Integrating of Computers into Imaging: Computed Radiography (CR)

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Objectives: Upon completion of this CME article, the reader will be able to

1. Define basic computer terminology and components
2. List operational/application components in an integrated computer-imaging department.
3. Describe the components of a computer radiology unit.
4. Explain how images are acquired.

Introduction

Diagnostic imaging relies on computer applications in today's departments. Radiology was once dependent solely upon the production of images utilizing ionizing radiation and chemical processing. Clinical use of digital images is increasing in healthcare. Currently, diagnostic imaging uses the greatest amount of digital information data second only to the information technology field.

Computed Radiography (CR) was developed in the 1980s using photo-stimulated phosphor plates. CR systems used in the United States are manufactured by numerous companies and may be applied in all aspects of general radiologic imaging. CR is an imaging technology that converts a conventional ionizing radiation image into digital form. It allows for images to be manipulated to suit image quality preferences; the ability to generate multiple images without additional exposures to the patient; lower radiation doses received by the patient while maintaining image quality; and the ability to digitally acquire (receive) and archive (store) images – Picture Archiving and Communication Systems (PACS).

Digital Imaging

Because imaging departments are moving from film-based images to digital-based programs, it is important to understand the fundamentals of Biomedical Imaging Systems. To fully appreciate, integrate, and operate digital applications in a department, it is imperative to have a basic understanding of the concepts of digital imaging, an overview of the various systems, and an understanding of the associated terminology. The overall application of computer technologies in imaging departments may involve the integrating of and/or the combination of Computed Radiography (CR), Digital Radiography / Fluoroscopy (DR), Hospital Information Systems (HIS), Radiology Information Systems (RIS), Teleradiology, and Picture Archiving and Communication Systems (PACS).

Computer Application in Imaging

Before listing and defining the various computer applications that may be utilized, conventional radiography should be reviewed to understand the advantages of moving into a digital imaging environment. Image production with conventional radiography requires the use of photographic film, intensifying screens that emit light upon exposure to ionizing radiation, and chemical processing. The image is developed and manifested on the film. It is then stored in a large envelope (jacket) upon review (read) by the physician and filed either numerically or alphabetical. Because the image production involves chemical processing, long-term storage may result in a deterioration of image quality. Another concern with conventional radiography (as it relates to film storage) is the loss of the film jacket due to misfiling, incorrect patient information, duplicate filing, and/or patients with the same or similar name.

Migrating into a digitalized department can start with the application of a radiology information system (RIS). In a hospital environment, a radiology information system should be interfaced with the hospital information system (HIS). Thus upon admission, a patient's information and demographics can be retrieved by both programs. The RIS function can include scheduling, completion of the examination, billing, and reporting of the examination findings. The RIS can then be interfaced with a PACS (picture archival and communication system). The PACS network is a series of computer servers. The computers are able to communicate through the use of a digital imaging and communication of medicine (DICOM) format. Along with computed radiology, other digital radiography systems may be part of the network such as the various imaging modalities of computed tomography (CT), magnetic resonance imaging (MRI), nuclear medicine (NM), ultrasound (US), and digital fluoroscopy. A PACS also has web-based functionalities such as the ability to retrieve and clinically review the images in other locations or hospital departments, as well as, the ability to be communicated through teleradiology.

Hardware

The physical/system unit of the computer is referred to as the hardware, and it is the primary managing device. It supplies the instruction for the computer's operations. It is also the processing system that is commonly referred to as the central processing unit or CPU. The CPU serves to convert input data into output data, and it also serves as a storage device with primary memory that is used to store the operational programs and data. On the other hand, the Random Access Memory (RAM) is the most common computer memory that is used by programs to

perform their necessary tasks while the computer is on and being actively used. RAM is the erasable component of memory that is not permanently stored. The Read-Only Memory (ROM) is a memory chip that contains non-erasable programs.

The **output devices** receive the processed data and may generate either hard copies or soft copies. Output devices include such items as printers, optical disks (OD's), computer disks (CD's), magnetic tape, and monitors (cathode ray tubes – CRT's or liquid crystal displays – LCD's). A soft copy is a temporary display of the processed information usually displayed on a computer monitor, whereas, a hard copy is permanent or recorded data obtained from a printer (print out) or found on a disk or CD, etc.

