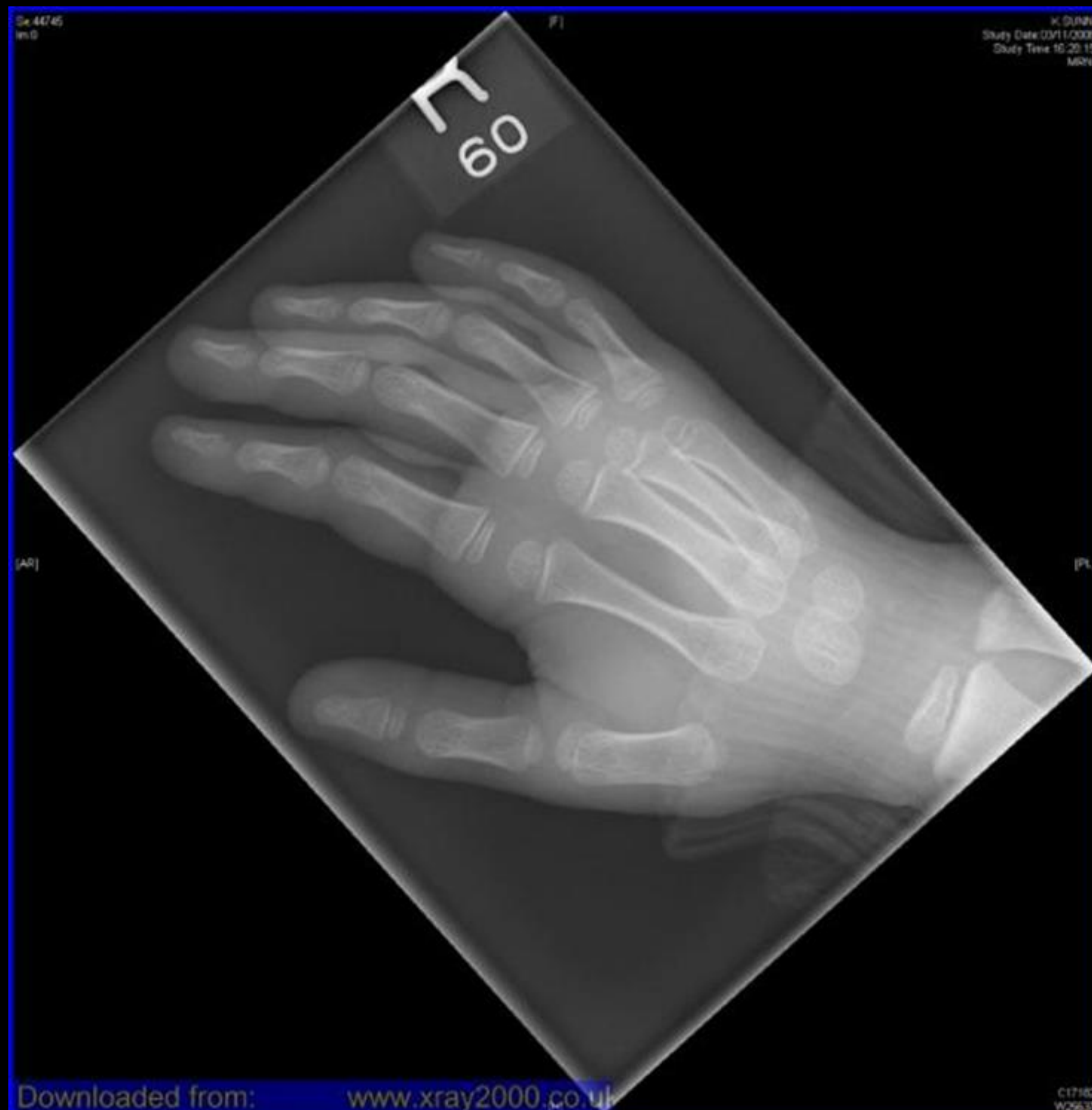
Artifacts 2

Suspenders

Trauma board

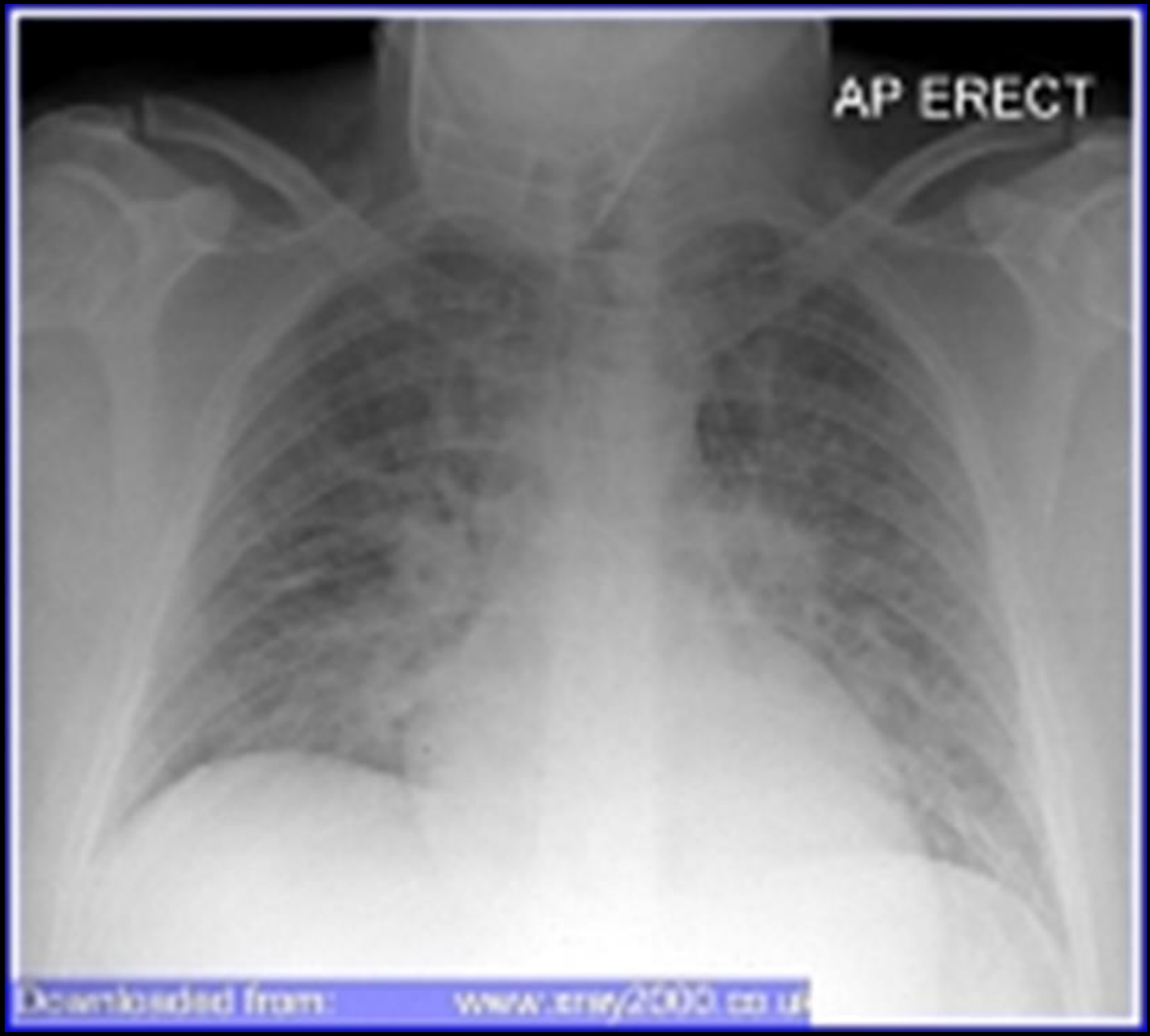
Clothing



Button

Hair

Mask



Tubing

Glasses

Dirt on IR

Faulty CR Reader

Marker

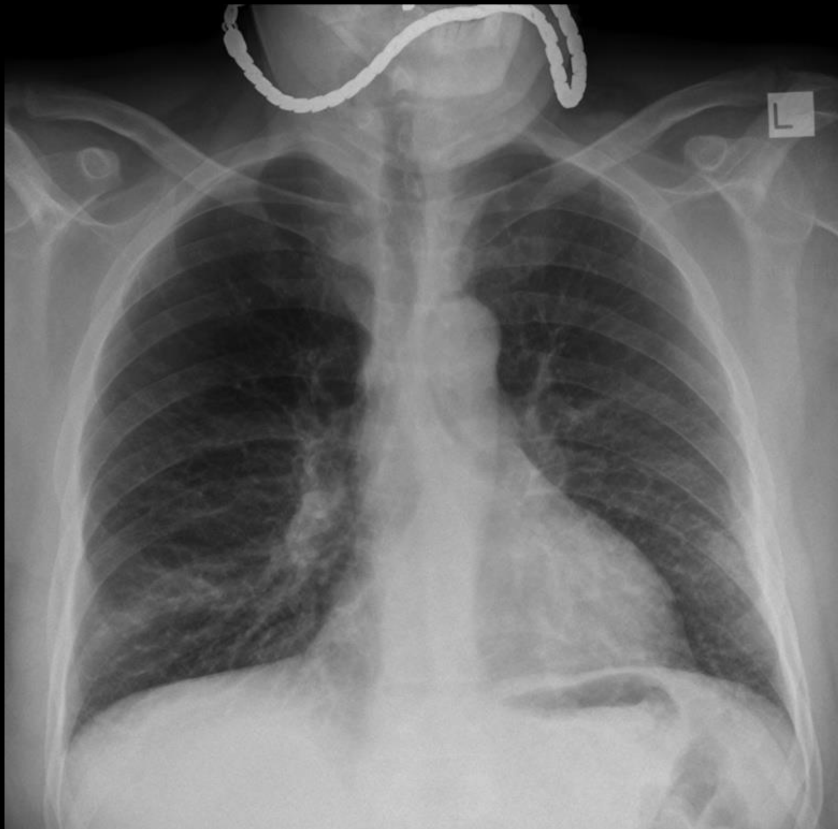
Motion

Motion

Motion

Motion


L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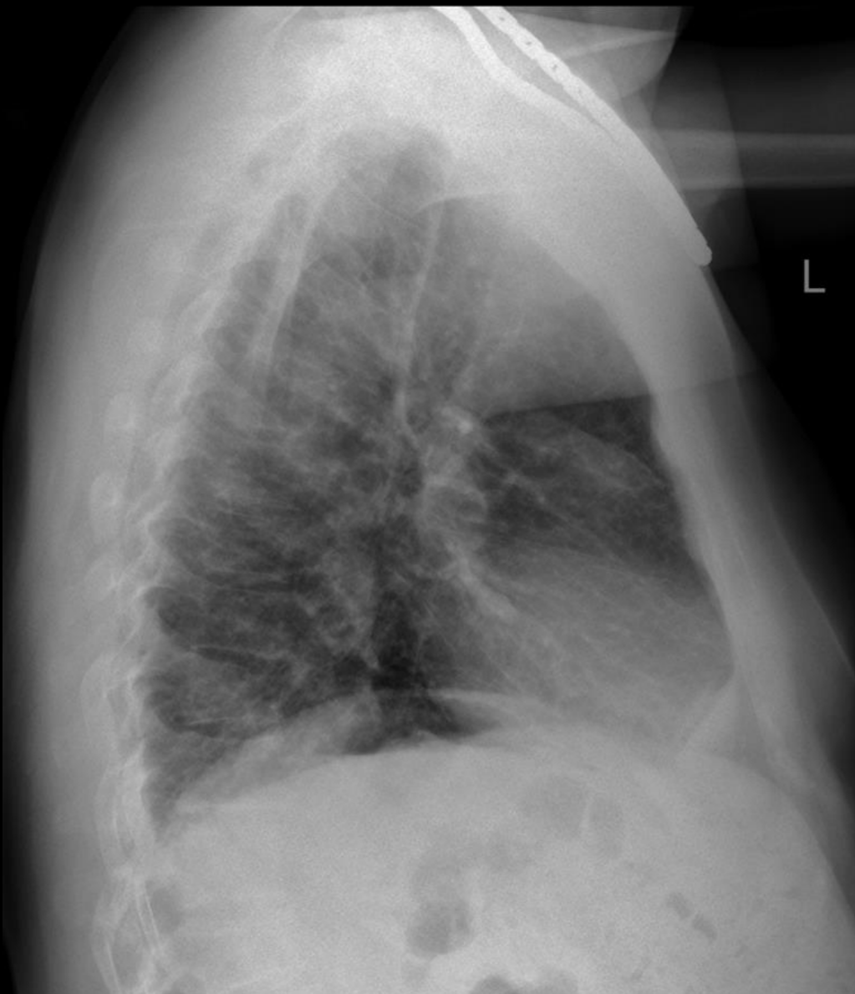
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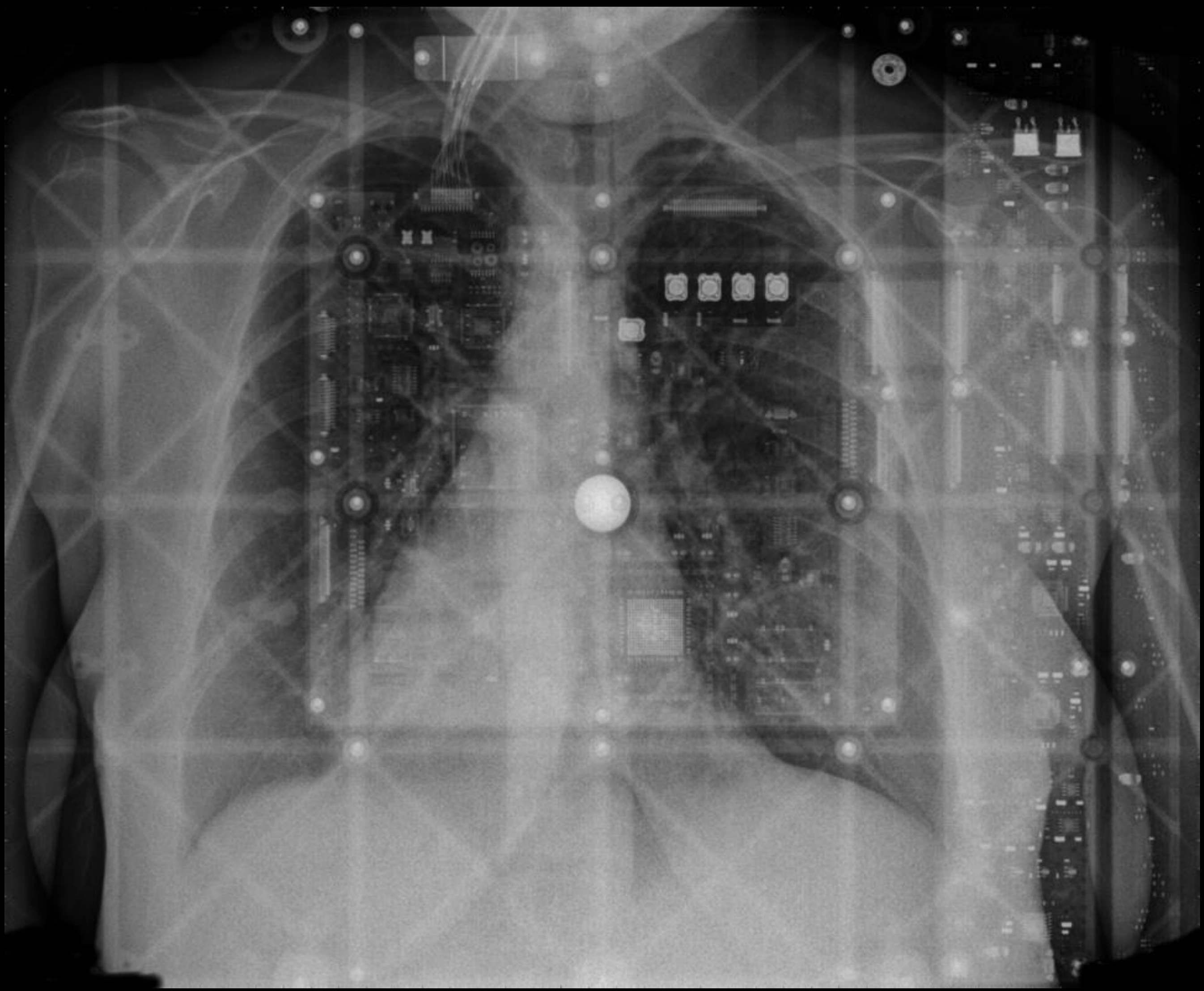
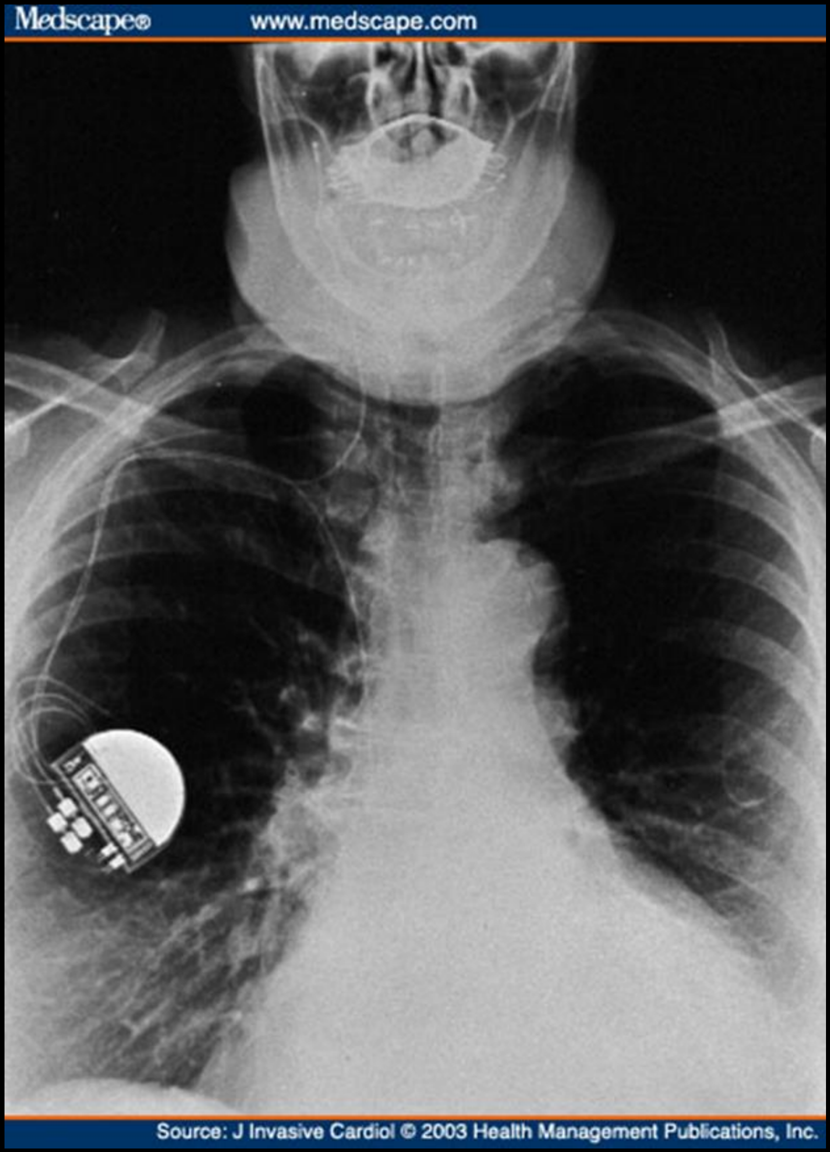
Upside down IR



