# Image Information Overload: The Challenge

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# What is it Like to Be a Radiologist/Healthcare Provider Today?

- National statistics suggest that radiologists are reading more studies than ever before
- Dire radiologist shortages across the country have further exacerbated this problem
- Challenge is to read more studies without sacrifice in quality

# “Fighting a Losing Game”
## Metaphor for Radiology in the 21st Century?

# First 5 Phases of the Transformation of the Radiologist's Interpretation Process

- 1. Film
- 2. Static soft-copy
- 3. Dynamic
- 4. Stack mode and linked stack mode
- 5. Multi-planar and volumetric navigation

# Phase 1: Film Based Interpretation Using Alternators and Multiple View Boxes

Dr. Reiner Zoom and Pan

Dr. Reiner Edge Enhancement

# Phase 2: Static Soft-Copy Interpretation

- Cross sectional images presented in static “tile” mode similar to film

# Static Soft-Copy Interpretation

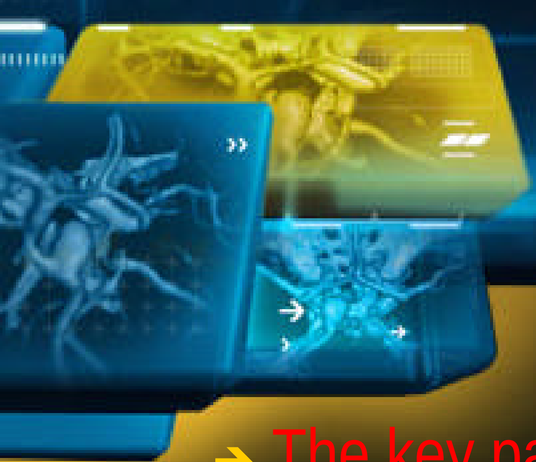
- Radiologists judge the image quality based on how closely it simulates the “look” of film
  - 4 or more monitors
  - Must optimize the image for initial presentation as with film

# Phase 3: Dynamic

- Radiologists learn to rapidly and eventually unconsciously window and level and to use other workstation tools

# Phase 4a:  Stack Mode and Linked Stack Mode

- Takes advantage of the visual system's enhanced ability to detect motion or other changes in a visual field
- Stack mode increases interpretation efficiency as well as accuracy
- No one has published on linked stack mode but is promising



# Phase 5: Volumetric Navigation Multi-planar and 3D Imaging

- The key paradigm shift:
  - Just as digital imaging disengages the process of acquisition, storage and display previously associated with film
  - **Process of image review is separated from the manner in which they were acquired and reconstructed**

# Pathologists vs. Radiologists

- Pathologists have traditionally performed volumetric imaging with vast amounts of image information on a slide which can be moved around in a single plane
- Pathologists then navigate through multiple different focal planes on single slide

# Radiologist Image Interpretation: From Static to Dynamic

- Amount of data on single pathology slide to digitize for tele-pathology might be the equivalent of hundreds or thousands of multi-channel CT scanners
- Radiologists will need to behave more like pathologists, exploring a slide from different perspectives at different levels than the passive radiologist reviewing images on film model

# Volumetric Navigation

- CT scanners, for the most part, acquire images in the axial plane
- However once a volume of patient data is acquired, the radiologist is now free to review or navigate through the data in an unlimited number of ways

# Information Overload

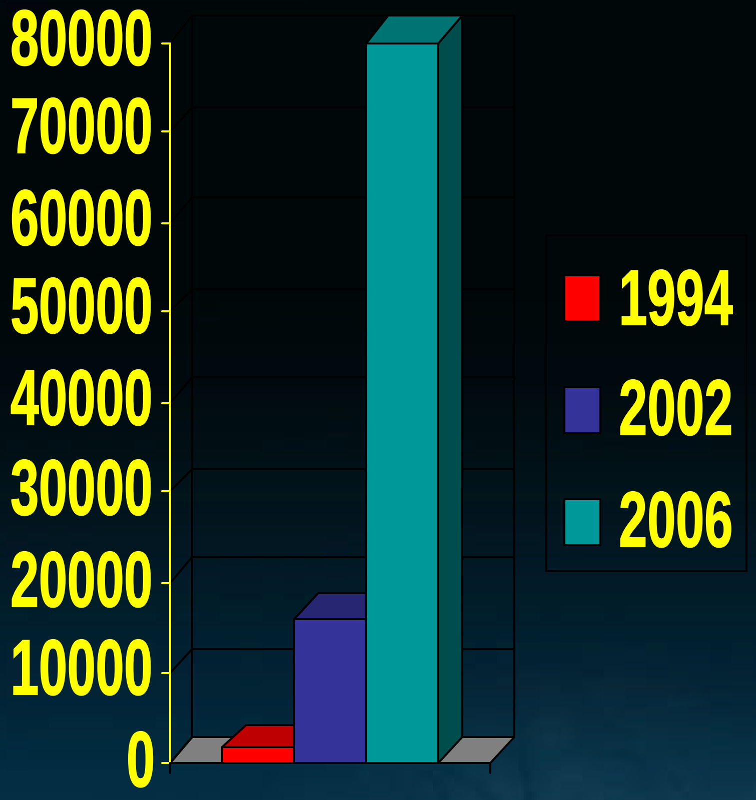
- Stack mode is not adequate for review the 300 to 500 images acquired for a routine CT of the chest or the abdomen and pelvis and is even less so for the 1,500 to 2,000 images acquired for a CTA "runoff" study