In a PACS environment, a series of network switches, servers, and gateways (DICOM converters) are part of the overall hardware. Hardware for CR systems employs computerized applications in addition to an imaging plate (IP). The system has four essential components:

1 Imaging Plate
2 Laser Scanner
3 Computer Processor
4 Image Recorder (laser printer and storage system)

The IP was introduced to replace film/screen cassettes. The imaging plate is flexible and coated with a barium fluorohalide phosphor substance. These phosphor crystals are photo-stimulated, which means that their electrons become excited thereby increasing their energy level when they are exposed to ionizing radiation. The energized plate traps the excited electrons and then is stabilized when scanned by a helium-neon laser. During this process, light energy is emitted as the electrons return back to a more stable state. This emitted light (photon) is then converted into electrical energy that then is converted into digital data.

Software

Computers must have operational instructions. The operating system (OS) is the interface between the hardware and various applications. The OS is one aspect of software, and it is designed to control specific equipment, scientific calculations, tasks, and functions. The other aspect of software is all the various software programs that run under the OS. Although other programs are designed to function under the OS, the OS is needed by all applications and hardware because it is what allows the computer to fully load and function.

When referring to an OS, the three primary systems on the market are Windows (created by Microsoft), the Macintosh operating environment, and Linux. Windows dominates the personal

computer world, running, by some estimates, on 75% or more of all personal computers. The remaining 25% are mostly Macintosh or Linux operating systems. Windows (as well as the other operating environments) provides a graphical user interface (GUI), virtual memory management, multitasking, and support for many peripheral devices. Windows eliminates the need for a user to have to type each command on a command line (like the previous MS-DOS format) by using a mouse to navigate through drop-down menus, dialog boxes, buttons, tabs, and icons.

Image Viewing

CR systems also include software for image processing, viewing, and archiving. Retrieving the digital image is performed at a user terminal. The user terminal may also be referred to as the Professional Workstation. The user terminal is a computer that is most often operating from a Windows-based program. The most common software applications are based on familiarity of Windows operation by using menus, shortcuts, toolbars, and drag/drop functions. Understanding the basic concept and operations of Windows allows for better facilitation of computed radiography software.

The following is a list of common terms used in Windows operation:

Active window

The current window that's in front of all the other windows and is currently being used.

Background

When referring to multitasking operating systems, a background process is an active program currently running but, not seen on the computer monitor. The background is also used to describe the Windows computer wallpaper.

Cascade

An option in Windows that will organize all windows that are open so that the user can easily view and access all open windows. Generally, a cascade will go from the top left to the bottom right on the screen.

Cursor

Also known as a caret, a cursor is a visual representation on the screen that allows the user to specify where they want text to be placed. It is usually displayed as a vertical flashing bold line. The mouse pointer may also sometimes be referred to as a cursor. It is a visible object that is used to point, click, drag and drop items on a graphical user interface system.

Explorer

Also known as Windows Explorer, Explorer is used in Microsoft Windows 95 and above to

explore and manage the files on the computer drives. Although similar, Microsoft Explorer is not the same as "My Computer" and is not "Microsoft Internet Explorer," even though Internet Explorer is sometimes improperly referred to as Explorer.

Hibernate

Portable or laptop computers have what is known as a smart battery. Hibernate is a function designed to keep the desktop settings and program settings currently in use from being lost due to power failure. The "hibernate" restores programs and settings back to the point when the computer shutdown.

Icon

An icon is a small picture or design that represents a program or file and is displayed on the main window. When the icon is clicked, it will be run or opened. Usually, a single click runs the program, and a double click on the icon opens it. Icons are used with Graphical User Interface (GUI) Operating Systems such as Microsoft Windows and the Apple Mac OS.

Menu

The menu may also be known as the file menu. The menu is a list of commands and/or choices available for use. Menus are commonly used in GUI operating systems and allow a user to quickly access various options the software program is capable of performing. File menus are commonly accessed using the computer mouse; however, it may also sometimes be accessed using shortcuts and/or the keyboard.

Mouse pointer

The mouse pointer is often displayed in the shape of a large I, arrow, or a small hand with a pointing index finger. The mouse pointer moves as the user moves his or her mouse control and is used as a reference point as to where the mouse control is located on the display screen.