Chin


Medscape®
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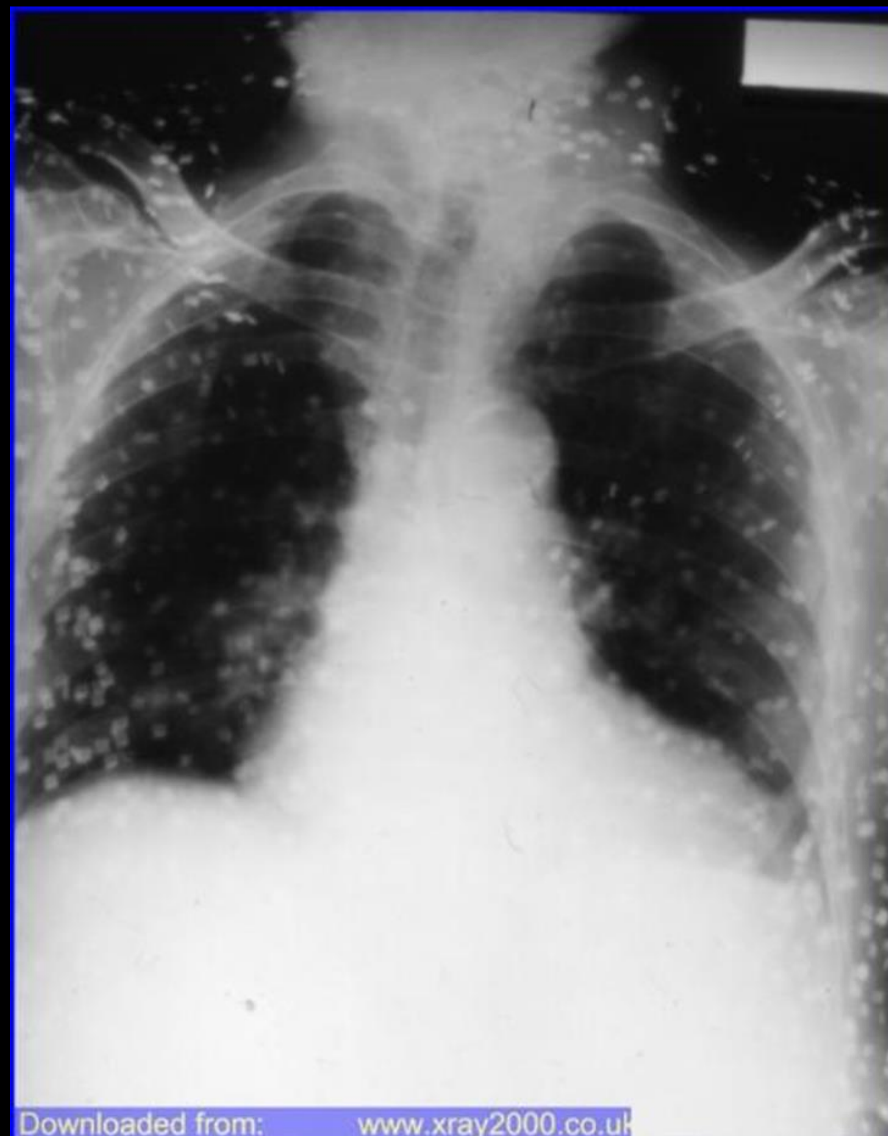
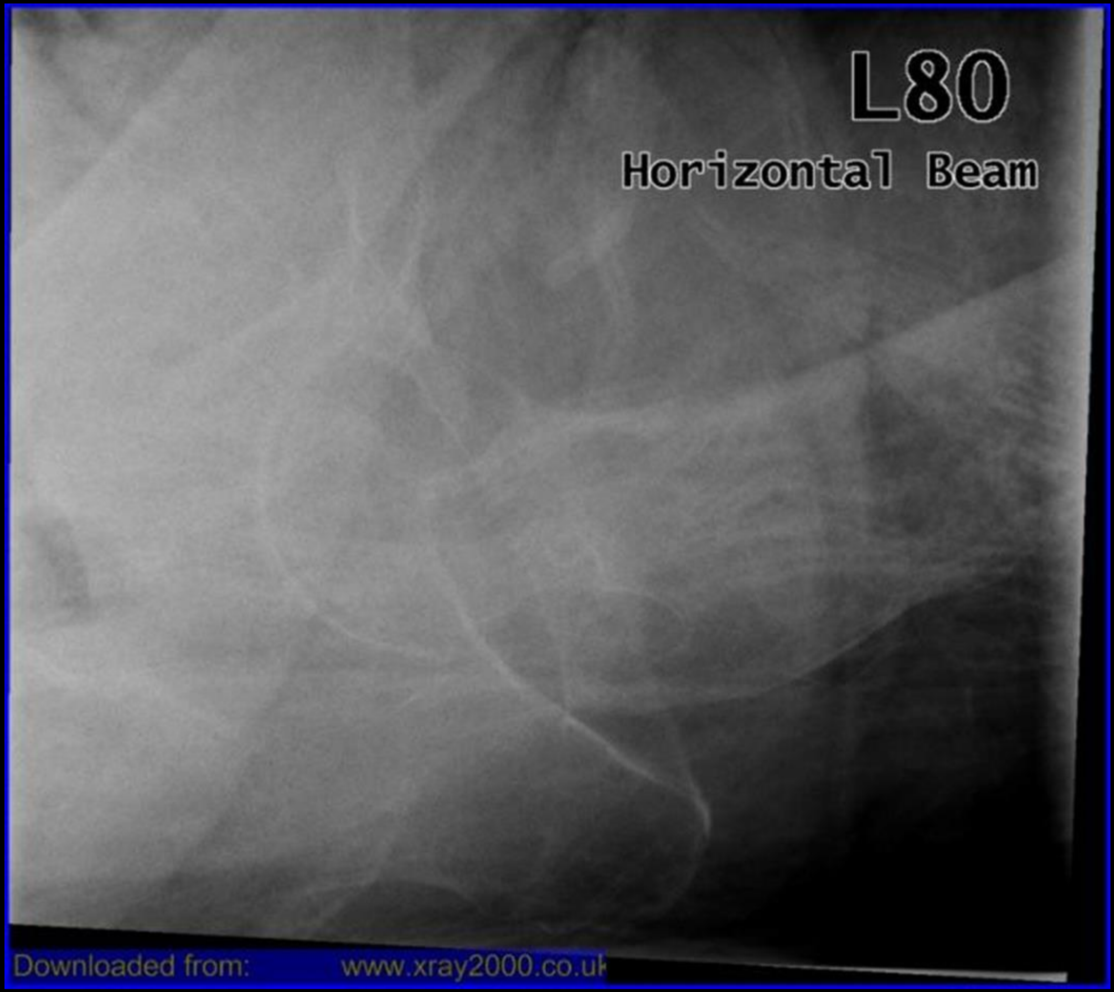
Source: J Invasive Cardiol © 2003 Health Management Publications, Inc.

Sequins

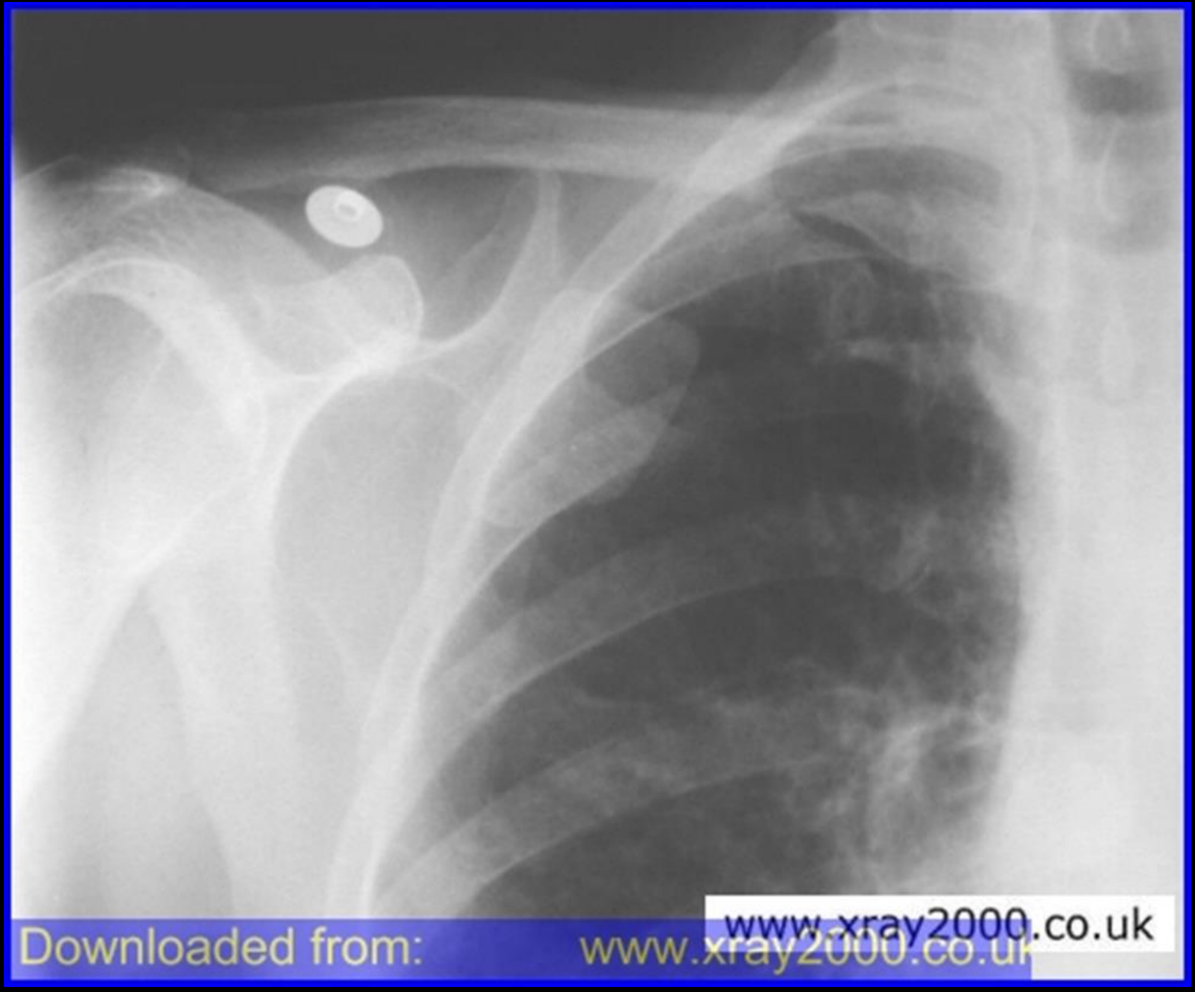


Clothing

Clothing

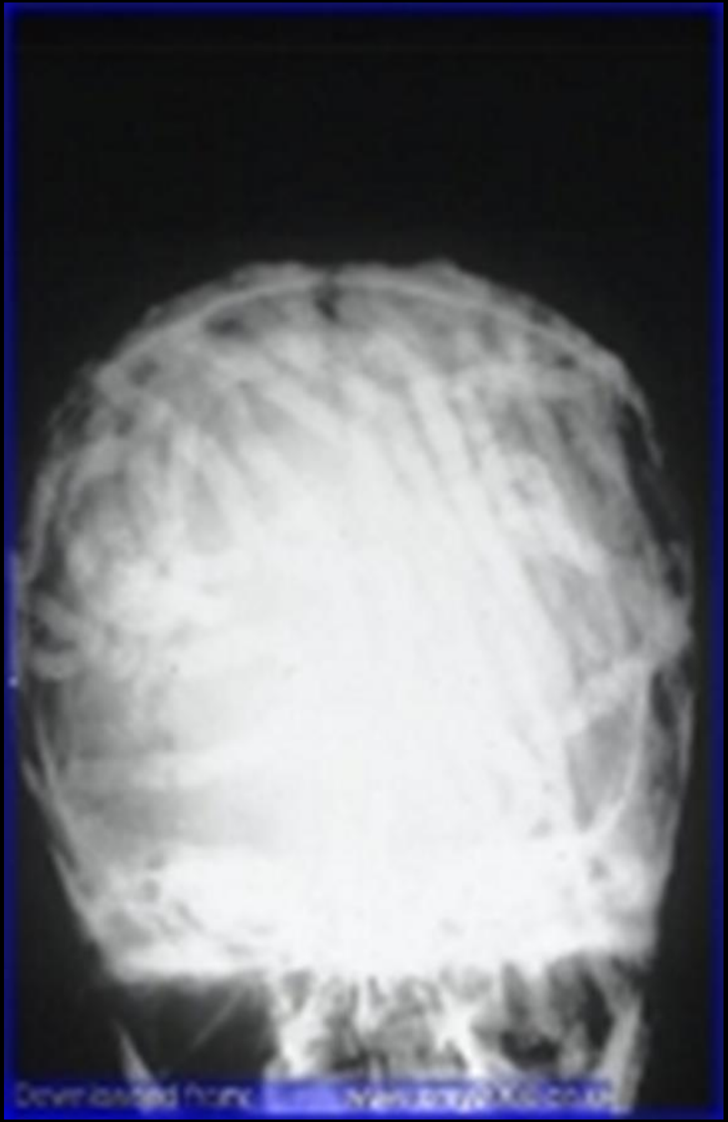


Button



Hair

Hair



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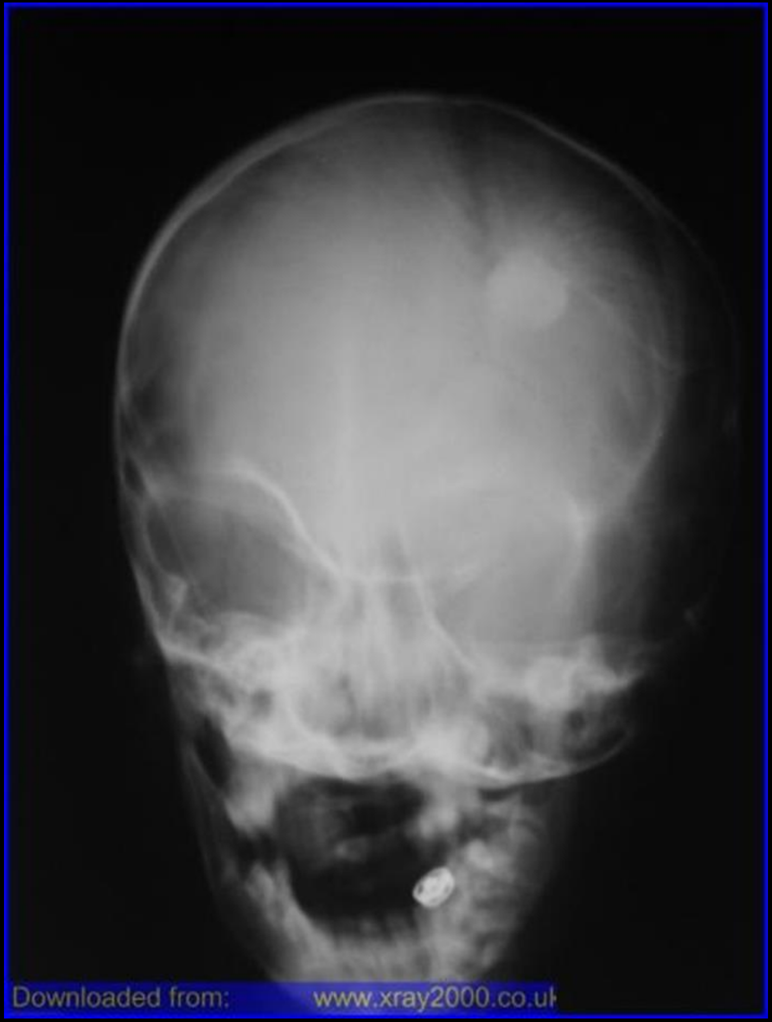


