Radiologist’s Digital Workspot

John A. Carrino, M.D., M. P. H.
Hospital for Special Surgery
New York, NY
Radiology Workspot Requirements

• Visualization

• Information

• Decision Support
Radiology Workspot Requirements

- Visualization
- Information
- Decision Support
Medical Imaging Objectives

- Extract info from within living organisms
- Provide spatially discrete mapping
- Image as a surrogate record of morphology & physiology
- Guidance for Procedures
“Radiology is the only medical specialty created by technology”

Bob Moliter

SCAR News, April 1995
Physics Asks…

How do matter and energy interact

- Do nothing at all
- Scatter, reflect, refract
- Absorb
- Excite (e.g., glow or spin)
- Impart molecular change

Courtesy of Jeff Siewerdson, PhD
<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>Contrast resolution</th>
<th>Spatial resolution</th>
<th>Temporal resolution</th>
<th>Physiologic/Functional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiography</td>
<td>+</td>
<td>+++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Fluoroscopy</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>CT</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>MRI</td>
<td>+++</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>US</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>NM</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+++</td>
</tr>
</tbody>
</table>
The Nobel Prize in Physics 1901 was awarded to Wilhelm Conrad Röntgen "in recognition of the extraordinary services he has rendered by the discovery of the remarkable rays subsequently named after him".

http://www.nobelprize.org/nobel_prizes/physics/laureates/1901/
The Nobel Prize in Physiology or Medicine 1979 was awarded jointly to Allan M. Cormack and Godfrey N. Hounsfield "for the development of computer assisted tomography"
The Nobel Prize in Physics 1952

"for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"

Felix Bloch

Edward Mills Purcell

USA

Harvard University
Cambridge, MA, USA

The Nobel Prize in Chemistry 1991

"for his contributions to the development of the methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy"

Richard R. Ernst

Switzerland

Eidgenössische Technische Hochschule

The Nobel Prize in Physiology or Medicine 2003

"for their discoveries concerning magnetic resonance imaging"

Paul C. Lauterbur

Sir Peter Mansfield

USA

University of Illinois Urbana, IL, USA

United Kingdom

University of Nottingham, School of Physics and Astronomy
Nottingham, United Kingdom
DIAGNOSIS

Exposure

Energy Source Subject

Signal Pattern

Imaging System

Image

Detect

Clinician Eye-Brain Combination

Sensory Image

Clinician Brain

Display System

Viewing System

Display
The reason a radiologist is required to assume that the overwhelming number of ambiguous things are normal, in other words, is that the overwhelming number of ambiguous things really are normal. Radiologists are, in this sense, a lot like baggage screeners at airports. The chances are that the dark mass in the middle of the suitcase isn't a bomb because you've seen a thousand dark masses like it in suitcases before, and none of those were bombs—and if you flag every suitcase with something ambiguous in it, no one would ever make his flight. But that, of course, doesn't mean that it isn't a bomb. All you have to go on is what it looks like on the X-ray screen—and the screen seldom gives you quite enough information.

Malcom Gladwell, 2004, The New Yorker
Satisfaction of Search (SOS)

• Important source of error in the detection of subtle abnormalities
• Obvious abnormalities capture visual attention and decrease vigilance
• History appears to direct perceptual resources to the prompted abnormalities, thereby alleviating satisfaction of search
Imaging and Therapy

Dx  GTx  Tx

Courtesy of Jeff Siewerdson, PhD
Figure 1a  <p>Evolution of radiologic imaging display paradigms. (a) Analog light box or alternator. (b) Analog view of digital modality (CT) using tile mode with one set window and level. (c) Simple picture archiving and communication system (PACS) workstation using digital display but largely static film paradigm. (d) Dynamic digital display paradigm with simultaneous stack or cine mode of images from multiple orthogonal MR sequences. (e) Advanced postprocessed 3D volume-rendered CT images with color and multiplanar reformations. (f) PET, CT, and fused PET/CT, from top row to bottom row, respectively.</p>

Published in: "Optimizing Analysis, Visualization, and Navigation of Large Image Data Sets: One 5000-Section CT Scan Can Ruin Your Whole Day" Andriole et al.
Radiology Vol. 259, No. 2: 346-362
©RSNA, 2011

One PowerPoint slide of each figure may be downloaded and used for educational, non-promotional purposes by an author for slide presentations only. The RSNA citation line must appear in at least 10-point type on all figures in all presentations. Pharmaceutical and Medical Education companies must request permission to download and use slides, and authors and/or publishing companies using the slides for new article creations for books or journals must apply for permission. For permission requests, please contact the Publisher at permissions@rsna.org.
Radiology Workspot Requirements

• Visualization
• Information
• Decision Support
Premise

• Relevant clinical information enables the radiologist to interpret imaging findings in the appropriate context, leading to . . .

