APPH 226:
Digital Image Acquisition : PSP (Cassette based) and the Reader

Objectives: 4.1, 4.2, 4.3, 6.1

MRT Program

Digital Radiography

- Categorized into:
- Computed radiography
  - CR
  - PSP (photostimulable phosphors)
- Direct radiography
  - DR
  - FPD (flat panel detectors)

Computed Radiography

- Can be integrated into existing radiography rooms
- No physical modification of x-ray unit required
  - AEC may need to be re-calibrated
  - Techniques within APR and manual technique charts will need to be adjusted
- Require a CR reader and a computer workstation

Computed Radiography

- Main difference between PSP and conventional radiography is:
  - An imaging plate (IP) takes the place of film and is in charge of storing the image
  - After the exposure, the cassette is 'read' and the phosphors release the stored light, converting it into an electrical signal, which is then digitized
  - The cassette is simply a lightproof container which protects an imaging plate instead of film

Primary Parts of CR system

- Cassette
- PSP plate (inside cassette)
- Cassette/CR reader
- Computer work station

Cassette

- Purpose: to contain the PSP plate
- Made of lightweight plastic
- Inside is lined with felt to protect against static buildup, dust and mechanical damage to the plate
- Backing made of aluminum or lead to absorb backscatter radiation
- Will have a window for barcode label to scan cassette to match with image information

PSP Plate or Imaging Plate (IP)

- Made up of several layers, similar to film-screen based system
  - Protective layer
  - Phosphor layer
  - Reflective layer
  - Conductive layer
  - Support layer

Layers of Imaging Plate

- Protective Layer
  - Purpose: to protect the phosphor layer
  - Thin layer of plastic
  - Coating over top of the phosphor layer

Layers of PSP plate

- Phosphor Layer (Active Layer)
  - Critical component of plate, contains the phosphors
  - Usually barium fluorohalide with europium
  - May contain dye to help prevent light spread
  - "Traps" electrons during exposure
  - Can be turbid or structured
    - Turbid – random distribution of phosphor crystals within active layer
    - Structured – columnar phosphor crystals within active layer resembling needles standing on end and packed together

Layers of PSP Plate

- Reflective Layer
  - Reflects light released during ‘reading phase’ toward the photodetector
- Conductive Layer
  - Reduces and conducts away static electricity
- Support Layer
  - Sturdy material to give some structure to the plate
  - May also have lead layer to absorb backscatter

Barcode

- On backing of cassette, there will be a window with a barcode
- Allows technologist to match the cassette with the patient information
- For every image, the barcode must be scanned to ‘assign’ the correct patient information to it

Acquiring the Image

- Image acquisition occurs in the same way
- A patient is positioned, and the body part aligned with the IR
- Patient is exposed with proper kVp and mAs, using the appropriate SID
- The difference is just in how the image is recorded

How it works – Image Acquisition

- When the PSP plate is exposed to x-rays, the x-ray photons interact with electrons in the crystals within the imaging plate
- Interaction gives energy to the electrons in the crystals, trapping them in an area of the crystal called the 'phosphor center'
  - The energy transfer caused by the x-rays exposing the PSP, results in excitation of electrons into a metastable state.
  - About 50% of these electrons return to their ground state immediately, emitting visible light

How it works – Image Acquisition

- Remaining metastable electrons are what create the latent image
  - Electrons return to ground state over time
    - Trapped signal can be held for hours, even for days, but the signal begins to deteriorate almost immediately – causing latent image to fade
    - After 8 hours, significant signal loss may occur
    - This is why it is best practice to process an exposed IR as soon as possible

Europium

- Is used as an activator for the phosphor
- Role is to capture some of the energy during the interaction process
  - Without it, there would be no latent image
- When the x-rays interact with the europium activated barium fluorohalide of the phosphor layer, some light is emitted immediately, but because of the europium, some of the x-ray energy (trapped electrons) will be stored as the latent image

Europium

- Quantity and distribution of the trapped electrons is proportional to the x-ray exposure received
- During processing, the energy of the trapped electrons is released by exposure to a laser
  - Called photostimulable luminescence

How it works - Stimulation

- After the image has been taken, the next step is processing through the CR Reader
- 1st step is stimulation
  - Finely focused beam of infrared light is directed at the PSP
    - Used to be Helium laser beam, but now usually a solid state laser is used
    - Beam diameter is 50-100 μm
      - Determines the spatial resolution of the CR system
- As the laser penetrates, it spreads
  - The thicker the PSP is, the more the laser will spread

