Introduction to Digital Radiography [CR/DR], Computed Tomography [CT], and Magnetic Resonance Imaging [MRI]

Daniel A. Feeney DVM, MS
Professor of Veterinary Radiology

College of Veterinary Medicine
University of Minnesota

1

What Is Digital Radiography?

- Making radiographic images as versatile as pictures from your digital camera
- Making radiographic images visible and storable on a personal computer or a hospital-wide system
- ELIMINATING (or at least minimizing) HARD COPIES???

2

Food For Thought

→ →

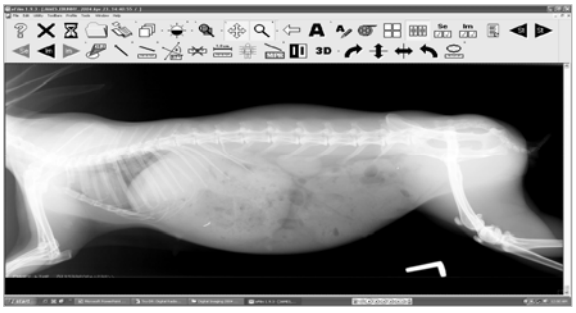
3

Food For Thought

→ →

4

Image Viewing Software



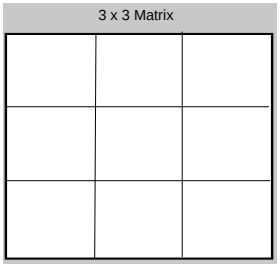
E-film [MERGE] as example

Digital Images

- Composed of a matrix of pixels
  e.g. 512 x 512 pixels, 1024 x 1280, etc
- Pixels = “picture elements”
- Each pixel is assigned a value (number)
- In imaging, the value of each pixel determines the grayness of the pixel [current standard is 256 shades of grey]

6

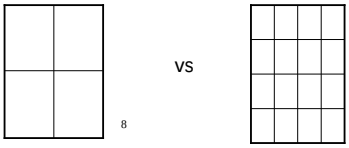
Image Matrix (pixel arrangement)?



7

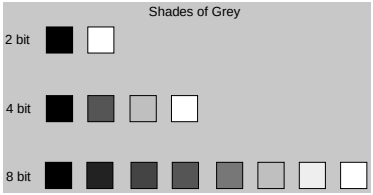
Digital Images – Take Home Points

- More bits per pixel will yield more shades of grey (a longer scale) in a displayed image
- The larger the image matrix (for a given area imaged), the greater the spatial resolution (clarity)
- Therefore, increasing the number of pixels (while keeping image area same) will result in smaller pixel size.



8

2 bits, 4 bits, 6 bits, a $?



- A pixel that has only 1 bit depth would only have two possible values (0 and 1)
- A pixel that has 8 bits would have a maximum value of 255 (2^8 -1).

9

Connectivity – the importance of DICOM

- Digital Imaging and Communication in Medicine
- DICOM standard is critical for information exchange between modalities (CR/DR, CT, U/S…), image viewing software, storage devices, and printers
- Provides image and image information standards for ALL modern imaging modalities

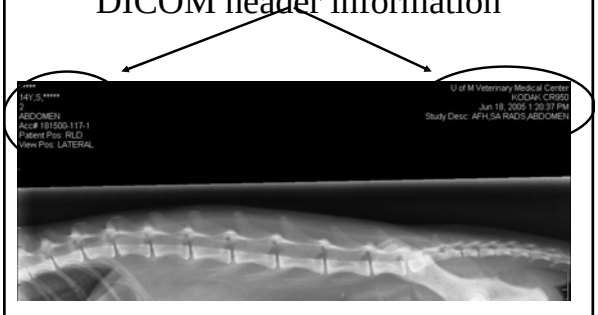
10

DICOM

- Think of DICOM like a JPEG or TIFF file with consistent labeling fields (.dcm)
- DICOM defines the protocols for storing, querying, retrieving, sending, and printing digital images
- DICOM images also contains critical image "header" information
  - Patient ID, name, study date, positioning, etc.

11

DICOM header information



12

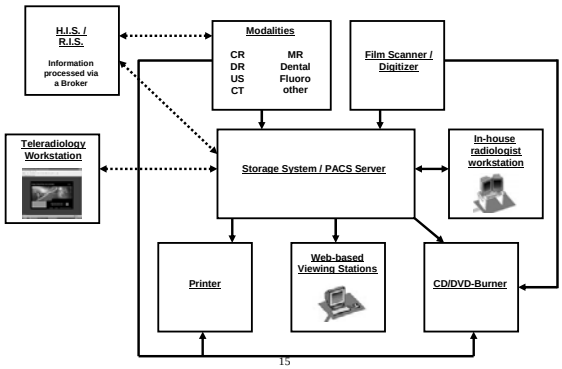
What Is A PACS?
(Picture Archive & Communication System)

