From the Editor's Desk: Best of the Hotline

EACH ISSUE we will be reprinting a “Best of the Hotline” column from the Online Expert Hotline Archive (See Paul Nagy’s editorial in this issue). I chose the first two questions to reprint, and will ask others to pick their favorites in future issues. The first question is one that has been investigated repeatedly over the years and will probably continue to be investigated as monitors and diagnostic workstations improve and evolve. Which monitors/workstations should we use for a diagnostic workstation? This is a great question with an outstanding answer. The second question I selected because this is a problem for all of us who acquire studies containing multiple examinations and accession numbers. One update on the first answer given is that DeJarnette Research Systems has now released their product, an automated system for separating these studies.

QUESTION

I am looking for information regarding the standards/requirements for primary read stations used for ANY type of study (ie, the station might be used to read any type of study that is resident on the PACS). The American College of Radiology (ACR) information seems extremely sketchy. Are you aware of such a standard? Or is there a “standard of care” that is commonly used?

ANSWER

There are no standards for primary reading (diagnostic) workstations for PACS, just as

there were no standards for the number of light boxes at a reading station or the number of lighted panels on an automated film changer. Our old reading rooms, for example, contained typical eight-panel (four-over-four) film alternators. However, some of the reading rooms had six-over-six film alternators; it varied by subspecialty (we are an academic medical center with the department segmented mostly by imaging technique or anatomy).

In addition, there are no specific requirements for diagnostic workstations other than those set by institutions and practices themselves. The ACR Standard for Teleradiology makes some recommendations for workstations for teleradiology applications, and some have used these as a baseline requirement for diagnostic workstations. Some general principles are available for guidance, however:

1. Workstations should maintain the full pixel matrix and bit depth of the image that was output from the acquisition device (after whatever processing that device performs). Note that this does NOT mean that the monitors have to be able to display this full pixel matrix at one time but that the whole dataset should be available through zoom-and-pan operations for spatial resolution and window width/level operations for gray-scale resolution.
2. Determine the number of monitors needed. Drs. Eliot Siegel and Bruce Reiner at the University of Maryland/Baltimore Veterans Affairs Medical Center have reported that for general reading, moving from one display to two significantly decreased radiologist

reading time per exam but that increasing from two displays to four had only a very small effect. Our chest and body CT reading areas use four-monitor workstations. For chest, because a large fraction of the studies involve two images per study, four monitors allow the current and previous studies to be displayed simultaneously. In our body CT area, a majority of patients have prior studies, and a four-monitor workstation allows simultaneous stack views of the current and prior studies with two series each (e.g., noncontrast and contrast). Our ultrasound section, in contrast, uses single-monitor workstations. For study comparison, the screen can be split to show the prior study in one portion and the current exam on the other. Workstation performance is also a factor in determining how many displays are needed. If changing between images in a multiple-image radiographic study (eg, spine survey) is very fast, this may obviate the need for multiple monitors. Because the visual system simply cannot view even two monitors at full resolution, having more than one monitor is a way to reduce the time needed to view two images. Rather than wait for the second image to display, the radiologist simply turns his or her head. There is a counterargument to this: As perception studies have shown, experienced radiologists can fix their gaze on an abnormality in an image within a fraction of a second to a couple of seconds. They do not necessarily make a diagnosis in this short time, but their visual system has been trained to find abnormalities. Exactly how this works is not fully understood, but it is known that these abnormalities are not spotted as the result of an exhaustive search. Something in the image cues the radiologist to the abnormality; it has been proposed that peripheral vision probably plays a role. In this case, spreading out many images in the visual field may not be just a convenience for the radiologist.

3. Image display operations should be performed quickly. Subsets of this principle include:

- A. Display of an image requested from the PACS storage system: For images in the

short-term storage device or on any storage in the workstation, the time from requesting the image (clicking on an icon, etc.) should be no greater than about 2 seconds. There is great debate over how this number was derived but it is widely accepted as the level that is tolerable.

- B. Grayscale adjustment and zoom-and-pan operations should be in real time (that is, no time lag between what you do to control the operation—for example, move a mouse—and what happens on the display). Time lags here make a workstation nearly unusable.
 - C. Image measurement (distance, angle, and pixel value statistics) should also be very quickly done. Moving the cursor for measurement, for example, should be in real time.
 - D. Display of ancillary information (reports of prior studies, patient information that is in the image header, etc.) should be displayed at least as rapidly as the images.
 - E. Any operation, such as retrieving a prior exam from the long-term storage system (should the PACS be structured this way), that may take longer than a few seconds should let the user know that something is happening. For example, the cursor icon might change or a progress bar might be shown. Otherwise, users may not know whether the workstation is actually carrying out the request or has crashed.
4. User ergonomics: This is probably the most debated feature of workstations. Subsets of this area include:
 - A. The “Beard, Chang, Horii” test (so named because it has been advocated by these individuals): When evaluating a workstation, the user should try using any candidate workstation **WITHOUT** getting any instructions. If the user can manage to get to basic tasks such as display worklists or patient lists, display and manipulate images, or bring up the next study, then the user-interface design probably follows a logical and simple mental model.