Double Exposure

Double Exposure

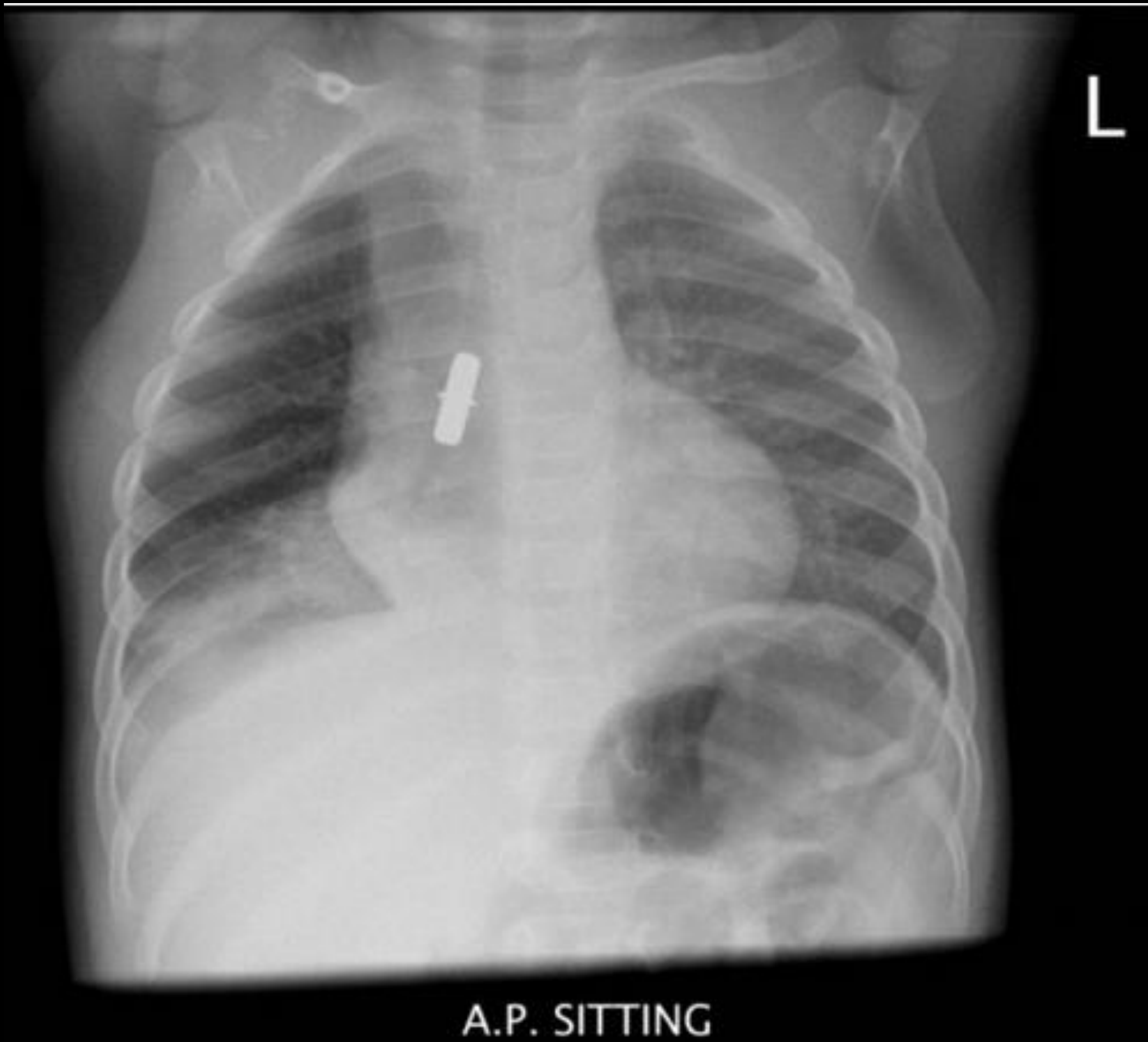
Double Exposure


R




L

L


L
A.P. SITTING

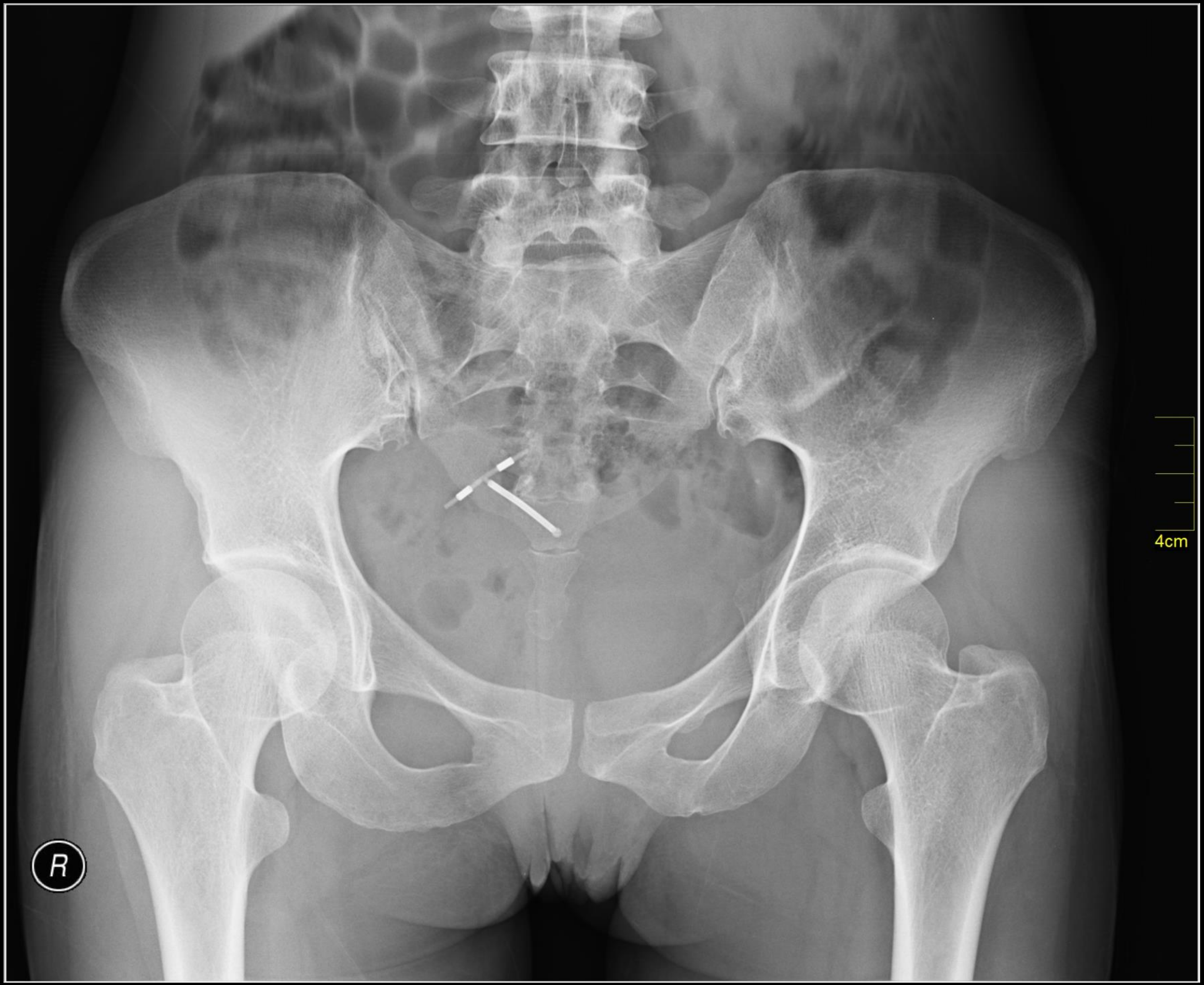

R


© CEN


© CEN


L
© PA


R


4cm
R

PACS Fundamentals

The **picture archiving and communication system (PACS)** is becoming more commonplace in today's hospitals because hospital administrators have come to see the necessity of having such a system to serve physicians and patients even though it is expensive. The initial capital cost is great, but the benefit of having the system far outweighs the cost.

Digital imaging and communications in medicine (DICOM) is a universally accepted standard for exchanging medical images among the modality, viewing stations, and the archive. First completed in 1985, this standard laid the groundwork for the future development of integrated PACSs. Now each modality and PACS communicates via DICOM, and DICOM continues to be refined every year.

When a patient arrives for a procedure, the technologist either has to manually type in the patient's demographics, risking error, or alternatively pull the information directly from the radiology information system (RIS). A modality can pull this information when it supports the service class of modality worklist management, and the RIS can either interface via DICOM or through a gateway that creates an interface with the Health Level 7 (HL-7) device and the DICOM device.

HL-7 is an American National Standards Institute (ANSI)–accredited Standards Developing Organization (SDO). The standards set by this organization are used in most health care applications such as medical devices, imaging, insurance, and pharmacy. The HL-7 standards oversee most clinical and administrative data such as demographics, reports, claims, and orders.

HL-7 standards are generally used in communication between the **hospital information system (HIS)** and the **radiology information system (RIS)**.

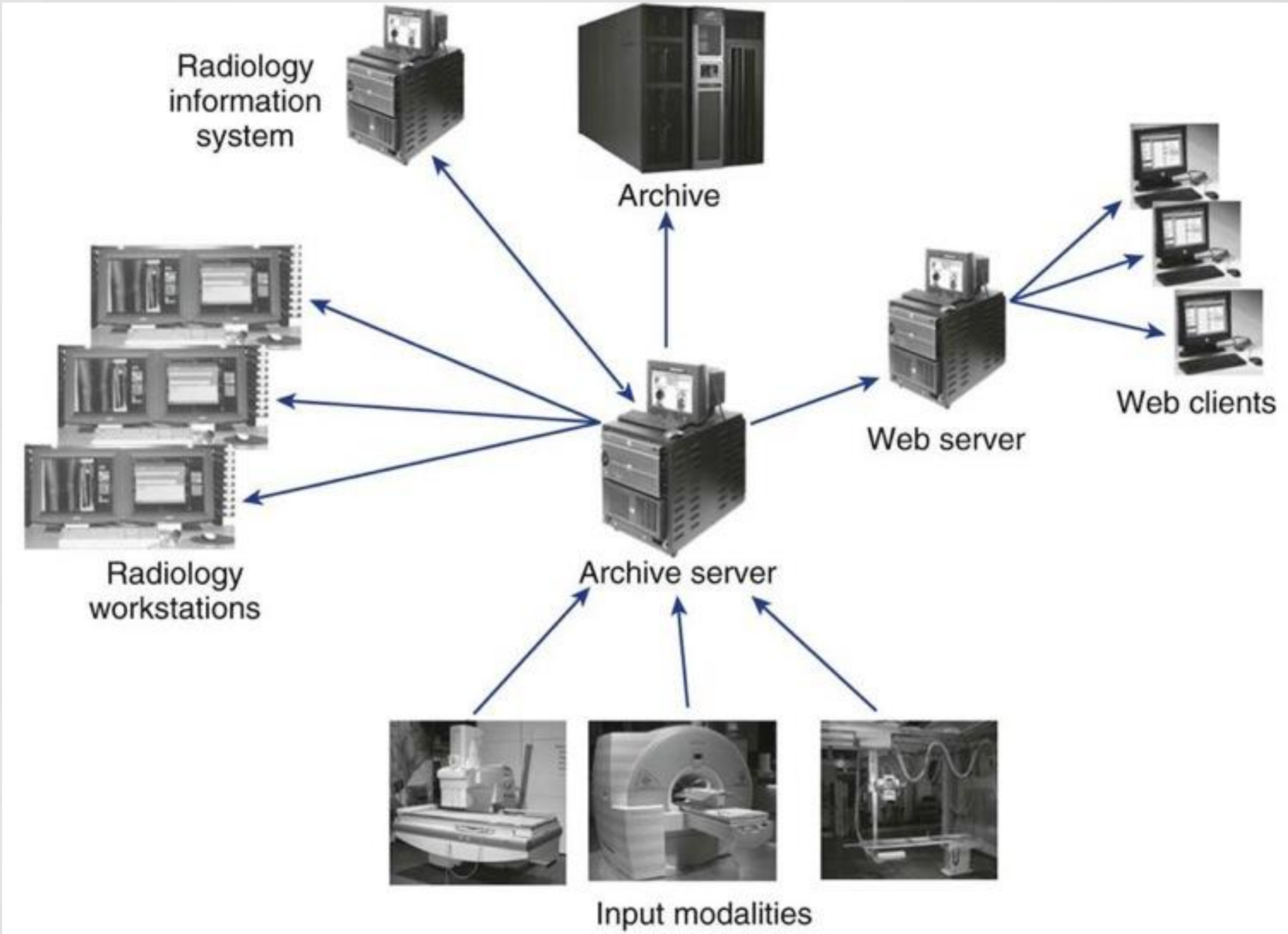
The HIS holds the patient's full medical information, from hospital billing to the inpatient ordering system.

The RIS holds all radiology-specific patient data, from the patient scheduling information to the radiologist's dictated and transcribed report.

The electronic medical record (EMR) has recently come to the forefront of information technology. The EMR is either a part of the HIS or runs along with it and contains all of the patient's record, including lab results, radiology reports, pathology results, and nurses' and doctors' notes.

The EMR interfaces with most of the ancillary service systems to retrieve reports so that they can be viewed in this one common format. PACS have also begun interfacing with EMRs to present images to referring physicians through the same common system.

Electronic Health Record (EHR), takes this concept further by bringing together all the patient’s clinical information across all providers and episodes of care, making a complete clinical history available to every stakeholder who needs it, throughout the patient’s lifetime.


Radiology information system
Archive
Radiology workstations
Archive server
Web server
Web clients
Input modalities

PACS three fundamental parts:

- image acquisition
- display workstations
- archive servers

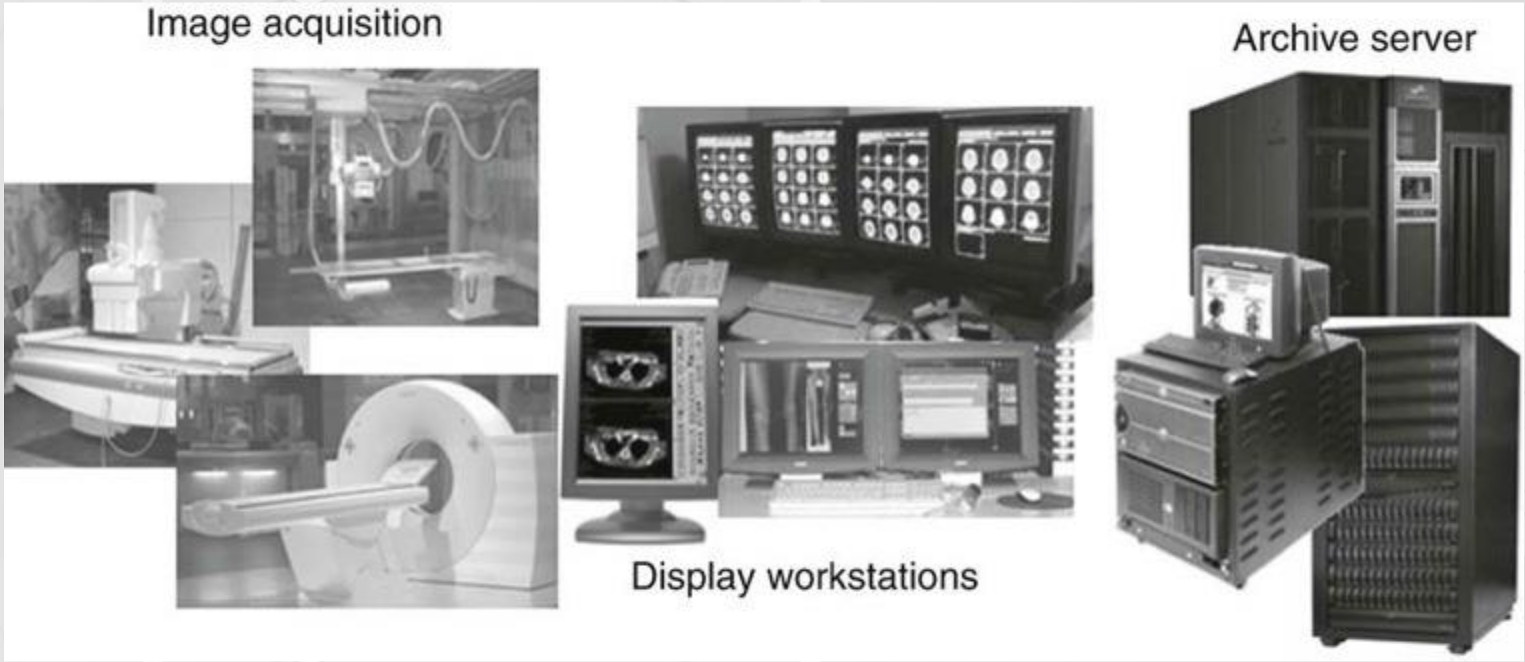


Image acquisition
Archive server
Display workstations

Image Acquisition

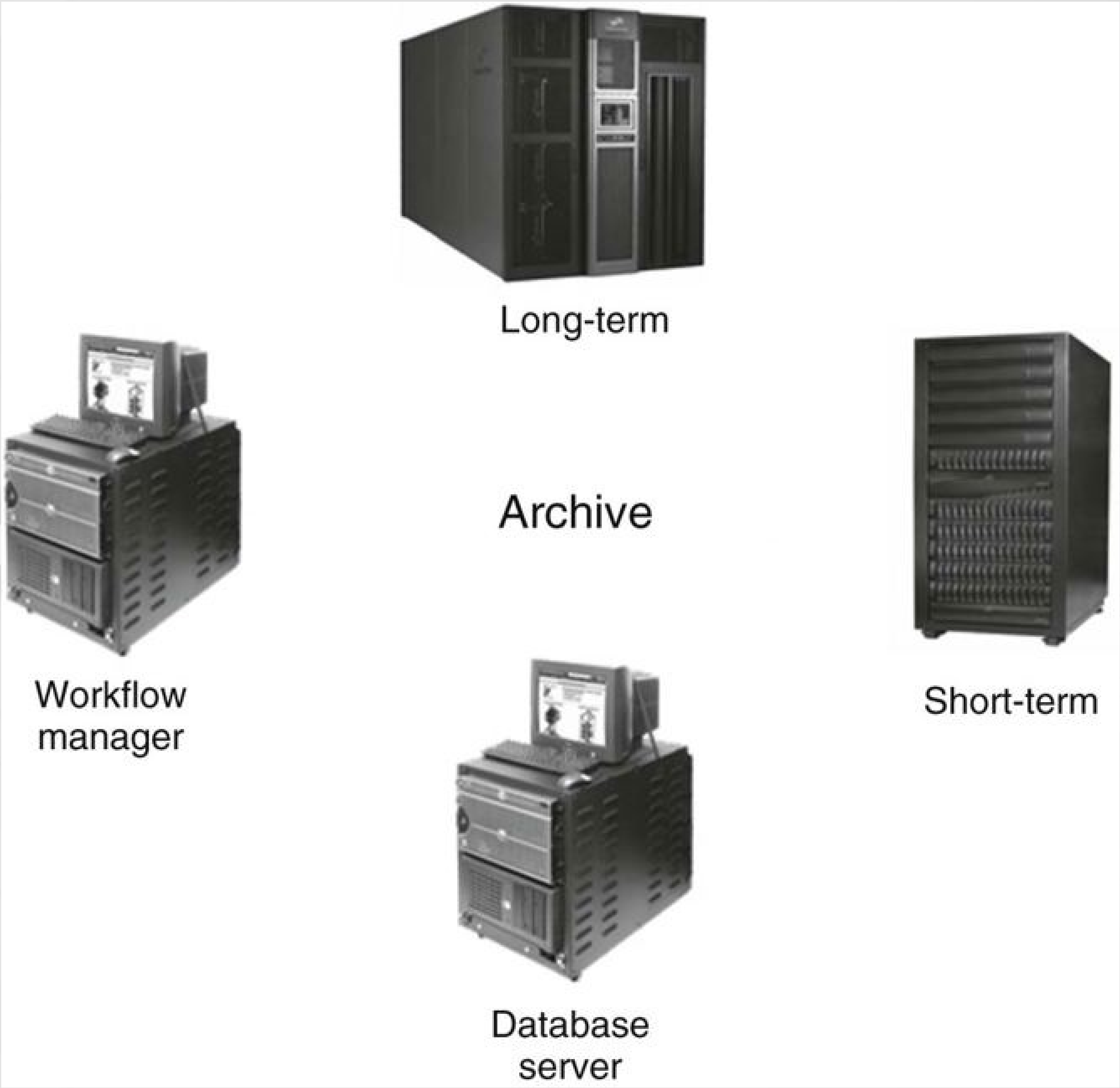
In modern radiology departments, most images are acquired in a digital format, meaning that the images are inherently digital and can be transferred via a computer network. Ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), and nuclear medicine have been digital for many years and have been taking advantage of PACS far longer than general radiography has.

Display Workstations

A display workstation is any computer that a health care worker uses to view a digital image It is the most interactive part of a PACS, and these workstations are used inside and outside of radiology. The display station receives images from the archive or from the various radiology modalities and presents them for viewing. The display workstation has PACS application software that allows the user to perform minor image-manipulation techniques to optimize the image being viewed. Some display stations have advanced software to perform more complex image-manipulation techniques.

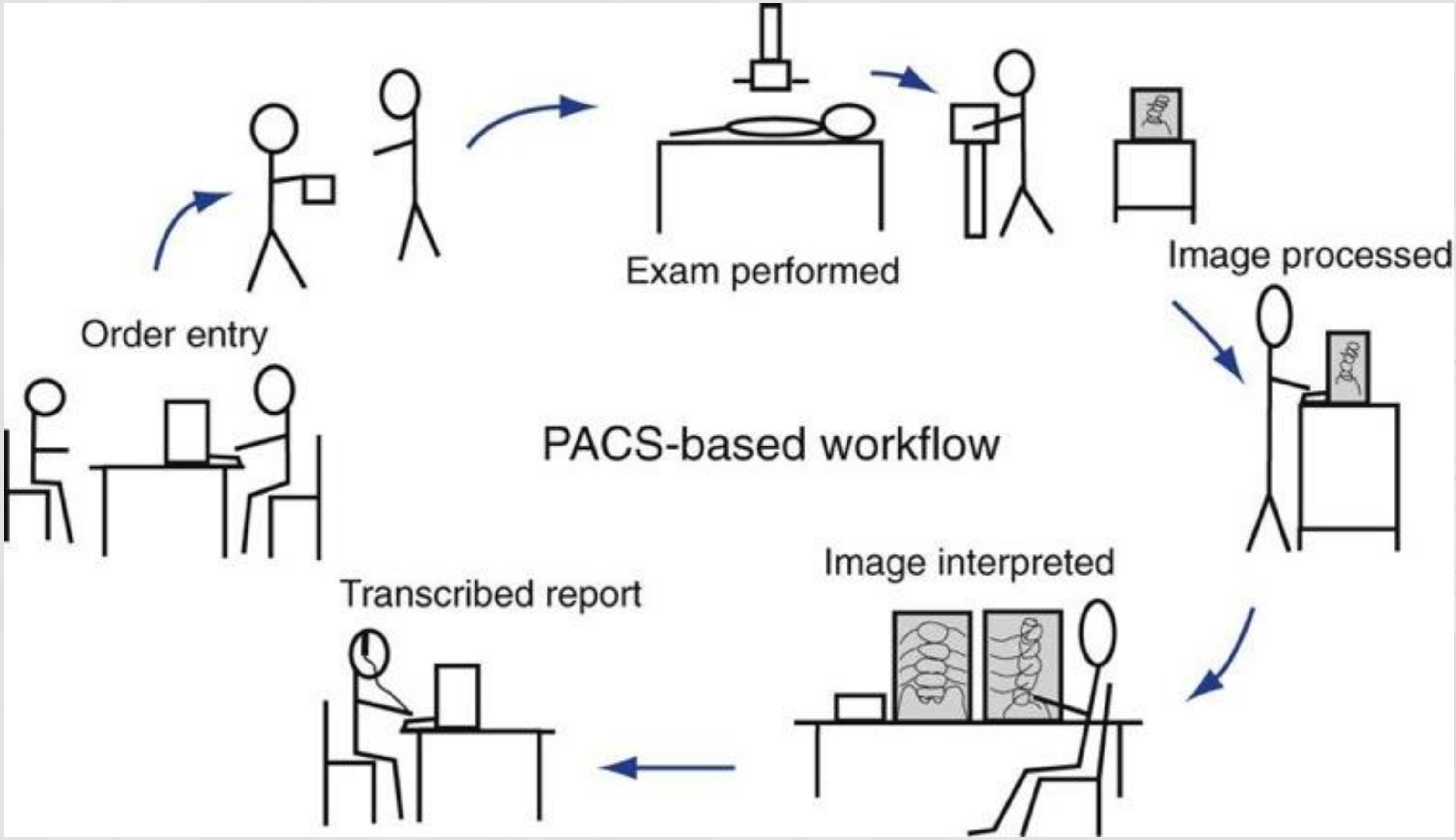
Archive Servers

An archive server is the file room of the PACS. It is composed of a database server or image manager, short-term and long-term storage, and a computer that controls the PACS workflow, known as a workflow manager. The archive is the central part of the PACS and houses all of the historic data along with the current data being generated. In many institutions the archive serves as the central hub that receives all images before they are released to the radiologists for interpretation.


Long-term
Archive
Workflow manager
Short-term
Database server

Workflow

Workflow is a term that can be used in any industry or in any organization. It simply means how a process is done, step by step. In radiology, the term workflow has always been used to describe how an examination is completed, from order entry to transcribed report. The workflow in each radiology department is different because there are many variables.


Exam performed
Image processed
Order entry
PACS-based workflow
Image interpreted
Transcribed report

The first step in any radiology department workflow is the entry of the order. The order may be a paper prescription from the ordering doctor, or the order may have been placed in the computer system by any hospital staff member. Either way, an order is placed in the radiology information system (RIS), and a requisition is generated. A requisition generally contains the following information:

- Patient's name
- Patient's hospital identification (ID) number
- Date of birth
- Ordering physician's name
- Examination ordered
- Reason for examination
- Chief complaint

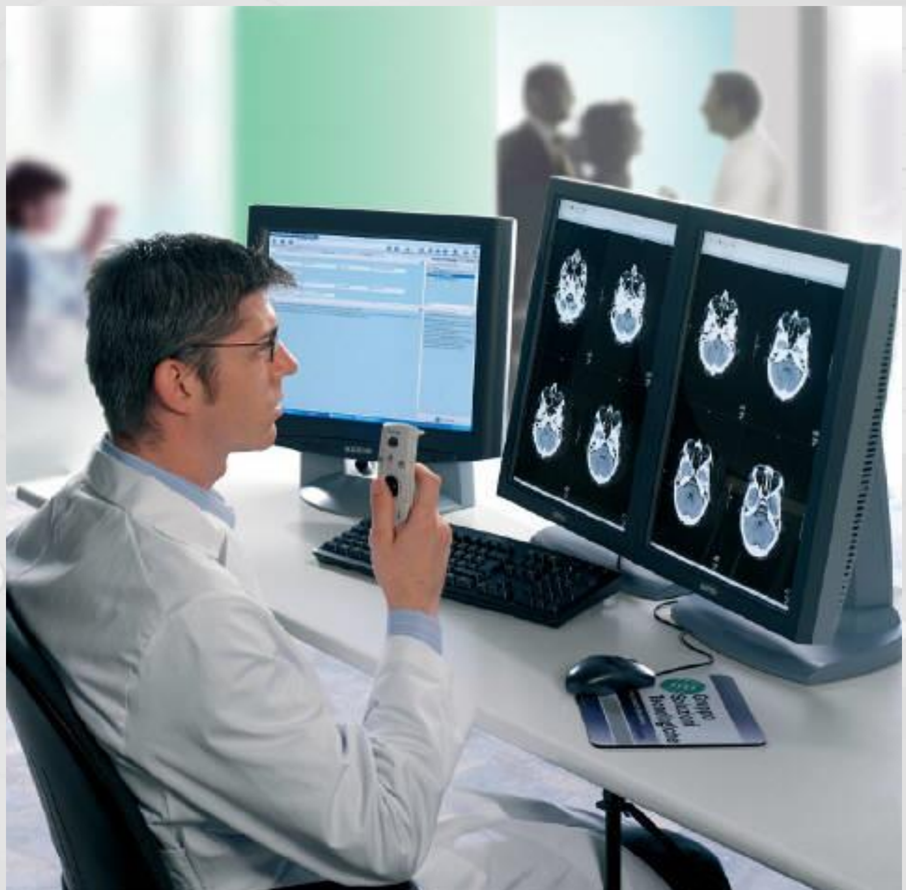
The order is input into the RIS, and the RIS sends a message to the PACS to find all historic images and put them on the short-term archive. This eliminates waiting for the file room to retrieve a film jacket from the off-site storage location.

The technologist prepares the room, retrieves the patient, and performs the patient history. The history is recorded on the paper requisition or input electronically into the patient's computerized medical record.

The technologist performs the examination, and depending on the type of image acquisition device, the images are processed and repeated as necessary and sent to the appropriate PACS device. The patient images have been tagged with information from the RIS so that historic image reports are available at the PACS when the new images are sent. If the patient's physician does not have access to the electronic images, a compact disk (CD) or digital versatile disk (DVD) can be made that contains the images in digital format.

The requisition is either taken to the radiologist, or the radiologist may pull the images from an electronic worklist. The radiologist also pulls up historic images and reports and compares the previous images with the current images.

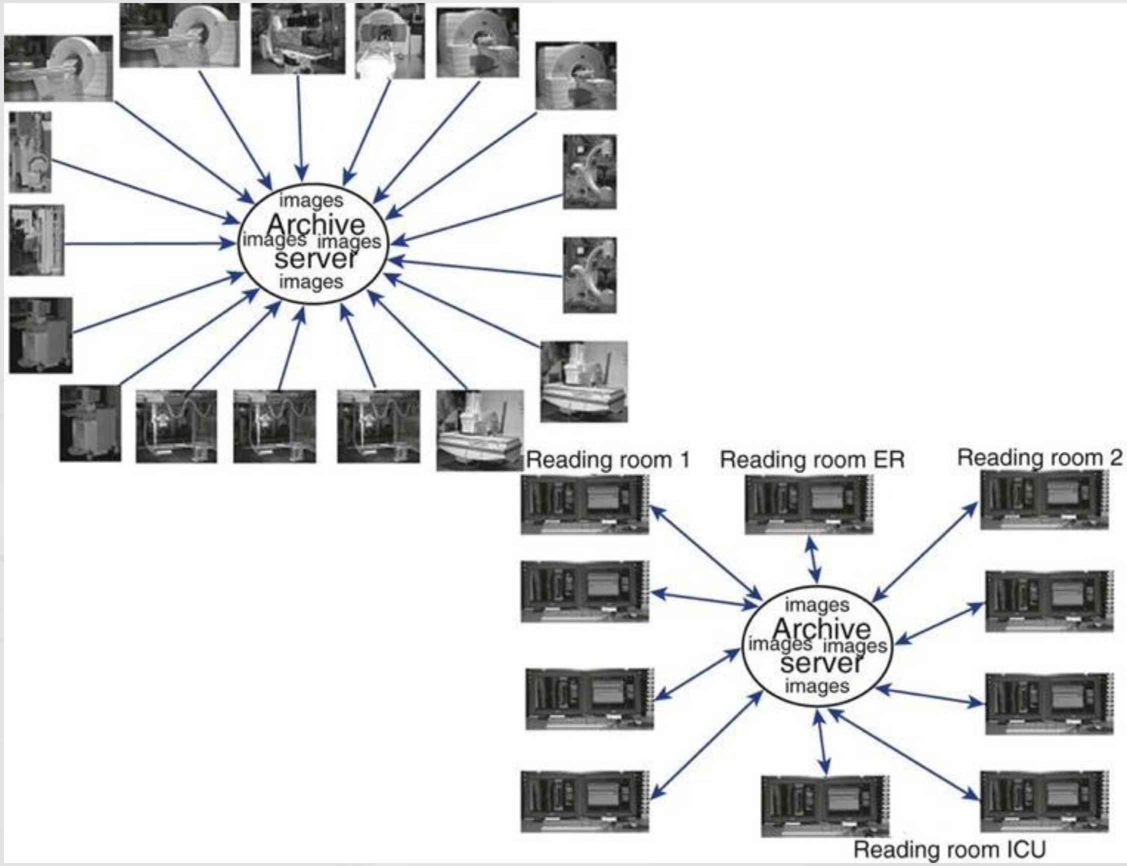
The radiologist dictates a report and has it transcribed, or voice recognition software may be used. If the radiologist uses voice recognition software, he or she can review the report right after dictation, make corrections, and sign the report, making it final.