Operating system

An operating system (OS) is a software program that enables the computer hardware to communicate and operate with the computer software. Without a computer operating system, a computer and software programs would be useless.

Pop-up menu

Pop-up menus are not visible until accessed. When accessed, a new window will open with a new menu, and it is commonly displayed above all other screens on the monitor. Clicking the right mouse button often accesses pop-up menus.

Safe mode

Windows safe mode enables the user to enter safely into Windows after an improper

shutdown of the computer. It allows for correction of any problems before logging into normal mode. What makes safe mode different from normal mode is it uses the Windows default drivers and settings.

Shortcut

When referring to a shortcut, it is a link that takes the user to a program. Shortcut icons allow users to create links to their programs. A small arrow in the bottom corner of an icon identifies it as a shortcut in Windows. A file that ends with a file extension of .lnk is a shortcut. A shortcut is also used to describe a keyboard shortcut.

Task Manager

Task Manager is a software utility found in Microsoft Windows NT 4.0, Windows 2000, and Windows XP. This function enables a user to view each of the tasks currently running on the computer, each of the processes, and the overall performance of the computer. The Task Manager is easily accessed by pressing: "Ctrl + Alt + Del" on the keyboard.

Taskbar

The taskbar is a bar that displays programs that are currently running. It is commonly located at the bottom of Microsoft Windows 95, Windows 98, Windows NT, Windows 2000, Windows ME, and Windows XP operating systems. The taskbar also displays the time and utilities

Toolbar

The toolbar is commonly located on the top of a Windows application. It consists of a row of boxes that control various functions of the software. The boxes often contain images that correspond with the function they control (such as the image of a printer for the printing function or **B** for bold and U for underline, etc.)

User interface

The user interface is a component of a software program or hardware device that is used to navigate and control aspects of the software program or hardware device.

Window

A "window" is what is displayed on the computer's monitor screen in a GUI system that shows the program currently being used. Microsoft Windows is so named because it utilizes the aspect of "windows." The use of "windows" allows the user to view multiple programs at once. The majority of "windows" give the option of minimizing and maximizing that allows the user to view or hide a program temporarily. When a "window" is minimized, it often disappears from view on the computer monitor screen but can be returned to view by clicking on its icon that will be displayed in the taskbar at the bottom of the screen.

Image Production

Image quality and reduction of exposure to ionizing radiation are the most important elements in imaging. No matter what genre is used in acquiring an image, production of diagnostic information in the shortest amount of time and least amount of energy is imperative. With computed radiography, the imaging plate (IP) is designed to look like conventional imaging cassettes (film/screen combination). The IP's are also designed in the same standard cassette sizes and can be used in the department in stationary imaging rooms or during mobile imaging. The basic function of the IP is to act or perform like conventional cassettes in that images may be acquired from the tabletop or bucky apparatus using manual or automatic exposure techniques.

Once exposed, the IP is then inserted into a hardware device that is designed to process the obtained data. A laser beam reads the now photo-stimulated phosphor plate by generating luminescence (or light) that is proportional to the stored photon energy. As the laser beam is directed across the IP, the stored information is released in the form of visible light that is then multiplied and amplified into analog signals. The computer CPU is loaded with a software interface that operates a scanner. The obtained signals are then scanned to covert the analog image into a digital format. The analog signals are digitalized by an analog-to-digital converter and then are processed and compiled into a series of gray tones that imitate a conventional radiograph. The digital image reader enables the plate to be read quickly and then erased so that it is ready for the next exposure.

As previously stated, the main goal in image production is to produce images with the highest quality while keeping patient exposure to a minimum. In computed radiography, the result of the image production is based upon the operation of the computer program. Therefore, it may seem that conventional imaging rules for exposure are irrelevant. However, CR systems have incorporated exposure indicators as a means for determining if the appropriate exposure was utilized. This exposure index can help avoid overexposure by setting an acceptable target range for the exposure indicator. The result will be patient radiation dose reduction. The terms "dose creep" and "technique creep" are terms used to describe digital imaging techniques. Dose creep is seen in general diagnostic imaging and is the gradual long-term increase in radiation dose. This is the result of unnecessary chronic exposure to the patient by technologists' dependence the software will compensate for overexposure of technical exposure factors. The term "technique creep" should be used instead because it is used with each of the various digital imaging systems.