- Simplest: a hospital system for digital image distribution and storage
  - Access any patient's images from any computer
  - Access any patient's images from home
  - Could include any appropriately formatted digital image (endoscopic or dermatologic pictures)
- Mid-range: a hospital system for the distribution/storage of images and the associated interpretations
  - A Radiology Information System (RIS)
- High-end: fully integrated imaging (RIS), medical record, and hospital information system (HIS)

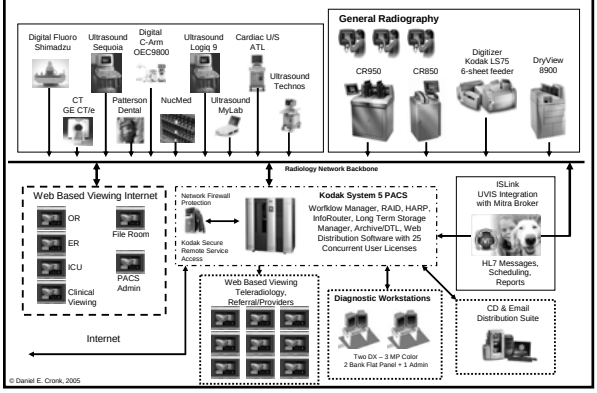
Components of a PACS

- Imaging modality:
  CR, DR, MRI, CT, US, NM, etc.
- Hospital intranet [LAN]/internet connections
- Viewing computers/workstations
- Central computer (server)
- Storage components – hard drives, DVD
- Potential interface to the hospital information system (HIS)

Example PACS Configuration



University of Minnesota College of Veterinary Medicine PACS



Why Might A Digital System Be Relevant To Private Practice?

- Easy access to current and previous patient imaging data
  - May require transition period [both old films and digital images]
  - May require "incremental digitization" of old films
- Better utilization of tech and doctor time
  - May be offset by the need for computer expertise
  - Less time filing, tracking and retrieving
- No Darkroom
  - No film inventory
  - No hazardous chemicals (disposal and OSHA issues)
  - No automatic processor or hand developing tanks
  - No service contracts
  - Free up space for production or storage

What Would "Going Digital" Enable Me to Do?
(that I'm not doing now)

- Improve quality of "marginal" exposures
  - NOT a solution to bad radiographic technique
  - NOT an alternative to quality control
  - Net effect is fewer "retakes"
- Retrieve images from any "enabled" computer
  - From home
  - At a meeting (wireless)

What Would "Going Digital" Enable Me to Do?
(that I'm not doing now)

- Easily send images for second opinion
  - Direct internet transfer (? ISP upload speed)
  - NOT an alternative to quality control
    - e.g. send bad images and hope for information
- Easily send images for referral
  - Burn a CD/DVD
  - Direct internet transfer (? ISP upload speed)

19

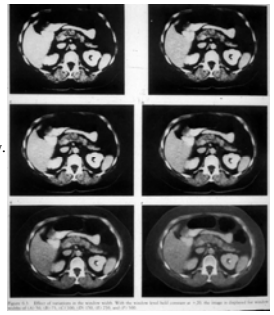
Image Viewing
(software/workstation)

- Provides tools for image manipulation
  - Magnification
  - Window/leveling
  - Hanging Display
  - Comparative viewing with previous images
  - Image labeling

20

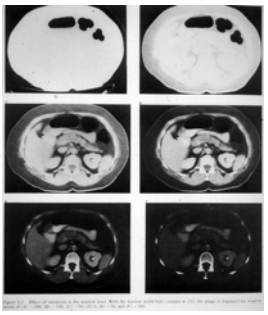
Computed Tomography [window width]

FROM: Morgan CL: Basic Principles of Computed Tomography. University Park Press, Baltimore, 1983.



Computed Tomography [window level]

FROM: Morgan CL: Basic Principles of Computed Tomography. University Park Press, Baltimore, 1983.



Picture of Workstation

23

What Are The Types Of Digital Radiographic Systems?

- CR (computed radiography)
  - Cassette-equivalent (europiumdoped barium-fluoro-halide crystallized matrix plate)
  - Laser spot scanning → photostimulation luminesence (PSL) → photomultiplier detection
  - X-ray → latent image in plate phosphor → light (PSL) → light detected → analog to digital conversion (ADC) → pixels
- CCD (charge-coupled device)
  - Scintillation phosphor → light → minification via optical coupling lens → CCD device

24

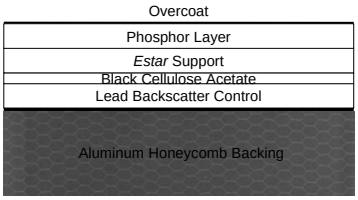
What Are The Types Of Digital Radiographic Systems?