System Architecture

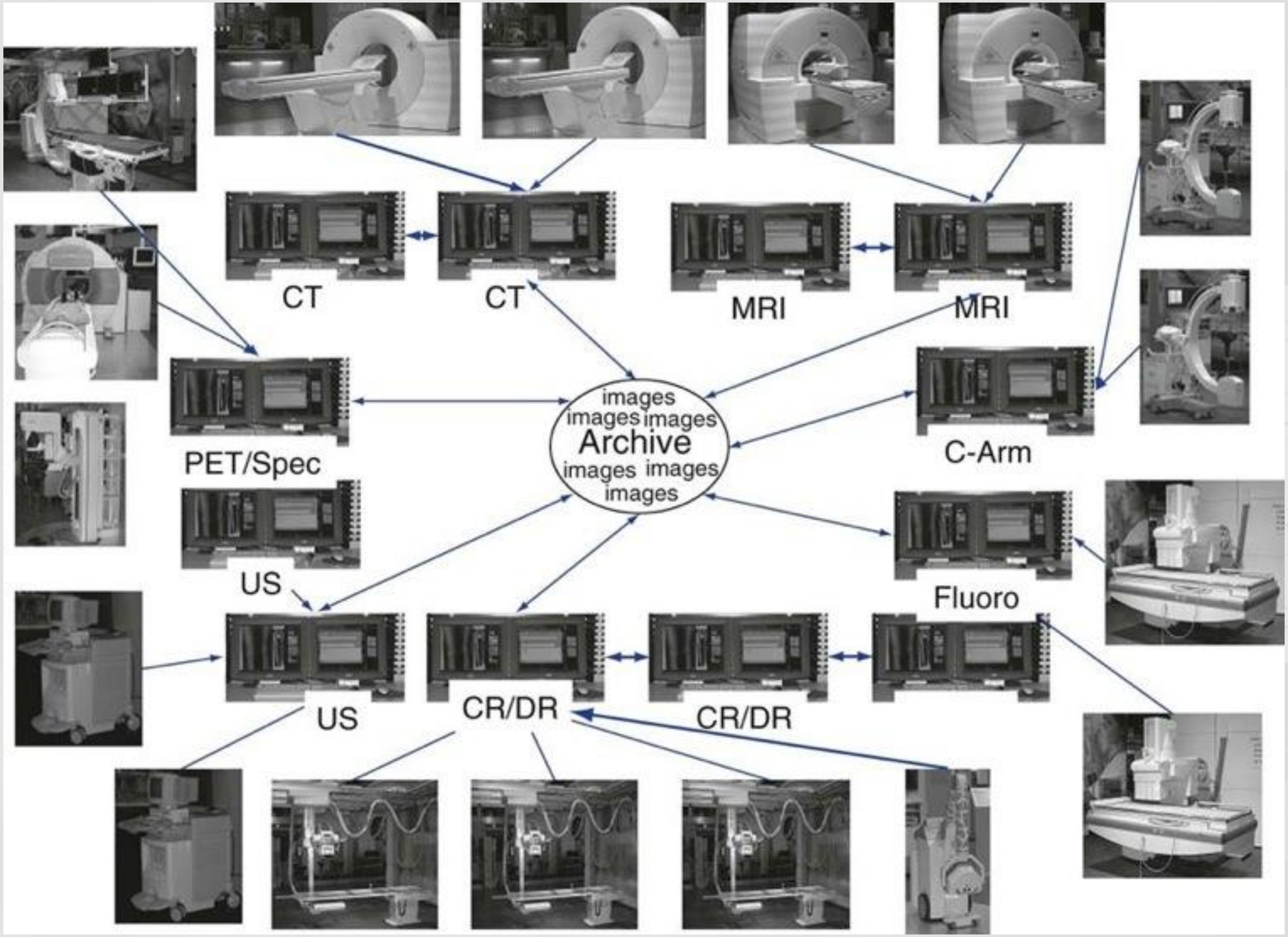
System architecture can be defined as the hardware and software infrastructure of a computer system. In a PACS, the system architecture normally consists of acquisition devices, storage, display workstations, and an image management system.

In a client/server-based system, images are sent directly to the archive server after acquisition and are centrally located. The display workstation functions as a client of the archive server and accesses images based on a centralized worklist that is generated at the archive server. The health care worker at the display workstation chooses a name from the central list, and the archive server sends the image data to the display station. After the “client” is finished, the image data are flushed from its memory. Most systems allow basic image manipulation at the display workstation or “client,” and the changes are saved on the archive server.



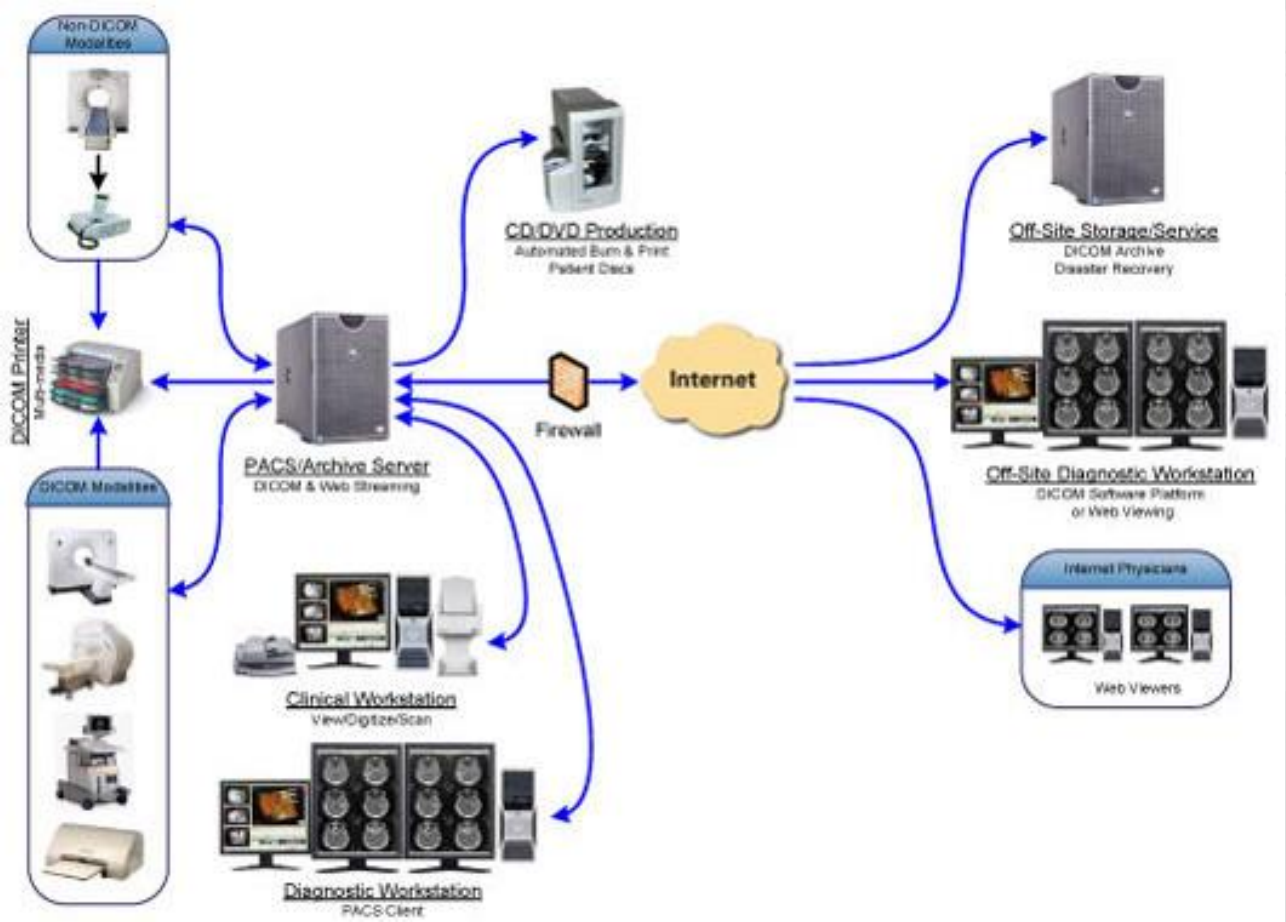
In a distributed or stand-alone system, the acquisition modalities send the images to a designated reading station and possibly to review stations, depending on where the order originated (i.e., the intensive care unit or the emergency room). In some systems, the images are sent from the modality to the archive server, and the archive server distributes the images to the designated workstation.

The workstations can query and retrieve images from the archive. All images are then stored locally and subsequently sent to the archive server after they have been read. These images remain on the local hard drive of the workstation until they are deleted either by a user or at a predetermined time set by system rules.



CT
CT
MRI
MRI
images
images images
Archive
images images
images
PET/Spec
C-Arm
US
Fluoro
US
CR/DR
CR/DR

A web-based system is very similar to a client/server system in how data flow. The significant difference is that both the images and the application software for the client display are held centrally. This means that when someone wants to view images from a web-based application, he or she simply searches for the pertinent images and the web browser will display the images that are held in the web server. This does not require special software to be downloaded to the computer.



The display workstation is the most interactive part of a PACS, consisting of a monitor and a computer with a mouse and keyboard. In addition, each system has hardware and software that fits the users' requirements.

Common screen resolutions that are found on today's monitors are:

- 1280 × 1024 (1K)
- 1600 × 1200 (2K)
- 2048 × 1536 (3K)
- 2048 × 2560 (5K)

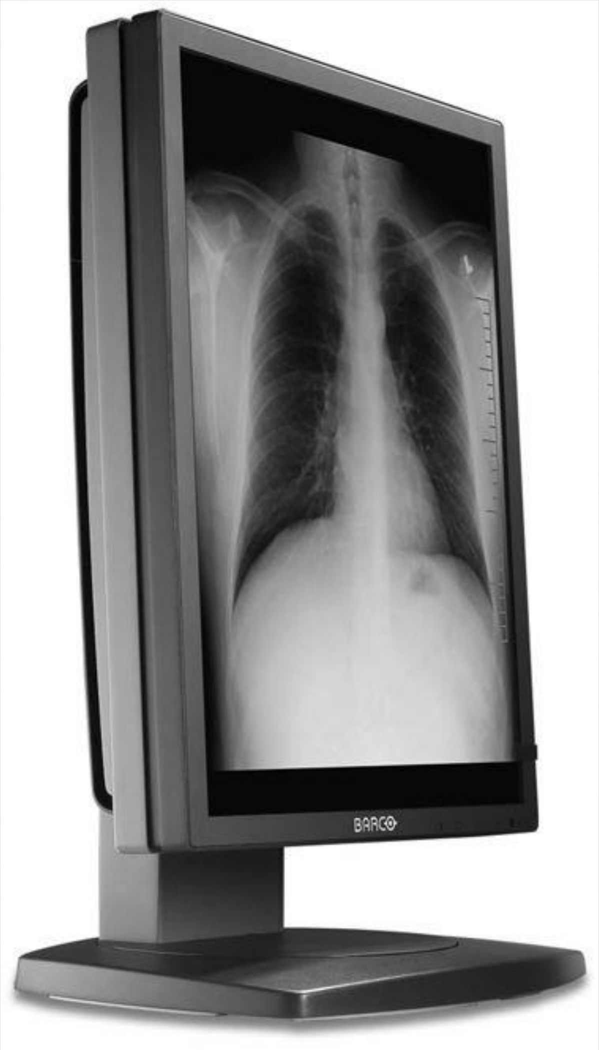
Most cross-sectional imaging is read on a 1K square monitor.

Most digital projection images are read on at least a 2K portrait monitor.

Mammography requires a 5K or 5-megapixel resolution to provide the viewing capacity needed

1 K

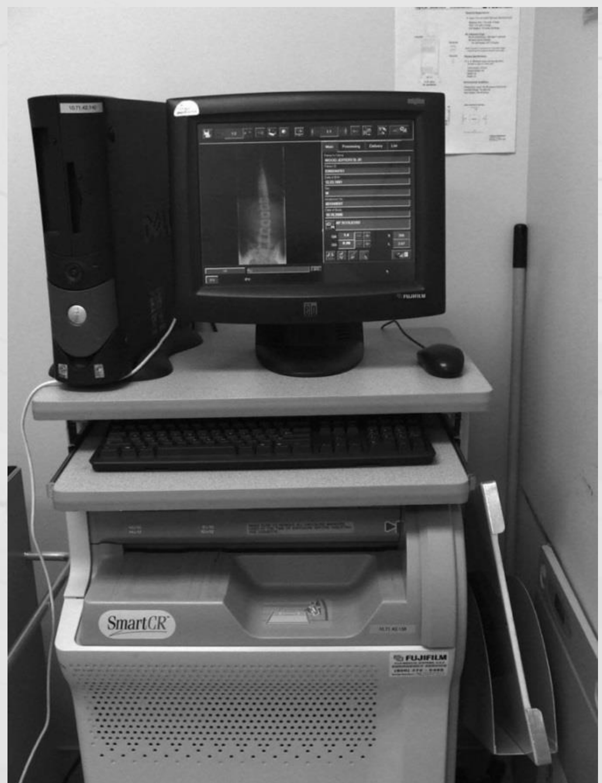
2K



The radiologist reading station is used by a radiologist when making a primary diagnosis. The reading station has the highest quality hardware, including the best monitor.

The physician review workstation is a step-down model of the radiologist reading station. Many vendors use the same level of software but may eliminate some of the more advanced functions. One of the most important features on a physician review station is the ability to view current and previous reports along with the images. This can be accomplished with the integration of RIS functions with the PACS software

The technologist quality control (QC) station is used to review images after acquisition but before sending them to the radiologist. The QC station may be used to improve or adjust image quality characteristics, or it may be used to verify patient demographic information. Many QC stations are placed between the computed radiography (CR) and digital radiography (DR) acquisition modalities as a pass-through to ensure that the images have met the departmental quality standard. The technologist QC station generally has a 1K monitor. When manipulating images, the technologist must be careful not to change the appearance too much from the original acquired image. The technologist should consult frequently with the radiologist to ensure that the images being sent are of the required quality.



The file room workstation may be used to look up examinations for a physician or to print copies of images for the patient to take to an outside physician. Many hospitals are moving away from printing films to save the cost of the film and are instead moving toward burning CDs with the patient's images.

PACS workstations functions can be broken down into four categories:

- navigation functions
- image manipulation and enhancement functions
- image management functions
- advanced workstation functions.

Navigation functions are used to move through images, series, studies, and patients. The worklist is used to navigate through patients. Most worklists are customizable for the user. One doctor may want to see only unread CT studies, and another may want to see all neurologic studies done that day regardless of the modality.

Once a patient has been selected from the worklist, the images load into the display software. In most PACSs, each user has the ability to set up custom **hanging protocols**. A hanging protocol is how a set of images will be displayed on the monitor

Image Manipulation and Enhancement Functions:

- Window width/window level
- Annotations
- Flip and rotate
- Pan, zoom, and magnify
- Measurements

Image Management Functions

Most PACSs allow the user to modify patient demographics at the technologist QC station, the reading station, and the file room station. It is imperative that the patient demographics are correct. If wrong information is archived on an image, the image will be difficult to retrieve and may never be found again. Make changes only when the information is absolutely known to be wrong. To minimize errors, many hospitals allow only certain people the access to change demographics.

Another image management function is the query/retrieve function used to retrieve studies from the archive. The query function allows the user to query a study on multiple fields such as the patient's name or ID, date of service, or modality. Some systems also allow a query based on a diagnosis code or comment field.

Many vendors have provided a CD-burning option that allows users to save studies to a CD for outside use. The feature may be available only in the file room to control the CDs that are sent out. Health Insurance Portability and Accountability Act (HIPAA) compliance must also be maintained.

Another common feature is the ability to copy and paste images into a document. This is frequently used with the web-based systems when creating presentations for conferences. The patient information must be removed from the image before it is placed into a presentation.

Some hospitals have retained the ability to print films for outside use. This is also usually done only in the file room so that control can be maintained over the printed films for HIPAA purposes and cost reasons. Some hospitals have also connected workstations to paper printers for quick consults and medical records.

Advanced functions are usually placed on specialty workstations for the radiologist, but some are found on the technologist QC station to further enhance the images.