  – More relevant diff dx
  – More useful report for clinicians
  – Better outcome for the patient
SIIM 2014:
U Chicago: Obara, Sevenster, Quan, Travis, Chang

• Evaluated the quality of clinical hx accompanying radiology orders

• Did they include known chronic conditions pertinent to the radiological interpretation?
  – e.g., lupus, Crohn’s disease, cancer, HIV
SIIM 2014:
U Chicago: Obara, Sevenster, Quan, Travis, Chang

40% Relevant chronic conditions not in Hx/Indication from referring providers

35% Radiologist effort, added the information to report (EHR, prior rad report, or from MD)

25% No evidence radiologist was aware of relevant condition
Why not make better use of the EHR?

• Does “in the dark” = the best read?
• Clinicians have pt data
• Shouldn’t Radiology?
Clinical Data

Patient and Order Data

Order and exam data

Some order and exam data

Courtesy of Dr. Cree M. Gaskin, UVA
EHR Data while reading on PACS
How to get it

• EHR-driven workflow

• Enslave EHR, keep context with PACS

• Third-party to pull EHR data and share information
EHR-Driven: Single vendor RIS/EHR

Courtesy of Dr. Cree M. Gaskin, UVA
EHR-Driven = Centralized Activities

- Protocoling
- Reading studies
- Chart review/search
- “Meaningful use”
- Teaching file
- Tech work lists
- Manage referrals

- Report creation and signing
- MD performance metrics
- Administrative reports
- Peer review (prior while reading)
- Charting – orders, notes
- “Watch” patients; result tracking
- Communication with providers
EHR-driven: UVA

Courtesy of Dr. Cree M. Gaskin, UVA
Protocoling: Relevant Data

- Demographics
- Reason for exam
- Associated diagnosis
- Allergies
- Patient and provider contact information
- Order and scheduling questions/answers
- Prior matching exam
Protocoling: Available Data

• Relevant labs
• Previous protocols (2014) – copy forward
• Full chart access
EHR-Driven = Data

• Full patient chart
  – All patient information
  – All ordering information
  – All exam information
  – Pre-selected, filtered, boiled down
Patient images
EHR-driven workflow

• Centralizes tasks
• Efficient delivery of more data
• Better care? More informed “reads”
• Improved provider communication
• Improved stratified report turnaround times
• Meaningful use incentives – yes
Interpretation

• You see what you look for

• You look for what you know

• You need to know what you don’t know
The thickness of all growth plates has been notably reduced: this is less evident in the radius and ulna.

Fusion of the epiphysis and the diaphysis has begun in the distal phalanx of the thumb.

Epiphyseal fusion has begun in the 3rd - 5th proximal phalanges.

This standard represents typical skeletal development near menarche: it is similar to the 15 Year, 6 Month Male Standard, which corresponds with male puberty.

Epiphyseal fusion has begun in the 1st metacarpal.

Any accessory sesamoid bones which will develop are usually evident by this stage.

The 2nd metacarpal base has completed capping the trapezoid.
EXAMINATION: Bone Age Study (PA view of left hand and wrist)

DATE OF EXAM: August 29, 2012
CLINICAL INDICATION: []
COMPARISON: [<None>]
DATE OF BIRTH: June 09, 1999
SEX: Female

FINDINGS:
The bones exhibit normal morphology.
The patient’s chronological age is 13 years 2 months.

This report is partly based upon data from the Brush Foundation Study of Human Growth and Development. The standard deviation for this patient’s chronological age group is 10.67 years.

The bone age is estimated to be 13 years 6 months, which corresponds to 0.3 standard deviation above the mean.

IMPRESSION:
Normal skeletal maturity.

[Signature]
Bone age reporting by faculty*

**Manual**
- Time: 90 sec
- Report errors: 23%
- Preference: No

**Integrated software**
- Time: 45 sec
- Report errors: 0%
- Preference: Yes, 9/9

*abstract submitted to a spring 2015 meeting*
What is an Ontology?