- B. The "mysterious icon" test: Look at the icons displayed and see whether you can figure out what they do **WITHOUT** using the popup "hints" employed on many workstations. What icons do should be fairly obvious. Watch out for icon or menu selection layouts that put conflicting or "dangerous" (eg, "delete image") operations too close together or on icons with similar appearances. It is too easy to hit the wrong icon or menu item in such a design.
 - C. The "too many icons" evaluation. "How many knobs does a piece of film have?" is a question posed by Dr. Reuben Mezrich some years ago. It is a very telling question to ask about workstations. Elizabeth Krupinski at the University of Arizona has done important work showing that on-screen displays of workstation tool icons (of necessity) will result in gaze fixations on those tools. Whether this is in addition to (resulting in longer reading times) or in place of (potentially resulting in reduced detection rates) gaze fixations on the image itself is still being researched. Remember that in many film-based operations, particularly with multi-viewers (alternators, auto film changers), you can very likely change to the next study, turn the displays on and off, etc, without having to see the controls to do these operations. This is not true of most current workstation designs. We have started referring to conventional mouse-and-menu-driven designs as "high visual effort" configurations. Some workstation vendors have paid attention to this problem and offer "low visual effort" designs.
 - D. Do not forget ancillary ergonomics. If you buy an expensive workstation and then set it up on a cheap, nonadjustable table, you may make the workstation useless in a practical sense. If you force radiologists to sit on uncomfortable chairs, you will increase levels of dissatisfaction with your workstations. Adjustable furniture, comfortable chairs, and an appropriate reading room design are all necessary features of any plan to replace film-based operation with PACS.
 - E. Display protocols? These should be user-customizable and should ideally "follow the user" to any workstation at which he or she will read studies.
5. Automation and integration: A diagnostic workstation ideally should be a "single point of contact" for the radiologist (or other user, for that matter). Any information necessary to carry out work should be available at the workstation. That means interfacing to clinical, laboratory, and other information systems, in addition to the more typical RIS interface. Newer PACS designs are being offered as "integrated systems" and are usually combined PACS and RIS. However, this may not include the rest of the hospital information systems, so getting laboratory and pathology reports, for example, may still require logging on to a different system. Some prototype and institutionally developed systems also employ automation features. For example, they may automatically retrieve all patient data from other information systems and then display rules-based selections when examinations are displayed.
 6. Quality assurance: Workstation displays should conform to the DICOM Grayscale Display Function Standard (that is, they should support calibration to this standard). An added bonus would be support of the "Consistent Display of Images" and "Key Image Notes" profiles of the Integrating the Healthcare Enterprise (IHE) initiative. The DICOM Presentation State Storage SOP class support (that would allow saving an exam in exactly the state in which the radiologist viewed it) is also very useful but is not widely implemented at this time. Among the useful references on this topic are chapters in two books on PACS:
- Siegel EL, Kolodner RM: *Filmless Radiology*. New York, NY, Springer-Verlag, 1999.
- Dreyer KJ, Mehta A, Thrall J: *PACS: A Guide to the Digital Revolution*. New York, NY, Springer-Verlag, 2002.

QUESTION

I would like recommendations on how to archive a study that encompasses more than

one accession number and study type. For example, a CT of the chest and abdomen. The study cannot be broken into two parts by the technologist at scan time. If you store it under the CT chest accession number, then it will not show up on a typical relevant priors list for an abdominal study.

ANSWER 1

You have hit on a major problem confronting current imaging practice (typically from CT and MRI, but sometimes also with multiple-image trauma radiographic studies) and PACS. The best way for this to happen is to have the imaging equipment allow the technologists to separate the exams at the time the study is done. This should be **WITHOUT** having to stop and start the imaging process (stopping and starting clearly reduces or eliminates the effectiveness of multislice CT). There are some vendors that have fixed this problem in their new CT machines, at least.

However, if your CT or MRI vendor is not one of those (ask first if there's a software upgrade that would fix this problem), then you need some device that can intercept the exam between imaging equipment and PACS and allow it to be separated. One commercial example is the Mitra Relay (we are planning to use this for exactly this purpose as we expand our PACS). However, it requires the technologist or other person to interact with the examination. This does impact productivity, but compared with the alternative of **NOT** being able to retrieve comparison or previous examinations later, it is likely worth the effort.

A very interesting alternative was shown at the recent RSNA by DeJarnette Research Systems (DRS). They definitely billed it as "work in progress," but it would be an automated version of the Mitra Relay. It uses image histogram, patient position, and slice position information to figure out automatically where in the body the image is. It then separates the examinations using that information and associ-

ates the examination with the proper order number. This is **NOT** yet a product.

ANSWER 2

Here are three options (+ means advantage, – means disadvantage):

1. Store it out twice, once under each accession number. + Relatively easy to do. – Uses twice the storage. – Second study won't validate against the RIS.
2. Split the study with a Mitra Relay. + RT pushes the study to the Relay (a PC) and groups images into logical units for transmission to the PACS under different accession numbers. + Clean studies, images can even overlap. – Have to buy a Relay. – Have to integrate a Relay. – Have to teach someone to use a Relay.
3. Add a field to the PACS so it can "see" the study twice, once under each accession number. + Minimal effort on a busy RT as associated accession numbers can typically be queried by the PACS to the RIS. – Must get your PACS vendor to make the change (\$\$). +/– Studies do come up as priors but with the images for all examinations.

There are other solutions coming down the road but these are the three that most vendors/customers (that I know) have implemented and working today.

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