- Flat Panel Detector
  - DR (direct digital radiography)
    - Amorphous selenium photoconductive layer yields electrons
    - Charges stored in matrix array or storage capacitors
  - DR (indirect digital radiography)
    - CsI (light from X-ray) → photodiode (amorphous silicon) → thin-film transistor storage

25

Diagram of CR

- Plates have embedded photostimulable phosphors
- Similar to the intensify screen phosphors used in traditional film cassettes
- Used just like film-based cassettes



CR Image Formation

- X-ray production → x-rays thru patient → strike plate
- Latent image formation on the phosphor plate
  - Low energy electrons in the phosphors are elevated and trapped in a metastable energy state

27

CR Image Formation

- Plate is placed in film reader "processor"
- Plate is scanned with a red laser light
- Laser light inputs energy into the plate, knocking the electron out of the trap.
- The electron returns to lower energy level by giving of excess energy as visible light

28

CR Image Formation

- Visible light energy is detected by a collection of PhotoMultipler Tubes
- PMT's amplify the light energy signal
- The analog energy signal is converted to a digital image via an analog to digital converter
- Image is ready for final processing

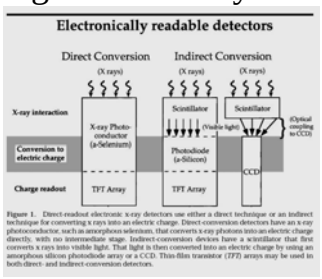
29

CR Image Formation

- The image is then computer processed with the appropriate algorithm
  - For example, a thorax image is processed to show bone, soft tissue, fat, and air opacities with appropriate relation contrast
  - A different algorithm would be applied to an abdominal image because of fat/soft tissue mixtures contributing to the image.

30

Diagram of DR Systems



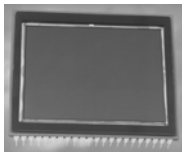
FROM: Chotas HG, Dobbins JT and Ravin CE: Principles of digital radiography with large-area electronically readable detectors; A review of the basics. Radiology 210:595-599. 1999.

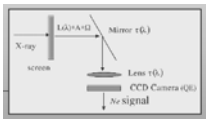
Diagram of CCD

FROM: Keith Wetzel, Eastman Kodak Company

Digital Radiography: CCDs Deserve Another Look

Advanced Imaging, October, 2004





Large Format CCD (3.88 x 5 cm)

What about image <u>resolution</u> in these systems?

- Spatial: (line pairs/mm)
  - typical film-screen = +/- 10 lp/mm
  - CR = 2.5 – 5.0 lp/mm
  - DR = 2.5 – 5.0 lp/mm
- Contrast:
  - CR better than typical film-screen
  - DR better than typical film-screen

Diagram of Basic Digital System

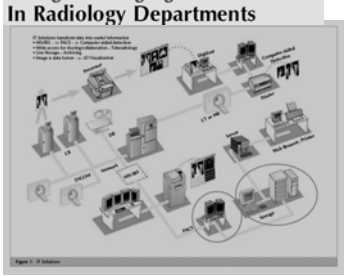
FROM: U-MN Kodak System

FROM Hudson Digital Systems

Diagram of PACS

FROM: Michael W. Jackman, Kodak Health Imaging Group

A Digital Imaging Transformation In Radiology Departments



www.HCTProject.com

What Are the <u>Costs</u> Of Private Practice-relevant Digital Radiography?

- CR
  - Basic $40-75K
- DR
  - Basic $75-120K
- CCD
  - Basic $35-60K (with new X-ray table)

What Type Of Digital Radiography Is Best For Private Practice?

- CR (computed radiography/cassettes)
  - Moderate Volume (3-6 cases/day)
  - Need for flexibility (horizontal-beam, intra-op)
- DR (flat panel detectors)
  - High volume (> 10 cases/day)
  - Fixed to one machine unless use "portable" system
- CCD (digital camera equivalent under table)
  - Moderate to high volume
  - Fixed to one machine

37

Advantages of Tele-imaging

- Brings a radiologist "into" the clinic
- Improves diagnostic yield and accuracy
- Improves patient care
- Continual CE for the clinic

38

References

- Andriole KP: Productivity and cost assessment of computed radiography, digital radiography, and screen-film for outpatient chest examinations. J Digit Imag 15:161-169, 2002.
- Chotas HG, Dobbins JT and Ravin CE: Principles of digital radiography with large-area electronically readable detectors; A review of the basics. Radiology 210:595-599. 1999.
- Dreyer KJ, Mehta A and Thrall JE: PACS: a guide to the digital revolution. Springer, New York, 2002.
- Huang HK: PACS and imaging informatics. Wiley-Liss, Hoboken, 2004.

39

References

- Kroft JM. Veldkamp WJH, Mertens BJA, et. al.: Comparison of eight different digital chest radiography systems: variation in detection of disease. Am J Roentgenol 185:339-346, 2005.
- Morgan CL: Basic Principles of Computed Tomography. University Park Press, Baltimore, 1983.
- Relner BI, Salkever D, Siegel EL, et. al.: Multi-institutional analysis of computed and direct radiography Part II. Economic analysis. Radiology 236:420-426, 2005.
- Relner BI, Salkever D, Siegel EL, et. al.: Multi-institutional analysis of computed and direct radiography Part I. Technologist productivity. Radiology 236:413-419, 2005.

40