• Description of essential reality
• What actually is, as opposed to what one can see (observation), or what one can know (epistemology)
• Metaphysical commitments or presuppositions embodied in the different natural sciences
Ontology

• Structured organization of knowledge

• In medical informatics, ontology has come to mean a structured list of concepts, typically prepared by an expert or panel of experts
Ontologic modeling of the biceps brachii muscle. (a) Drawing illustrates the biceps brachii muscle. (Reprinted, with permission, from reference 36.) (b) Chart illustrates a related ontology fragment, with relationships indicated by arrows and accompanying text (italics). Conceptual relationships may be interpreted as “subject-verb-object” sentences in which the subject is the concept at the origin of the arrow, the relationship itself constitutes the verb, and the object is the concept at the arrow’s destination. Different relationships are used to indicate parts (eg, biceps brachii muscle “has-part” long head of biceps brachii), types (eg, biceps brachii “is-a” muscle), and attachments (eg, tendon of long head of biceps brachii “attaches-at” supraglenoid tubercle). Note that ontologies also often encode reverse relationships (eg, long head of biceps brachii is “part-of” biceps brachii muscle) (not shown).

Published in: "Ontology-based Image Navigation: Exploring 3.0-T MR Neurography of the Brachial Plexus Using AIM and RadLex"
Wang et al.
RadioGraphics Vol. 35, No. 1: 142-151
©RSNA, 2015
Ontologic modeling of the biceps brachii muscle. (a) Drawing illustrates the biceps brachii muscle. (Reprinted, with permission, from reference 36.) (b) Chart illustrates a related ontology fragment, with relationships indicated by arrows and accompanying text (italics). Conceptual relationships may be interpreted as “subject-verb-object” sentences in which the subject is the concept at the origin of the arrow, the relationship itself constitutes the verb, and the object is the concept at the arrow’s destination. Different relationships are used to indicate parts (eg, biceps brachii muscle “has-part” long head of biceps brachii), types (eg, biceps brachii “is-a” muscle), and attachments (eg, tendon of long head of biceps brachii “attaches-at” supraglenoid tubercle). Note that ontologies also often encode reverse relationships (eg, long head of biceps brachii is “part-of” biceps brachii muscle) (not shown).

Published in: "Ontology-based Image Navigation: Exploring 3.0-T MR Neurography of the Brachial Plexus Using AIM and RadLex"
Wang et al.
RadioGraphics Vol. 35, No. 1: 142-151
©RSNA, 2015

One PowerPoint slide of each figure may be downloaded and used for educational, non-promotional purposes by an author for slide presentations only. The RSNA citation line must appear in at least 10-point type on all figures in all presentations. Pharmaceutical and Medical Education companies must request permission to download and use slides, and authors and/or publishing companies using the slides for new article creations for books or journals must apply for permission. For permission requests, please contact the Publisher at permissions@rsna.org.
Figure 2  <p>Web-based application architecture for an ontology-driven imaging atlas. The application server manages images in a DICOMDigital Imaging and Communications in Medicine archive and maintains a set of image annotations encoded with the AIMAnnotation and Image Markup standard. The application server responds to client requests for images using the DICOMDigital Imaging and Communications in Medicine Web Access to DICOM Digital Imaging and Communications in Medicine Persistent Objects (WADOWeb Access to DICOM Persistent Objects) protocol. RadLex data are dynamically retrieved from a separate ontology server through a Web services interface. In this example, the client has used DICOMDigital Imaging and Communications in Medicine WADOWeb Access to DICOM Persistent Objects to display a coronal T2-weighted SPACEsampling perfection with application optimized contrasts by using different flip angle evolutions MR image in the region of the brachial plexus (blue = axillary vein).</p>

Published in: "Ontology-based Image Navigation: Exploring 3.0-T MR Neurography of the Brachial Plexus Using AIM and RadLex"
Wang et al.
RadioGraphics Vol. 35, No. 1: 142-151
©RSNA, 2015

One PowerPoint slide of each figure may be downloaded and used for educational, non-promotional purposes by an author for slide presentations only. The RSNA citation line must appear in at least 10-point type on all figures in all presentations. Pharmaceutical and Medical Education companies must request permission to download and use slides, and authors and/or publishing companies using the slides for new article creations for books or journals must apply for permission. For permission requests, please contact the Publisher at permissions@rsna.org.
Figure 3a  Browser-based interface to ontology-driven imaging atlas. (a) Drop-down menus (top) provide a mechanism for selecting structures by category and name (the subclavian artery has been selected in this example). Image annotations are shown in the atlas in blue, with the currently selected structure highlighted in brighter opaque blue and other available annotations shown in darker transparent blue. (b) Any available annotation may be selected by moving the cursor over the structure of interest (the coracoclavicular ligament has been selected in this example). Annotations may be toggled on and off to more fully reveal the underlying imaging appearance. Additional information about a structure of interest may be obtained by means of a pop-up menu, which is invoked with the right mouse button. (c) Pop-up menu for the supraspinatus muscle with attachment information derived from RadLex.