The following may be used in establishing a target range:

1 Insufficient technical factors with a low exposure indicator will be demonstrated by a poor-quality image – resolution or sharpness will be reduced, and the image will have a mottled effect
2 Unacceptable levels of exposure will be reflected by high exposure indicators
3 Utilizing high kVp and low mAs techniques will achieve exposure indicators within the acceptable range.

Various manufacturers present the exposure indicators in a variety of methods. One system uses the term exposure index (EI). The center of the scale is set at 2000. Changes in the scale by +/– 300 EI represent a change in exposure by a factor of two. Other systems use the term "sensitivity number" or "S" number. For these systems, the center of the scale is set in the range of 100 to 200. The exposure rates (with the "S" number systems) have an inverse relationship where low "S" numbers represent excessive exposure, and high "S" numbers represent low exposure with the risk of producing poor image quality.

Windowing

Navigating the CR program starts at the main menu. The main menu includes data entry options such as entering patient information and demographics, selecting the type of exam, viewing and retrieving images, and other generic functions. Every acquired image that is viewed on the screen is displayed using a pre-set (default) brightness and contrast level. By changing the default values, the brightness and contrast controls may be adjusted. This is referred to as "windowing." Most CR systems allow for these adjustments; however, it is generally recommended that windowing be avoided. It is preferable to use the default parameters for three reasons:

1. Changes in the windowing may indicate inappropriate exposure
2. Misrepresentation of tissue differentials may occur
3. Information may be permanently lost from the default data

Minor window adjustments can occasionally be utilized; however, for patently unsatisfactory images, a repeat examination is recommended.

Although windowing is not generally advocated because it may misrepresent the original tissue differentials, enhancing the appearance of anatomical or diagnostic features that cannot be visualized within the default parameters can be an advantage. Rescaling programs allow for changes

in the screen level brightness when the image is displayed just like the mAs controls the overall optical density on a conventional image. Window width controls can sometimes affect the image contrast (differences in the shade). Adjusting this control may alter the appearance of the scale of gray shades displayed.

In conclusion, a good understanding of computed radiography application in Imaging Departments is essential in minimizing exposure, maximizing image quality, and improving operations. Computed radiography's primary function is to mimic conventional film/screen cassettes while creating a filmless department system. The primary difference between the imaging plate and film/screen cassette is that the imaging plate is a photo-stimulated phosphor plate that traps photon energy (when exposed) that can only be released by laser light scanning; whereas, conventional screens actually convert the photon energy to light which then exposes the film. Imaging plates can be re-used after the plate has been stabilized, processed, and erased by the hardware reader; whereas, conventional plates are only used once.

Computed radiography offers more flexibility and adaptability in image processing and technique. Computed radiography prefers high kVp and low mAs technical factors. As with conventional imaging, high kVp values allow for sufficient penetration and adequate density. The workstation allows for data entry, viewing of the obtained image, retrieval, and archiving. At the workstation, CR images may be manipulated and adjusted to meet departmental standards.

References or Suggested Reading

1. Carroll Q: Radiography in the Digital Age. Charles C Thomas Publisher, LTD, 2011.
2. Ballinger P, Frank E: Merrill's Atlas of Radiographic Positions & Radiologic Procedures, 14th edition. Mosby, 2019.
3. Bontrager K, Lampignano, J: Textbook of Radiographic Positioning & Related Anatomy, 9th edition. Elsevier Mosby, 2018.
4. Sklar B: Digital Communications: Fundamentals and Applications, 2nd edition. Prentice Hall PTR. 2001.
5. Ekstrom, M. P. (2012). Digital Image Processing Techniques. Academic Press.
6. Carter, C., & Veale, B. (2013). Digital Radiography and PACS - E-Book. Elsevier Health Sciences.
7. http://www.carestreamhealth.com/
8. http://www.computerhope.com/
9. http://www.orthocrat.com/

10. http://www.fujifilm.co.uk/
11. http://www.imagingdynamics.com/
12. Verma, B. S., & Indrajit, I. K. (2008). Advent of digital radiography : Part 1. Indian Journal of Radiology and Imaging, 18(2), 113. https://doi.org/10.4103/0971-3026.40289
13. Roberts, T: The Effect of Computers in Imaging and Radiation Safety, www.xraycredits.com

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