- MPR
- 3D
- Stitching

MPR


Patient Applications Transfer Edit View Settings Orientation Type Image Tools Fusion Options Help
Son16 Abd CTA E
Viewing
Filming
3D
Type Orien Image
Setti Histo
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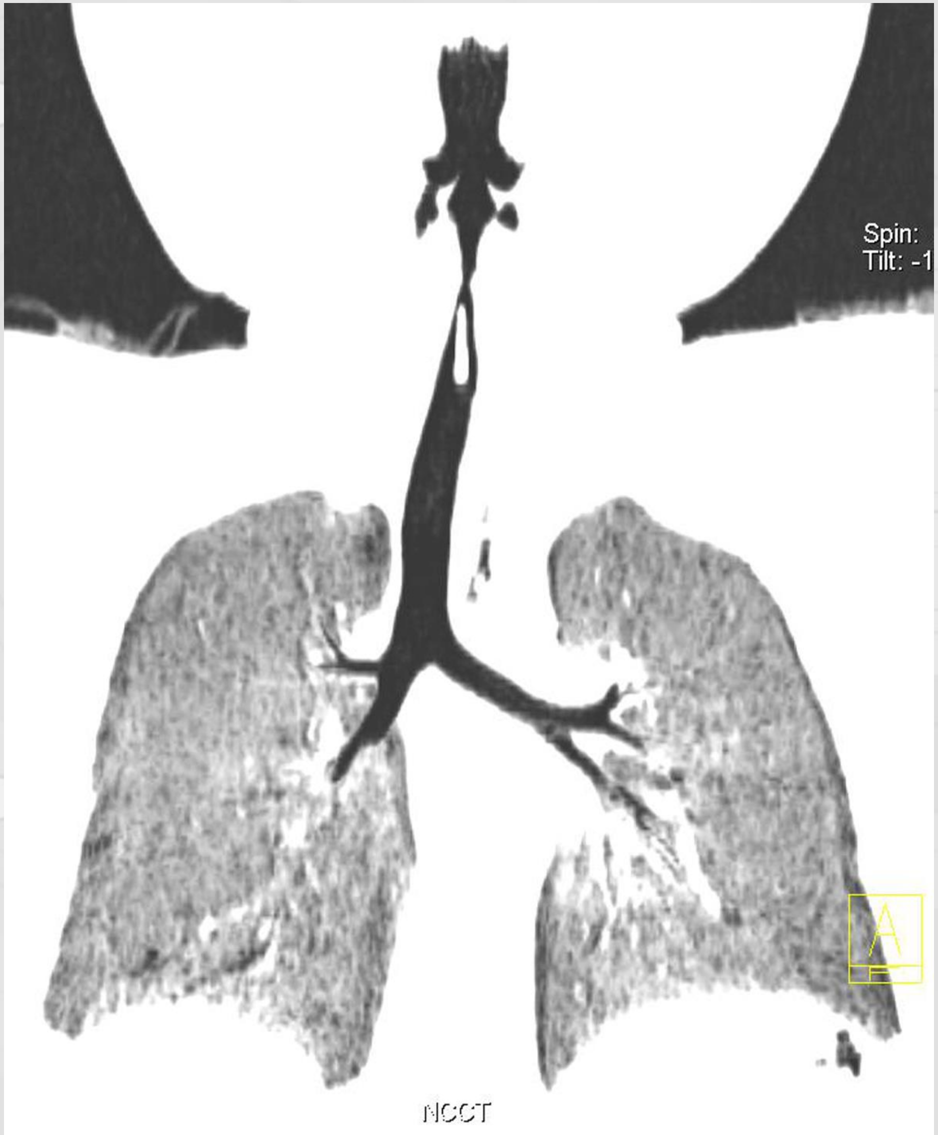
3D MIP


Patient Transfer Edit View Settings Orientation Type Image Tools Fusion Options Help
MR
Type Orien. Image
Filming
3D

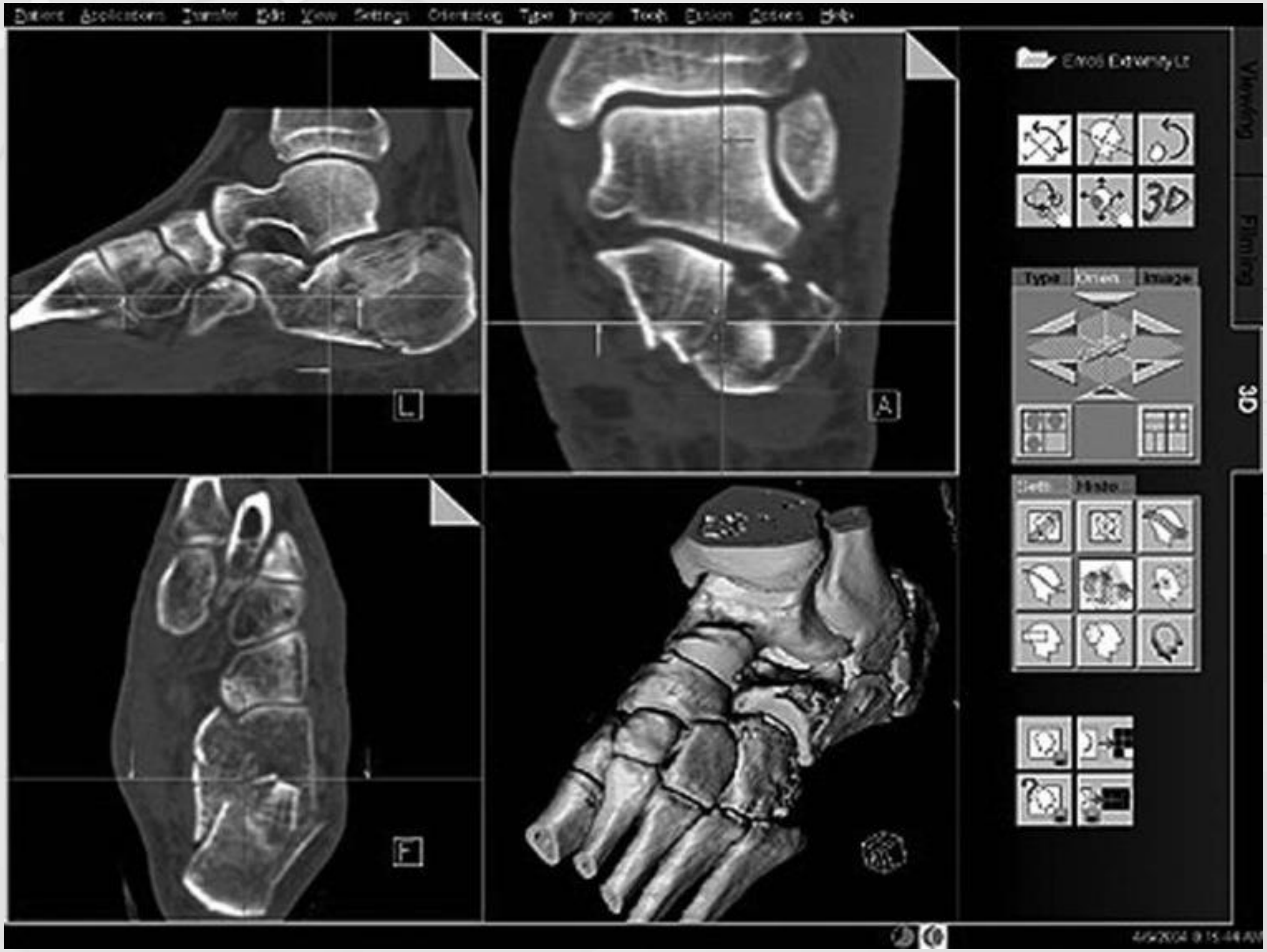
3D minIP



3D VR

Patient Transfer Edit View Settings Orientation Type Image Tools Fusion Options Help
3D_CT_VRT
Filming
3D
Type Orien Image
Setti

3D SSD



Stitching

Other long-term storage products that are still widely used are optical disk, tape, and magnetic disk. Optical disk and magnetic tape archive solutions use a jukebox to hold the tapes or disks; the magnetic disk uses an array. The jukebox has controller software that interfaces with the image manager to keep track of exactly where each image is located.

Magneto-optical Disk.
A magneto-optical disk (MOD) is very similar to a compact disk (CD) or digital versatile disk (DVD) in that it is read optically with a laser, but the disk itself is housed within a plastic cartridge. MODs tend to be more reliable than some of the other long-term storage options. The disks are rather robust and can withstand many years of reading. They can be read faster than some of their counterparts. The cost per gigabyte is a bit higher for MODs than for some of the other long-term storage options, but MODs are still a viable long-term storage option.

Digital versatile disks (DVDs) were first introduced for use in video. CDs were used by a few early PACS adopters, but users found that the CDs could not hold enough data to make a CD archive cost and space efficient. DVDs have a much higher capacity. In 2006, a double-sided, two-layered DVD held 17 GB of data, whereas a CD held 650 MB. DVDs are the least expensive method for long-term archiving per gigabyte.

Ultra density optical (UDO) disk is the new-generation MOD. A UDO disk uses blue laser technology in its read and write activities. Plasmon (Plasmon PLC, Hertfordshire, UK) introduced the first UDO disk in 2004 with a disk capacity of 30 GB (2006 MOD technology was at 9.1 GB), and the capacity is predicted to increase to 60 GB and then to 120 GB to accommodate industry needs. Currently, UDO technology operating costs are less than MODs and very competitive with DVD technology. The tape libraries being offered in 2006 held between 24 and 638 disks.

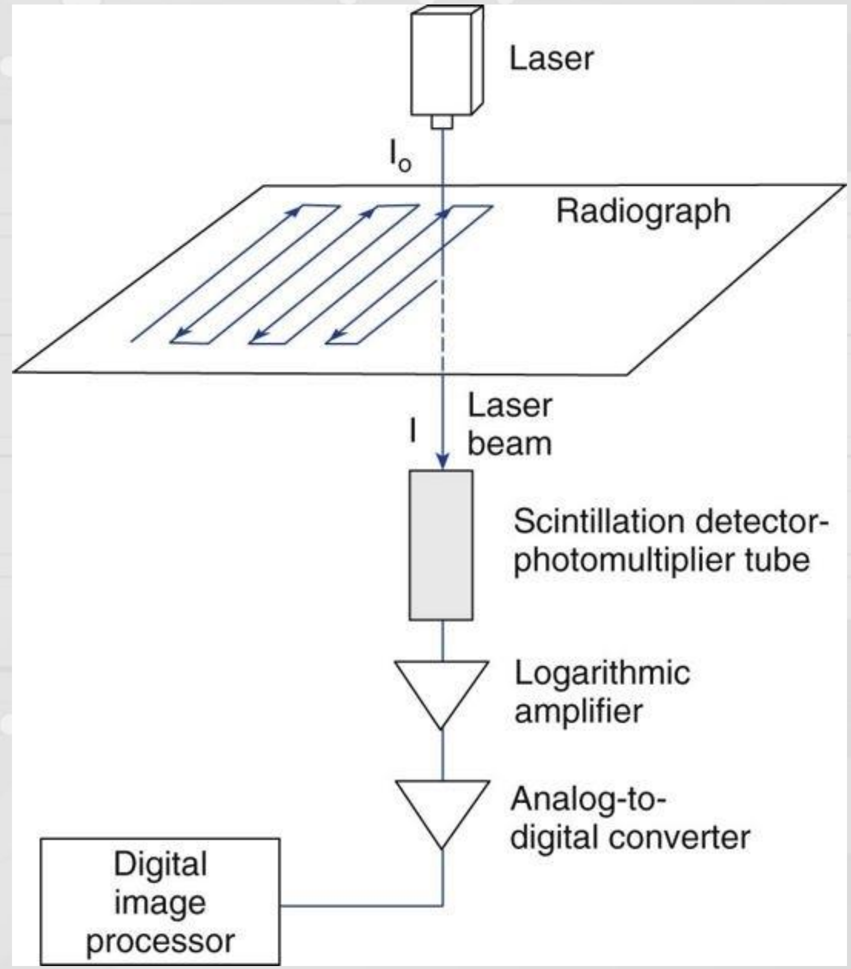
Tape is a fairly low-cost archive medium that comes in various sizes. These tapes are contained within a jukebox or library that has multiple drives and a robot arm to move the tapes in and out of the drives. These libraries can hold between 10 and 1448 tapes in one library. Most of the libraries are scalable, meaning that additional libraries can be added to the original.

Alternative to in-house archiving is an **application service provider** (ASP). An ASP is a company that provides outsourcing of archiving and management functions for a pay-per-use or pay-per-month charge. ASPs give smaller institutions access to the level of hardware and software they could not otherwise afford. Moreover, they assume responsibility for the day-to-day management of the archive system. Many ASP models have a short-term archive located on hospital premises, and the long-term archive is handled at the off-site location run by the ASP company. The short-term archive may be leased by the ASP, and the controller will pre-fetch images from the long-term off-site storage during the evening and night hours for the next day's schedule.

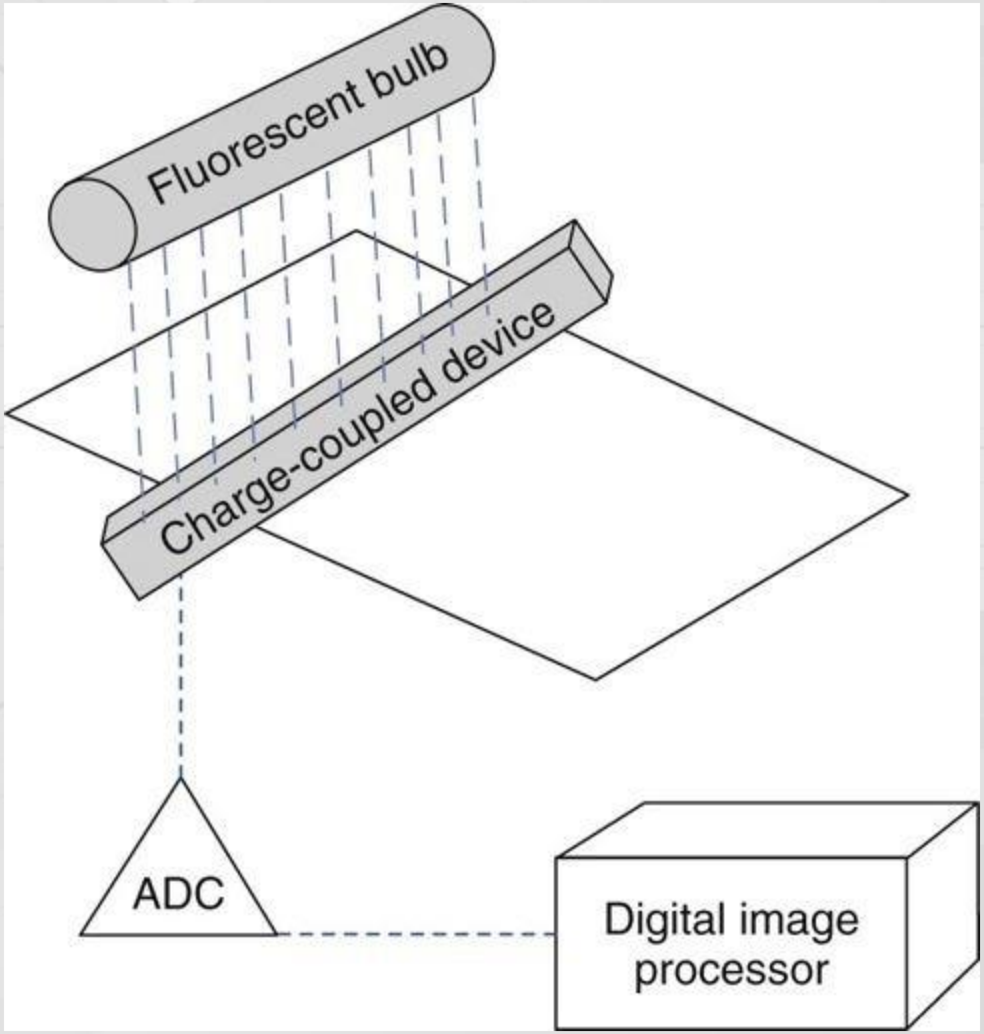
Another common use for an ASP is as a disaster recovery mechanism. Disaster recovery involves making copies of each tape or disk and sending them to another building or off-site location or, by using the ASP model, shipping them to an outside company for storage on a pay-per-use policy.

The film digitizer scans the analog film and produces numeric signals for each part of the scanned film. The numbers are fed into a software application that is attached to the scanner, and the scanner digitally reproduces the image using the numeric signals that represent each part of the radiograph.

A laser film digitizer uses a helium neon laser beam to convert the analog film image into a digital image. A laser inside the digitizer is bounced off a series of mirrors and scanned across the image. A photomultiplier tube picks up the light that is transmitted through the film.



A CCD film digitizer uses fluorescent bulbs that shine through the film and a CCD array that detects the light and transforms it into an electrical signal. The signal is then sent to an analog-to-digital converter and changed into a number that represents the intensity of light that passed through the film.



There are many uses for the film digitizer in the modern radiology department. Most departments list the following reasons for using a digitizer:

- Teleradiology
- Compare outside or old films
- Film duplication
- Computed aided diagnosis (CAD)

Imagers, also known as film printers, receive an image from a workstation and print the image based on printer LUTs and preset print layouts. Both of these parameters vary for each modality that produces digital images.

There are two major types of imagers: wet (chemical) laser imagers and dry laser imagers

Wet imagers use chemicals to process the film that has been exposed to the laser. The laser beam produces an intensity of light that is proportional to the signal being received to regulate the brightness recorded on the film. The laser emits a red light, so the film that is used must be red sensitive. As mentioned earlier, conventional film has silver halide crystals suspended in an emulsion; the wet laser film is not much different other than being red sensitive so that the laser may etch the image into the film. Because this film is sensitive to red light, it must be placed in its film magazine and processed in total darkness. This processing takes place in a bath of chemicals just like film used in the traditional film/screen department.

Dry imagers use heat to process the latent image that is etched into the silver emulsion by the laser. Just like conventional film, dry laser film also has silver within its emulsion, but instead of silver halide crystals, the dry film has silver behenate. The film is exposed with a laser in a fashion similar to the wet imager. The silver salts are then exposed to heat and turn to metallic silver to create the image on the film.

Reasons why film can and will be used in what nevertheless is called the filmless radiology department:

- Backup
- Difficult PACS locations (surgery)
- Outside physicians
- Legal cases
- Teaching purposes

Most hospitals try to reduce the amount of printing done in the department. One alternative to printing hard copies is to burn images to an optical disk.

All PACS vendors offer the ability to burn images to a CD or DVD for the purpose of sharing the images outside of the PACS. When a disk is burned with the patient's images, a DICOM viewer is also burned onto the disk. When the disk is put into a drive, the software automatically launches and displays the images. The software is generally very intuitive and easy to use and allows for minor image enhancements such as window/level adjustments and simple measurements.

Many referring physicians prefer having the images on disk rather than film because it takes up less space, can be added directly to the patient's office chart, and the images can be manipulated.