Published in: "Ontology-based Image Navigation: Exploring 3.0-T MR Neurography of the Brachial Plexus Using AIM and RadLex"
Wang et al.
RadioGraphics Vol. 35, No. 1: 142-151
©RSNA, 2015

One PowerPoint slide of each figure may be downloaded and used for educational, non-promotional purposes by an author for slide presentations only. The RSNA citation line must appear in at least 10-point type on all figures in all presentations. Pharmaceutical and Medical Education companies must request permission to download and use slides, and authors and/or publishing companies using the slides for new article creations for books or journals must apply for permission. For permission requests, please contact the Publisher at permissions@rsna.org.
Browser-based interface to ontology-driven imaging atlas. (a) Drop-down menus (top) provide a mechanism for selecting structures by category and name (the subclavian artery has been selected in this example). Image annotations are shown in the atlas in blue, with the currently selected structure highlighted in brighter opaque blue and other available annotations shown in darker transparent blue. (b) Any available annotation may be selected by moving the cursor over the structure of interest (the coracoclavicular ligament has been selected in this example). Annotations may be toggled on and off to more fully reveal the underlying imaging appearance. Additional information about a structure of interest may be obtained by means of a pop-up menu, which is invoked with the right mouse button. (c) Pop-up menu for the supraspinatus muscle with attachment information derived from RadLex.

Published in: "Ontology-based Image Navigation: Exploring 3.0-T MR Neurography of the Brachial Plexus Using AIM and RadLex"
Wang et al.
RadioGraphics Vol. 35, No. 1: 142-151
©RSNA, 2015

One PowerPoint slide of each figure may be downloaded and used for educational, non-promotional purposes by an author for slide presentations only. The RSNA citation line must appear in at least 10-point type on all figures in all presentations. Pharmaceutical and Medical Education companies must request permission to download and use slides, and authors and/or publishing companies using the slides for new article creations for books or journals must apply for permission. For permission requests, please contact the Publisher at permissions@rsna.org.
Figure 3c  <p>Browser-based interface to ontology-driven imaging atlas. (a) Drop-down menus (top) provide a mechanism for selecting structures by category and name (the subclavian artery has been selected in this example). Image annotations are shown in the atlas in blue, with the currently selected structure highlighted in brighter opaque blue and other available annotations shown in darker transparent blue. (b) Any available annotation may be selected by moving the cursor over the structure of interest (the coracoclavicular ligament has been selected in this example). Annotations may be toggled on and off to more fully reveal the underlying imaging appearance. Additional information about a structure of interest may be obtained by means of a pop-up menu, which is invoked with the right mouse button. (c) Pop-up menu for the supraspinatus muscle with attachment information derived from RadLex.</p>

Published in: "Ontology-based Image Navigation: Exploring 3.0-T MR Neurography of the Brachial Plexus Using AIM and RadLex"
Wang et al.
RadioGraphics Vol. 35, No. 1: 142-151
©RSNA, 2015

One PowerPoint slide of each figure may be downloaded and used for educational, non-promotional purposes by an author for slide presentations only. The RSNA citation line must appear in at least 10-point type on all figures in all presentations. Pharmaceutical and Medical Education companies must request permission to download and use slides, and authors and/or publishing companies using the slides for new article creations for books or journals must apply for permission. For permission requests, please contact the Publisher at permissions@rsna.org.
Ontology-assisted image navigation. (a) Pop-up menu reveals that the superior, middle, and inferior trunks of the brachial plexus, as well as a portion of the subclavian artery, course through the interscalene triangle. (b) Entries in the pop-up menu system are themselves selectable, and choosing the middle trunk of the brachial plexus links to a representative image and annotation. (c) Graphical annotation browsing may then be used to demonstrate that the middle trunk of the brachial plexus lies superior to the subclavian artery. In this way, the application facilitates exploration of the ontologic and spatial relationships between structures.