How it Works – Reading/Detecting

- The scan process produces lines of light intensity information that is detected by a photodetector
  - Metastable electrons return to ground state
  - Emits energy in the form of visible light
- Light signal is detected and measured by the photodiodes of the photodetector and the latent image is made visible
  - Some signal loss will occur due to:
    - Scattering of emitted light
    - Collection efficiency of photodetector
      - Photodiodes (PD) are the photodetectors of choice for CR

How it works - Erasing

- Final stage is erasing
- Stimulation cycle does not completely transition all electrons back into ground state
  - Will still have some excited electrons
  - Could result in a residual image on the IP
    - "Ghosting" artifact
- The phosphor is flooded with very intense white light from specially designed fluorescent lamps
- This will remove any residual latent image

Additionally…

- PSPs should be used soon after they've been erased
- Sensitive to radiation, can be fogged by background radiation
- Laser light used to stimulate the PSP is monochromatic, the emitted light is polychromatic and of much lower intensity
- Optical filters are needed to allow only emitted light to reach the photodetector, and block out the intense stimulating light

CR Reader – Drive Mechanisms

- After the CR Cassette is inserted into the CR reader, IP is removed for processing
- Horizontal IP placement
- IP fits into a precision drive mechanism which moves the IP slowly at a constant rate along the long axis
  - Called the 'slow scan' mechanism
  - Critical that the motor drive is absolutely constant
  - Movement must be constant as even small fluctuations can result in banding artifacts

CR Reader - Mechanisms

- While the IP is moving in the 'slow scan', a mirror is used to deflect the laser beam back and forth across the IP
  - This is the 'fast scan' mechanism
- Both scans (slow and fast) work together so that the laser beam is blanked during re-trace
- Error tolerance allowed is very small
  - Only fractions of a pixel
  - Edges of an image can appear 'wavy' in a CR reader that is out of tolerance

CR Reader – Vertical Placement

- Another method is with the cassette being placed vertically into reader
  - This is what we have in lab
- Once cassette is inserted, the IP is withdrawn downward and the cassette is scanned by a horizontal beam
- IP barely leaves cassette so it is less likely to be damaged
- Reduced occurrence of aliasing artifacts because the scan pattern is not parallel with grid lines

CR Reader – Optical Components

- Goal is to extract the information from the latent image as precisely as possible
  - Laser
  - Beam shaping optics
  - Light collecting optics
  - Optical filters
  - Photodetector

CR Reader - Laser

- Source of stimulating light
- Light spreads as it travels
- A lens system keeps the beam diameter small when it is focused onto the mirror
  - Less than 100 μm
- When the mirror deflects the laser across the IP, it changes size and shape
  - Additional beam shaping optics correct this and keep the size, shape and intensity constant

CR Reader – Light Collection and Photodetector

- Light that is emitted from the IP is then funneled into a fiber optic collection assembly before it is directed at the photodetector (or PMT, PD or CCD)
- Before the light reaches the photodetector, it is filtered so that none of the stimulation light goes through and swamps the emitted light signal
  - Emitted light is the signal
  - Stimulating light is the noise
    - Proper filtering improves the signal-to-noise ratio

CR Reader – Computer Control

- After the light signal leaves the photodetector, the output analog signal transmits to a computer system
  - Light emitted from the phosphors is converted into an electrical signal
  - The electrical signal is sampled and digitized to represent a specific brightness and location within the image matrix
- Signal is shaped before the final image is formed and displayed
- Image can be stored temporarily before it is transferred to a workstation or archived

Imaging Characteristics

- Process of imaging with film vs CR is not very different
- Same process of positioning patient, using appropriate exposure techniques, patient care and radiation protection
- The only difference is in what happens after the exposure is taken
  - CR – processed through CR reader
  - Film – processed through film processor

Limitations of Film (Analog)

- Limited dynamic range (the range of exposure intensities that an image receptor can accurately detect)
- Cost
- Time
- Film processors – equipment and maintenance costs
  - Frequent quality control procedures
- Processed film is permanent, no adjustments can be made
- Cannot be electronically stored or duplicated
- Additional expense of storing radiographs and retrieving them

Readings

- Radiologic Science for Technologists 11th Ed
  - Pg. 283 – 292 (Stop at Image Receptor Response Function)

- Digital Radiography and PACS
  - Pg. 58 - 69