# CT Image Overload: Mayo Clinic Jacksonville Experience

- According to Dr. Richard Morin at the Mayo Clinic Jacksonville:
  - 1994: Daily number of CT images per radiologist was approximately 1,500
    - Only 24 seconds per CT image given 10 hour workday with no breaks

# Mayo: Image Information Overload

- 2002: 16,000 CT images per day per radiologist, approx. 2 seconds per image
- Projected 2006: 80,000 CT images per day about 0.45 seconds per image
- At 1 image per second would take >22 hours to review all of the CT images



# Volume Overload Seen in other Modalities

- General radiography
  - Dual energy subtraction routine at Baltimore VAMC, has doubled size of studies
  - Temporal subtraction could also increase size of general radiology studies
  - Tomosynthesis for general radiography and mammography could increase number of images generated by factor of 10 or more
- MR functional data and more complex sequences has increased number of images many times

# Image Information Overload from Other Modalities

- Cardiac angiography studies generate large numbers of images, may generate 30 images per second with each image 1,000 by 1,000 by 14 bit matrix
- Flat panel large detector CT in future will require very large amount of storage

# Strategies for Coping with Image Overload in CT

- Reconstruct thick CT sections
  - Acquire images using a multi-detector scanner using thin collimation and then reconstruct the images that are sent to PACS using much thicker (e.g. 5 mm. or 8 mm.) sections
- Yields three to ten fold reduction in the number of images sent to PACS.

# Problems with Image Generation by Technologists at Modality Workstation

- This works well for specialty studies such as virtual CT colonoscopy but is unsatisfactory for routine imaging for several reasons
  - It requires a large amount of additional technologist time
  - Reconstructed images take up a good deal of archival, network, and workstation memory space.

# Problems with Image Generation by Technologists at Modality Workstation (continued)

- Radiologists may be constrained to review routine images in the axial plane at a pre-determined, usually relatively thick plane of section, which negates the added value of the new generation of multi-detector scanners

# 3D Imaging

- Once considered by radiologists to be limited to “eye-candy” for referring clinicians and patients
- Can be very useful in providing:
  - general survey of an area
  - portrays anatomic structures such as the ribs that course in an oblique plane

# Readout Session: Routine CT of the Thorax, Indication Mass RUL on CXR

# Are We Trading Image Volume Overload for Clinical Image Information Overload?

- We can use these workstations to render images of the spine and other bones, pulmonary and abdominal and pelvis vasculature, and other structures that are comparable to dedicated studies of the spine and CT angiograms
- Single “routine” trauma study becomes:
  - CT brain, CT sinuses, CT coronal sinuses, CT cerebral angiogram, CT neck, CTA carotids, CT cervical spine, CT thorax, CT pulmonary angiogram, CT thorax, high resolution chest CT, etc.

# Clinical Controversies in Multi-planar and Volumetric CT

- Our abdominal and thoracic sub-specialists have asked
  - Are we now “responsible” for detailed reports of the musculoskeletal system and spine and of the individual vessels now visualized on a routine “body” CT study

# Clinical Controversies in Multi-planar and Volumetric CT

- Should they specifically and routinely comment, for example, on the renal arteries, aortic and iliac arteries, superior and inferior mesenteric arteries?
- What are the implications of this on the time required to dictate a study?

# Integration of Advanced Workstation Tools in PACS

- Integration of these advanced workstation tools which were typically built as features for dedicated modality workstations for the technologists into the workflow of a PACS can be very difficult
- In most departments, these high-end modality workstations are expensive
- These workstations are usually not networked to each other and comparison studies are rarely available due to the limited archival space

# Integration of Advanced Workstation Tools in PACS (continued)

- Non-radiology healthcare providers do not have access to the workstations and can only see rendered images that are pushed from the workstation to the PACS
- On the whole this typical set-up is inefficient, expensive, and provides limited accessibility to images

# Clinicians and Multi-planar / 3D Imaging

» Clinicians use multi-planar and 3D in many ways and will use 3D and multi-planar images routinely in next few years

- Clinical practice
  - Podiatrists -- evaluation of muscles, tendons, detailed fracture evaluation
  - Orthopedic surgeons – evaluation of hardware (difficult with conventional CT due to artifacts), more precise visualization of anatomy in patients with fractures and other pathology
  - Pulmonary physicians – coronal and sagittal perspective for chest imaging
  - Neurosurgeons – improved spine visualization especially on sagittal and coronal views