Disks also are much less expensive to produce and send out to physicians. One sheet of dry laser film costs approximately 48 cents, whereas a CD costs approximately 28 cents. The CD can hold multiple studies, and multiple sheets of film would be needed to print an entire study. The CD is also much less expensive to mail than the film. Disks will become much more common outside of the radiology department as the advantages are seen by those outside of the department.

FLUOROSCOPY

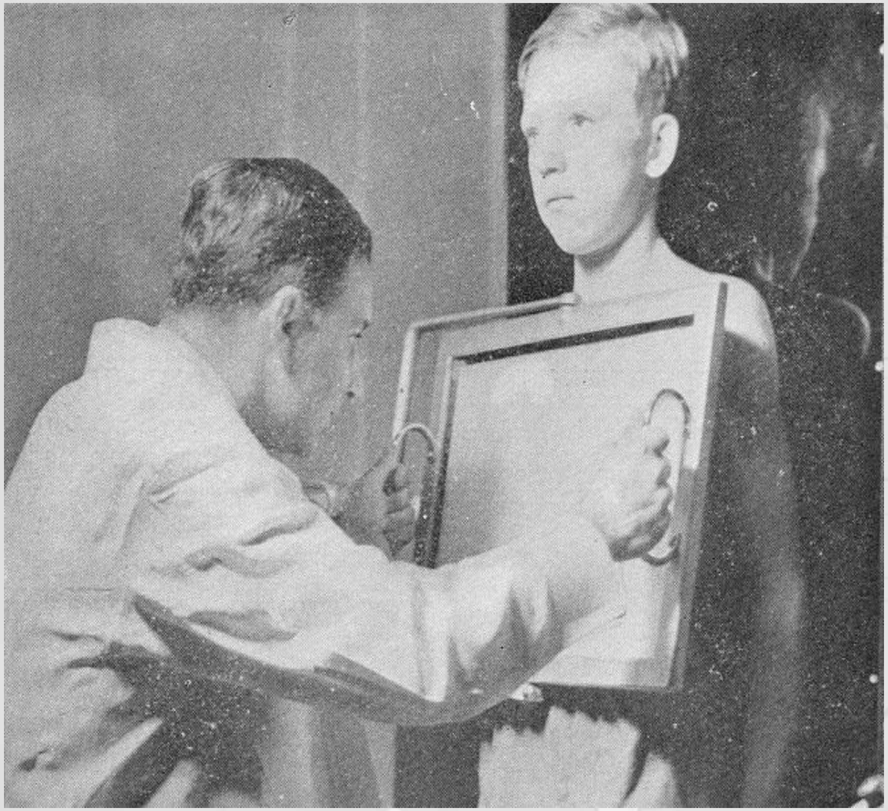
A radiologic technique in which a fluoroscope is used to visually examine the body or an organ. (A fluoroscope utilizes an X-ray tube and fluorescent screen, with the area to be viewed placed between the screen and the tube.) This immediate imaging, when coupled with an image intensifier, is invaluable in situations such as cardiac catheterization, thin needle biopsies of tumors, and localization of foreign bodies.

TUBE ABOVE THE TABLE

TUBE UNDER THE TABLE

C-ARM FLUOROSCOPY

CONVENTIONAL FLUOROSCOPY



kVp DEPENDS ON THE BODY PART BEING EXAMINED

- GALLBLADDER
- MYELOGRAM
- UGI
- BE

- 65-75
- 70-80
- 100-110
- 110-120

mA VARIES WITH THE BODY PART

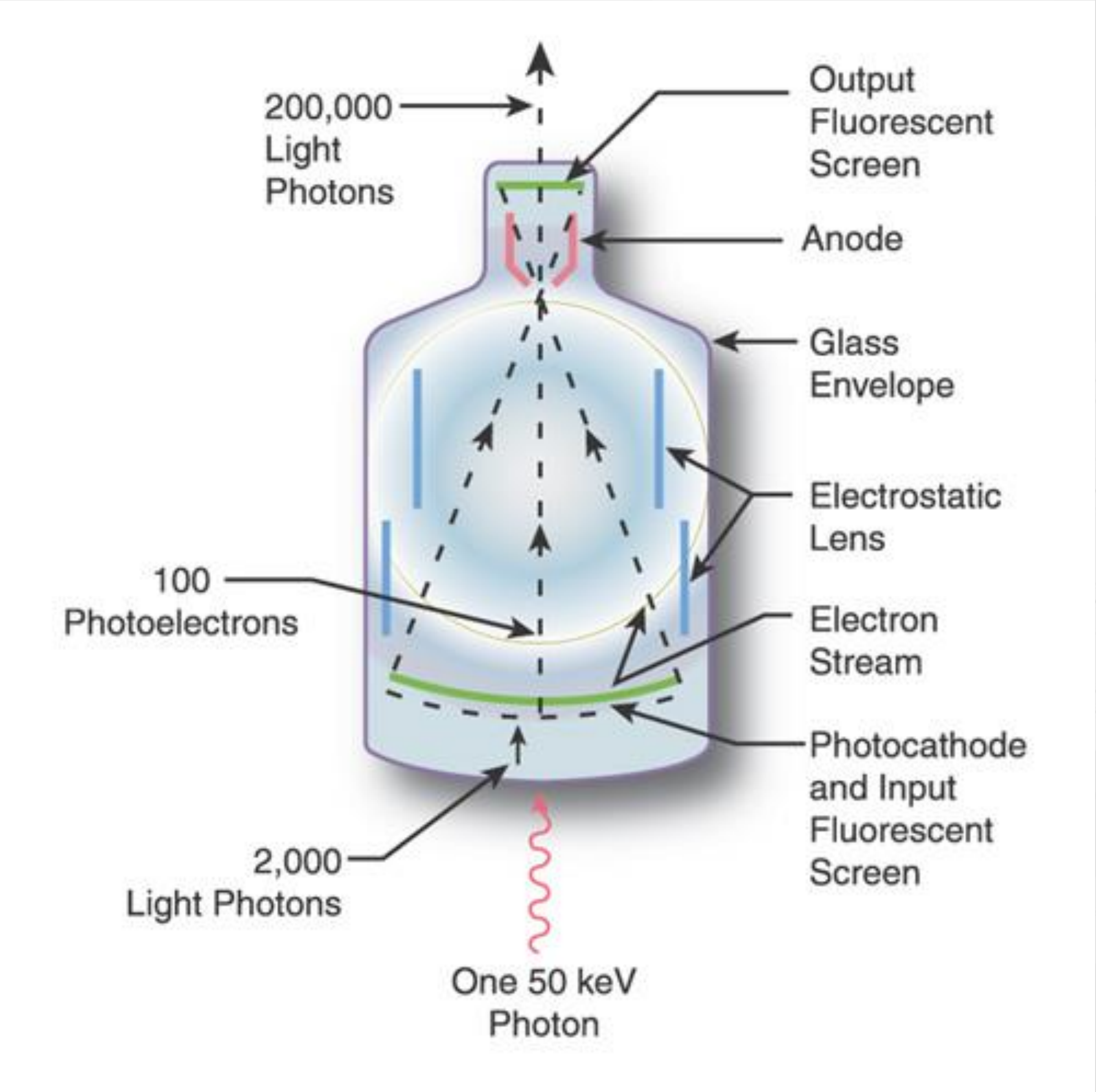
- USUALLY 1-5 mA

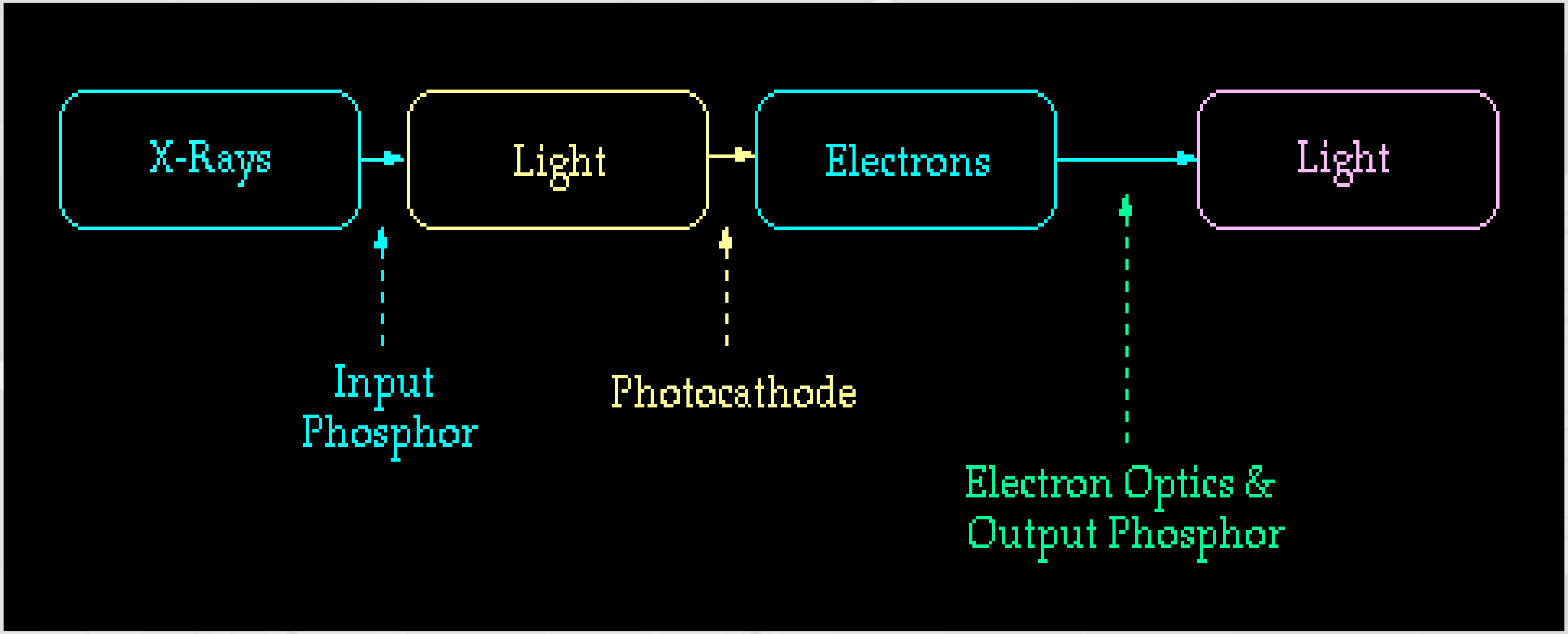
ABC AUTOMATIC BRIGTNESS CONTROL

- BRIGTNESS LEVEL AUTOMATICALLY MAINTAINED BY VARYING mA or kVp

IIMAGE INTENSIFIER

- INCREASES THE BRIGHTNESS OF AN IMAGE


200,000
Light
Photons
Output
Fluorescent
Screen
Anode
Glass
Envelope
Electrostatic
Lens
100
Photoelectrons
Electron
Stream
Photocathode
and Input
Fluorescent
Screen
2,000
Light Photons
One 50 keV
Photon



X-Rays
Light
Electrons
Light
Input Phosphor
Photocathode
Electron Optics &
Output Phosphor

BRIGTNESS GAIN (B.G.)

