wider applications for the system are legion, and we are beginning to develop these. Our SHO induction and student teaching materials have been re-written using abundant up to date images. Teaching packages for nursing education have been tailor made to suit our department protocols (for example, for wound closure), or to demonstrate particular local features (for example, safety and security measures in the department). We regularly lecture at a local Police Training College, and now only require to take a CD ROM, which contains the material necessary to give a two hour multimedia presentation using their on site projection facilities

This is only the beginning. Careful choice of equipment and database structure means that it would be a relatively trivial task to make our database available over a network. This could be via a local hospital intranet or through a secure password protected site on the internet. Images could then be retrieved at a distance for incorporation into a presentation or in the form of ready-made teaching materials.

The ethos in developing the system was to use a series of connected "off the peg" parts. These relatively low cost, standard pieces of equipment are then configured in a sophisticated way. This means that components—for example, the cameras, scanner or even the personal computer used—can be upgraded, interchanged or expanded in the future. We view development of our library as an investment in a valuable archive of teaching material, rather than in expensive computer equipment. This investment has already significantly enhanced the teaching activity in our department, in particular in making our daily hand-over meetings much more useful and enjoyable.

Contributors
Gareth Clegg and Stuart Roebuck formulated the idea for this project. They devised and implemented the system supervised and supported by David Steedman. All three authors were involved in writing the paper.
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