# Integration of Multiplanar and 3D Into the Workflow

- Perhaps the biggest barrier to the transition to the use of volumetric navigation has been the lack of integration of this capability in the current generation of PACS workstations
- It is not practical for a radiologist interpreting a study using a PACS workstation to walk (or even slide) over to a dedicated 3D/multiplanar workstation for each case

# PACS Workstation of Future

- In order to move from a Photoshop paradigm for interpretation static images as was the case with the old film alternators, we also need to completely rethink PACS workstation design
- Some have suggested that the controls absolutely must be more intuitive like a car

# What if PACS Vendors Designed Your Driver Controls?

- Car TRIP

# Comment Attributed to a boasting Bill Gates at Comdex Show

- "If GM had kept up with technology like the computer industry has, we would all be driving twenty-five dollar cars that got 1000 miles to the gallon.“

# GM's Response
## What if GM Had Developed Technology Like Microsoft Windows?

- Every time a new car was introduced car buyers would have to learn how to drive all over again, because none of the controls would operate in the same manner as the old car
- The airbag would ask "are you sure" before deploying
- **Occasionally, for no reason whatsoever, your car would lock you out and refuse to let you in until you simultaneously lifted the door handle, turned the key and grabbed hold of the radio antenna**

# How We Do It in Baltimore

- We use an enterprise wide 3D/multiplanar system in which a separate, 3D/multiplanar "PACS" provides the "horsepower" for advanced processing using a client/server model
- Approximately one dozen PC clients at a time can share the server at a time, allowing each generic "vanilla" PC connected on the network to function as though it had the power and speed of a high-end 3D/multiplanar advanced workstation
- All of the CT studies are pushed to the central server and thus made available to our hospital PC's located throughout the department and hospital

# Advanced Imaging Display and Processing: The Future

- Network speed increasing only relatively slowly in most hospitals and represents constraint for transfer of large datasets
  - Datasets of 1,000 to 4,000 (typical trauma CT at University of Maryland) or more images take too long to transfer to individual workstations

# Advanced Imaging Display and Processing: The Future

- We are now running into a new bottleneck, CT image reconstruction speed where reconstruction times take longer than scan times
  - Currently 2 images per second, even increasing to 20 images per second still over 3 minutes for 4,000 images, 30 minutes for 40,000 images
- In the future, we may routinely process on the fly from the CT raw dataset

# Future Solutions?

- Cannot transfer 4,000 (typical University Trauma case) or 1,000 images to local workstation just in time
  - » Network speed is becoming more of a bottleneck with only minimal improvements in most facilities during past few years
- In next few years, advanced display, imaging processing, and analysis tools will be performed centrally with resources shared across the network
  - » Model more like cable TV on demand with user controlled streaming videos that are interactive
- Can use this model not only for 3D and multi-planar but can share CPU and GPU and advanced hardware/software across network which is more efficient than providing this capability to every “thick” client or making network sufficiently fast

# What will the future bring diagnostic imaging in our ever continuing TRIP?

- The next major phases in the continuing TRIP will focus on decision support tools such as computer assisted diagnosis (CAD) and cuing and more sophisticated integration with the electronic medical record

# What will the future bring diagnostic imaging in our ever continuing TRIP? (continued)

- Computer assisted cuing may take many forms including an overlay in which, for example, micro-calcifications are circled on a mammogram and lung nodules are colored in a shade of red that depends on their probability of malignancy on a color display

# Other Coping Mechanisms in Addition to CAD

- Image content based indexing for search and retrieval has met with limited success but may be useful as a tool for decision support
- Lossy image compression can be performed for large datasets but our research suggests that thinner sections are less compressible using 2D DCT or wavelet compression (but 3D JPEG 2000 is promising)
  - This is becoming very important as we try to cope with new ways to archive and transfer these very large datasets

# Future Trends in Diagnostic Imaging to Cope with Image Information Overload

- Image navigation will improve substantially over the next few years with alternative input devices and better navigation software
- Clinical information will be extracted and summarized using a digital dashboard equivalent
- Image subtraction and image warping will be useful for comparison of current and prior studies which can be major challenge without these technologies

# New Challenges (continued)

- These future developments will undoubtedly create additional challenges and concerns that will undoubtedly require the creativity and expertise of the medical imaging community

# Radiologist of the Future: Maybe…

# New Paradigms for Image Interpretation?

# Dr. Barkley:  Radiologist of the Future?

# Image Information Overload: The Challenge

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# The Future:  The Good News…

- The best thing about the **future** is that it comes one day at a time.
  - » Abraham Lincoln

# Create Our Own Future

- The best way to predict the future is to create it…
  - » Alan Kay

# “The future ain't what it used to be”
## Yogi Berra