B.G. = Minification gain x Flux gain

MOST INTENSIFIERS: 5,000 – 20,000

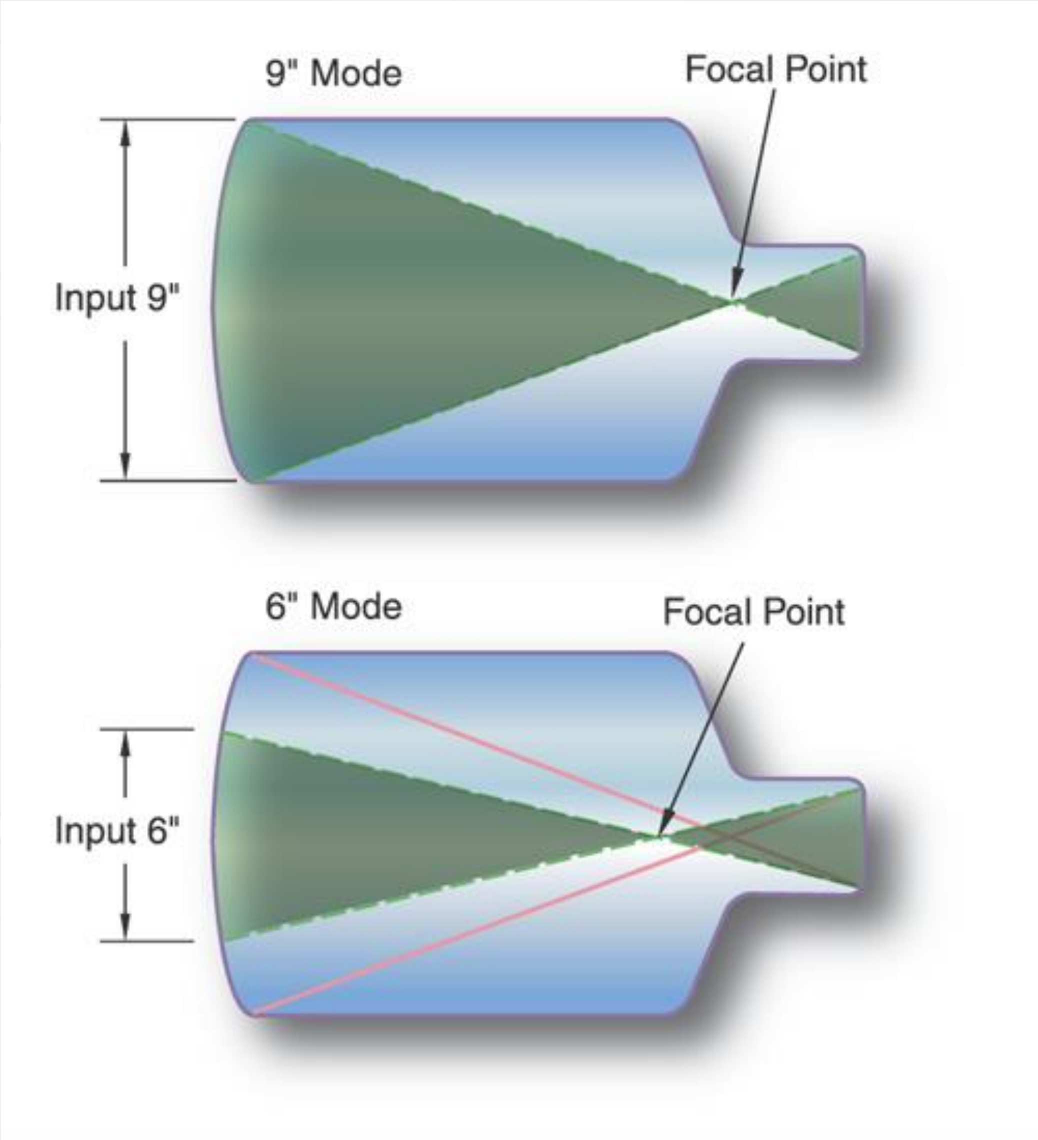
MINIFICATION GAIN

$$\frac{\text{SQUARE OF THE INPUT PHOSPHOR DIAMETER}}{\text{SQUARE OF THE OUTPUT PHOSPHOR DIAMETER}}$$

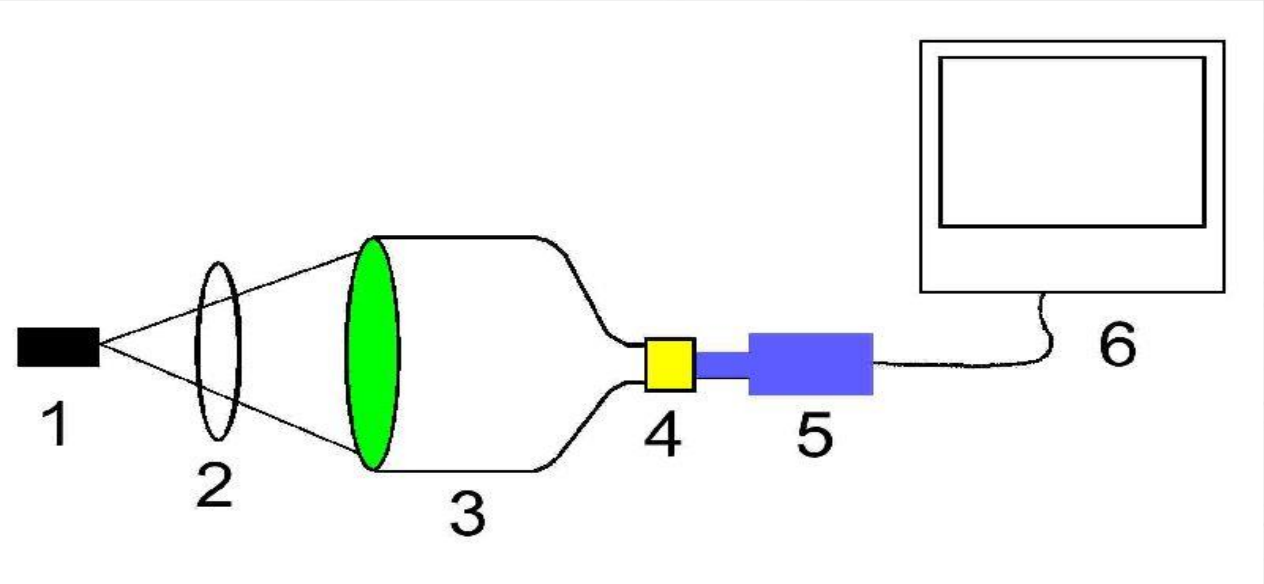
FLUX GAIN

$$\frac{\text{\# OF PHOTONS AT THE OUTPUT PHOSPHOR}}{\text{\# OF PHOTONS AT THE INPUT PHOSPHOR}}$$

MULTIFOCUS IMAGE INTENSIFIER

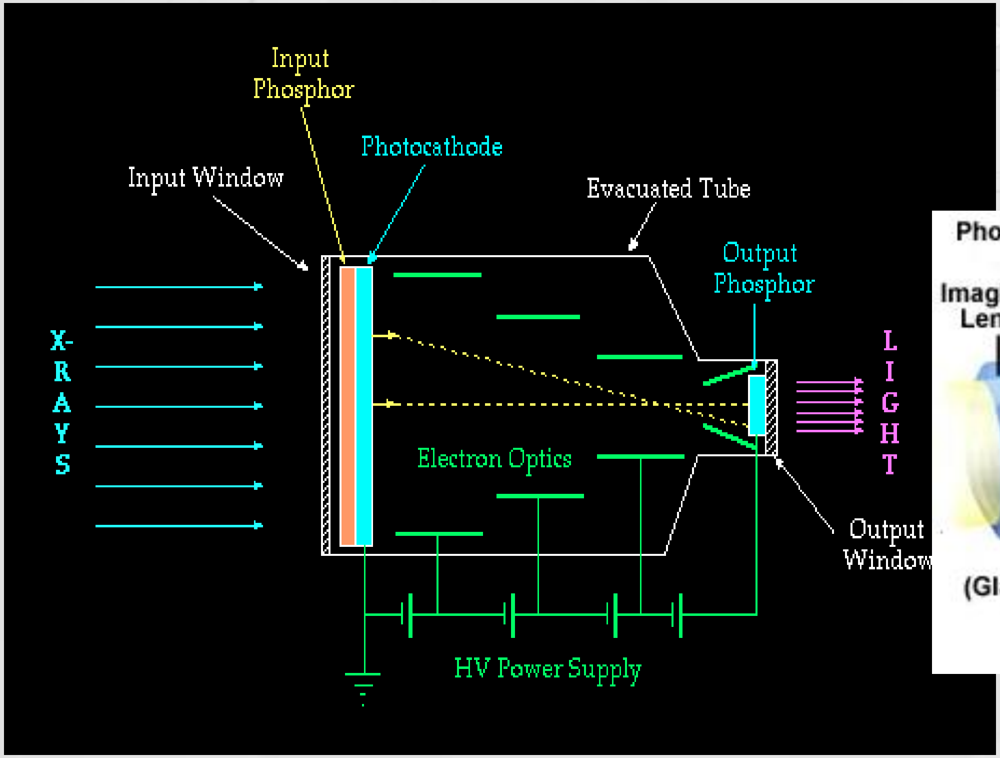


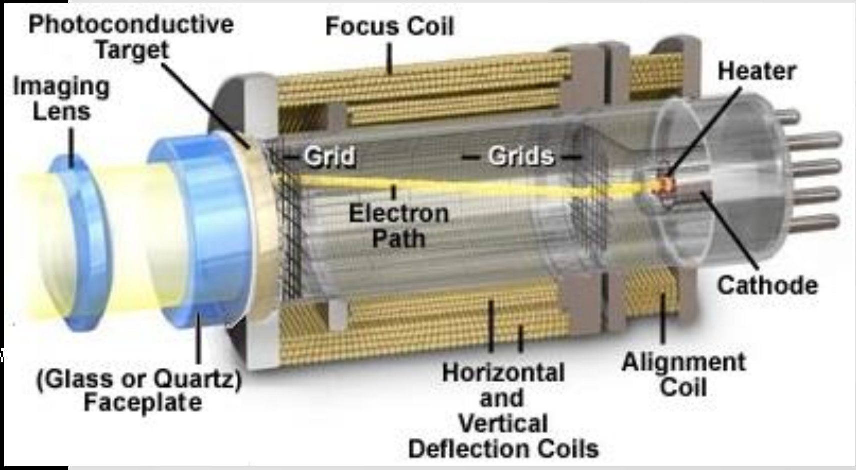
FLUOROSCOPIC DATA AQUSITION-IMAGE INTENSIFIED SYSTEM



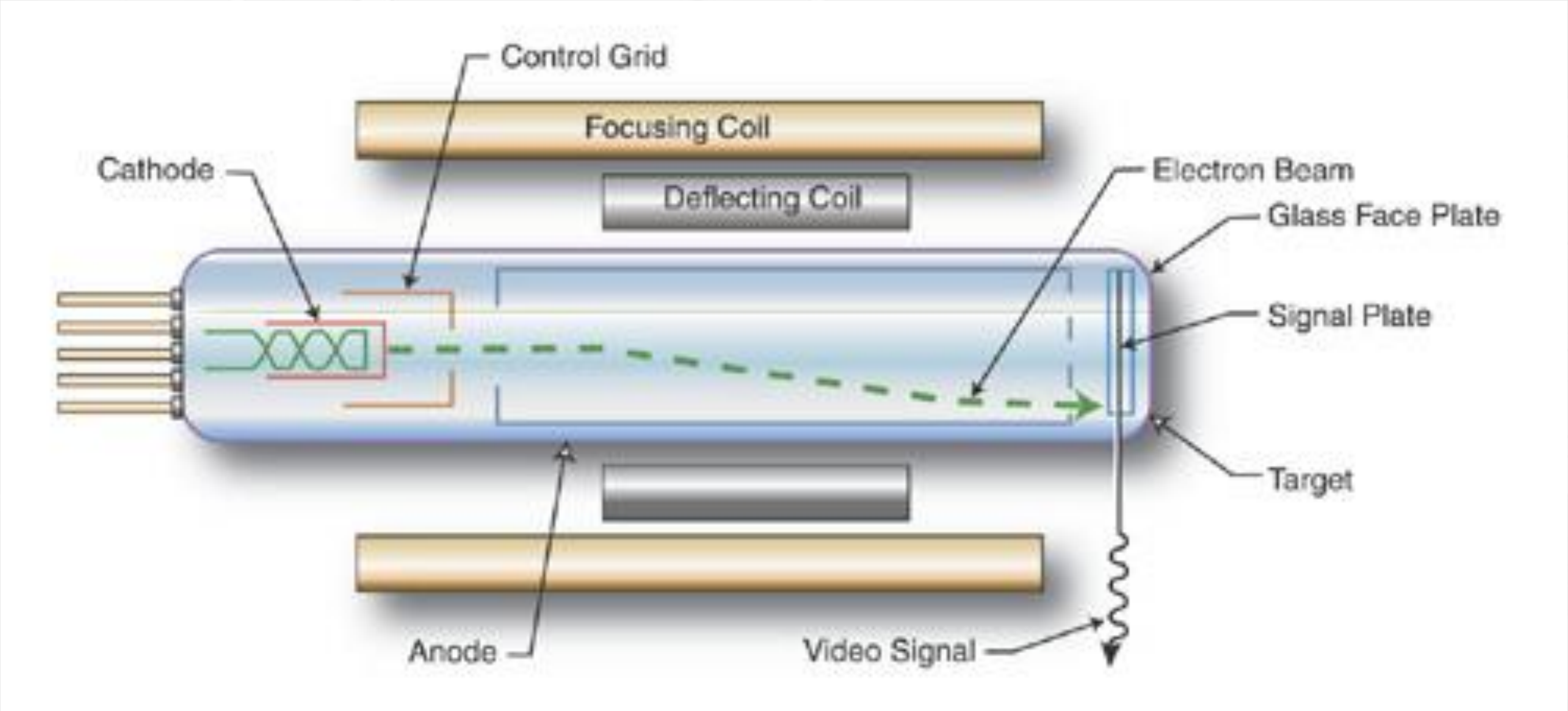
1. **X-RAY TUBE**
2. **PATIENT**
3. **IMAGE INTENSIFIER**
4. **OUTPUT PHOSPHOR**
5. **CAMERA**
6. **MONITOR**

CAMERA ATTACHED TO THE OUTPUT POSPHOR





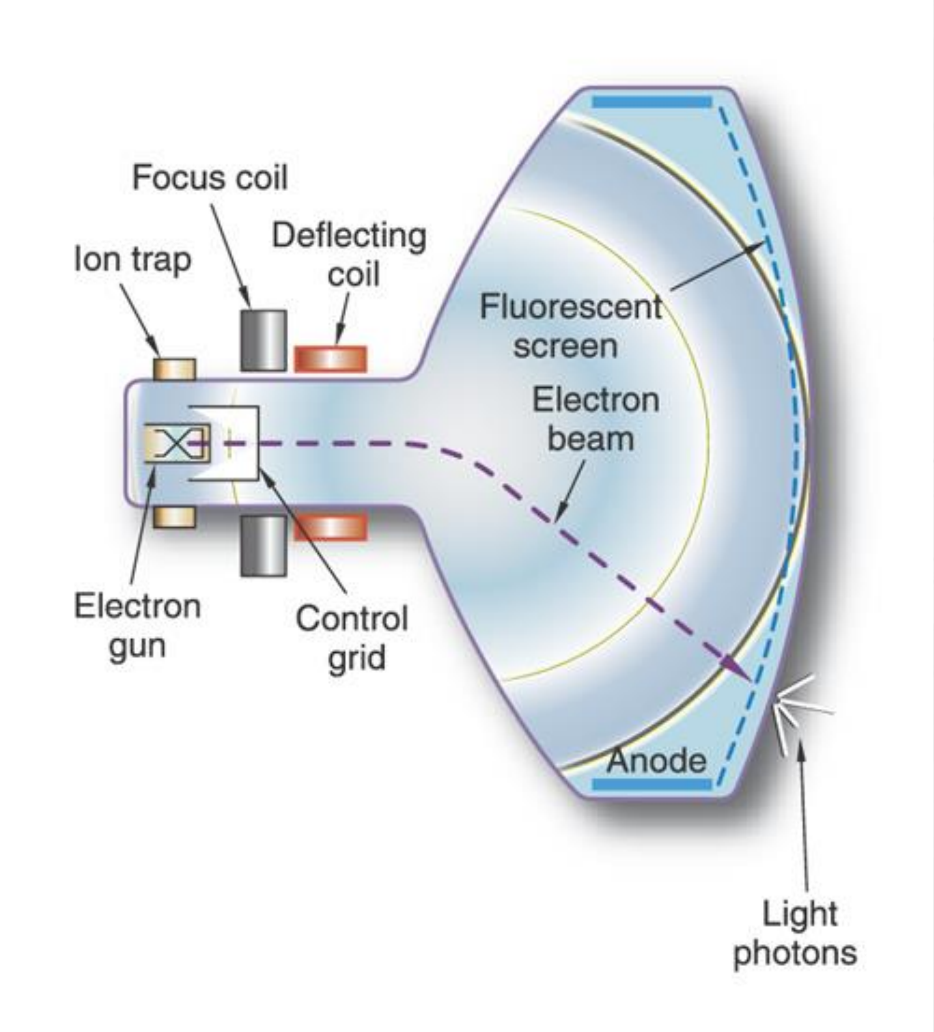
CAMERA


Control Grid
Focusing Coil
Cathode
Electron Beam
Deflecting Coil
Glass Face Plate
Signal Plate
Target
Anode
Video Signal

CAMERAS

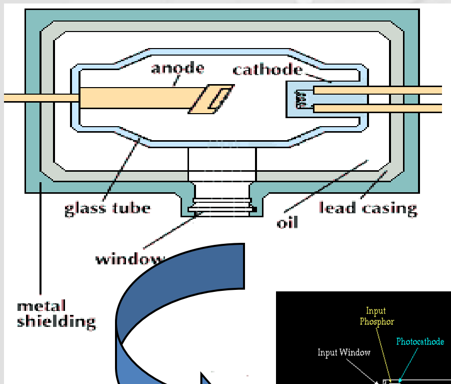
- PLUMBICON
- VIDICON

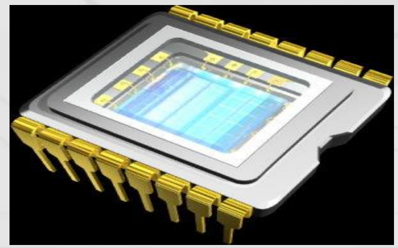
IMAGE DISPLAY

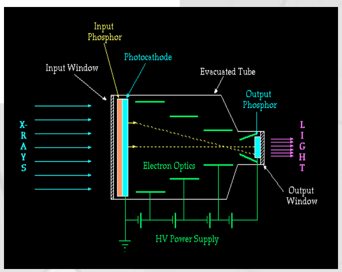


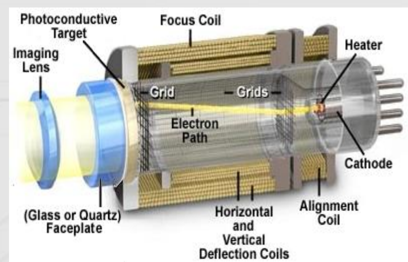
DIGITAL FLUOROSCOPY

FLUOROSCOPIC DATA AQUSITION-DIGITAL SYSTEM









ADC

DAC

ADVANTAGE OF DF OVER CONVENTIONAL I.I. FLUOROSCOPY

- SPEED OF IMAGE ACQUISITION
- POSTPROCESSING

DURING DF TUBE OPERATES IN RADIOGRAPHIC MODE

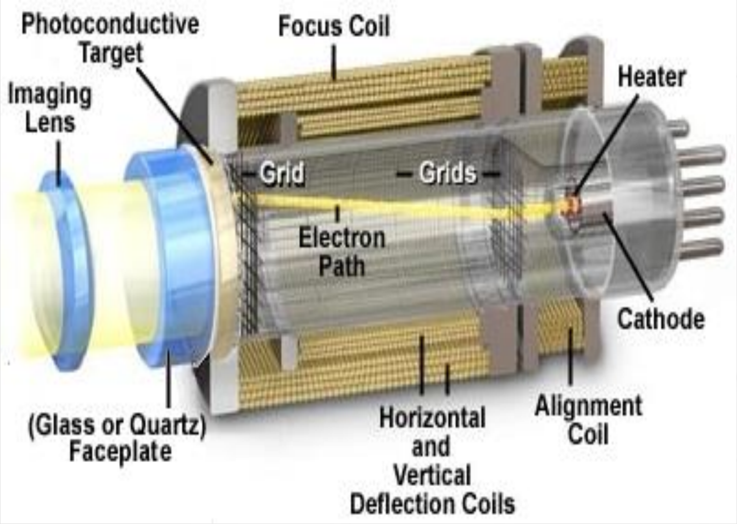
(HIGH mA value)

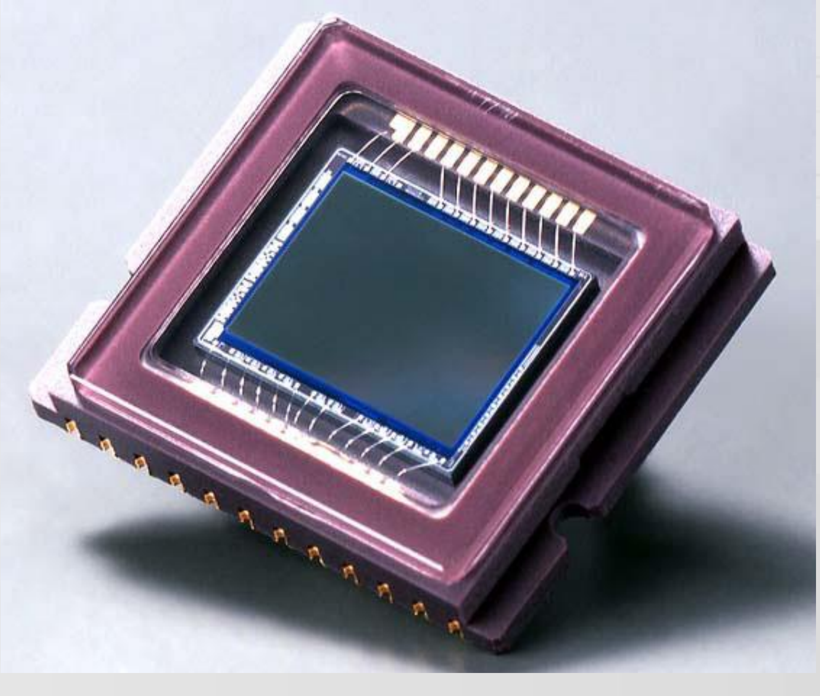
TUBE HEAT OVERLOAD!!!

NO, BEACAUSE OF PULSED BEAM!!!

PULSED PROGRESSIVE FLUOROSCOPY

IN 1980 CCD REPLACED THE CAMERA IN VIDEO SYSTEM





CCD SYSTEM ADVANTAGE OVER CAMERA SYSTEM

- HIGH DQE
- LOW LEVEL OF ELECTRONIC NOISE
- HIGH SPATIAL RESOLUTION
- NO LAG OR BLOOMING
- NO MAINTENANCE
- UNLIMITED LIFE
- UNAFFECTED BY MAGNETIC FIELD
- LINEAR RESPONSE
- LOWER DOSE

PIXEL SIZE

IMAGE INTENSIFIER SIZE / MATRIX