Published in: "Ontology-based Image Navigation: Exploring 3.0-T MR Neurography of the Brachial Plexus Using AIM and RadLex"
Wang et al.
RadioGraphics Vol. 35, No. 1: 142-151
©RSNA, 2015

One PowerPoint slide of each figure may be downloaded and used for educational, non-promotional purposes by an author for slide presentations only. The RSNA citation line must appear in at least 10-point type on all figures in all presentations. Pharmaceutical and Medical Education companies must request permission to download and use slides, and authors and/or publishing companies using the slides for new article creations for books or journals must apply for permission. For permission requests, please contact the Publisher at permissions@rsna.org.
Figure 4b  Ontology-assisted image navigation. (a) Pop-up menu reveals that the superior, middle, and inferior trunks of the brachial plexus, as well as a portion of the subclavian artery, course through the interscalene triangle. (b) Entries in the pop-up menu system are themselves selectable, and choosing the middle trunk of the brachial plexus links to a representative image and annotation. (c) Graphical annotation browsing may then be used to demonstrate that the middle trunk of the brachial plexus lies superior to the subclavian artery. In this way, the application facilitates exploration of the ontologic and spatial relationships between structures.

Published in: "Ontology-based Image Navigation: Exploring 3.0-T MR Neurography of the Brachial Plexus Using AIM and RadLex"
Wang et al.
RadioGraphics Vol. 35, No. 1: 142-151
©RSNA, 2015

One PowerPoint slide of each figure may be downloaded and used for educational, non-promotional purposes by an author for slide presentations only. The RSNA citation line must appear in at least 10-point type on all figures in all presentations. Pharmaceutical and Medical Education companies must request permission to download and use slides, and authors and/or publishing companies using the slides for new article creations for books or journals must apply for permission. For permission requests, please contact the Publisher at permissions@rsna.org.
Figure 4c  Ontology-assisted image navigation. (a) Pop-up menu reveals that the superior, middle, and inferior trunks of the brachial plexus, as well as a portion of the subclavian artery, course through the interscalene triangle. (b) Entries in the pop-up menu system are themselves selectable, and choosing the middle trunk of the brachial plexus links to a representative image and annotation. (c) Graphical annotation browsing may then be used to demonstrate that the middle trunk of the brachial plexus lies superior to the subclavian artery. In this way, the application facilitates exploration of the ontologic and spatial relationships between structures.

Published in: "Ontology-based Image Navigation: Exploring 3.0-T MR Neurography of the Brachial Plexus Using AIM and RadLex"
Wang et al.
RadioGraphics Vol. 35, No. 1: 142-151
©RSNA, 2015
Radiology

- Anatomy
- Physiology
- Pathology
- Interpretation
- Nosology
- Communication
WANTED
A STANDARD APPROACH TO INCIDENTALOMA

Radiology Business

Incidental Adrenal Mass (2 cm or less) Detected on CT or MR

- Imaging features are diagnostic
  - Myelolipoma, ca** = benign, no F/U
  - HU ≤ 10 or ↓ signal on CS-MR = adenoma

- Imaging features not diagnostic
  - > 4 cm
    - No history of cancer: consider resection
    - History of cancer: consider PET or biopsy
  - 1-3 cm
    - No prior imaging: No history of cancer
    - Suspicious imaging features
    - Benign imaging features
      - Presume benign, consider 12 month F/U or MR
  - Prior imaging
    - Stable ≥ 1 year
      - Benign
    - Lesion enlarging
      - Concerning for malignancy: Consider biopsy or resection

LEGEND

1. If patient has clinical signs or symptoms of adrenal hyperfunction, consider biochemical evaluation
2. Consider biochemical testing to exclude pheochromocytoma
3. Benign imaging features = homogeneous, low density, smooth margins
4. Suspicious imaging features = heterogeneous, necrosis, irregular margins

APW = absolute percentage washout
RPW = relative percentage washout
CS-MR = chemical shift MRI
F/U = follow-up
HU = Hounsfield unit
↓ = decreased

Adrenal washout CT

- No enhancement (≤ 10 HU) = cyst or hemorrhage
  - Benign
  - Adenoma
- APW / RPW > 60/40%
  - APW / RPW > 60/40%
  - Consider PET or MRI

Biopsy if appropriate or consider CS-MR if not done
DIKW Hierarchy

• Data
• Information
• Knowledge
• Wisdom
SEMIOLOGY

• The importance of radiologic semiology can be seen from the large number of articles, books, and Web pages dealing with radiologic signs

• Recognition of these signs forms an important part of the training process for radiologists
Apple Core Sign
PACS SUBSYSTEMS

- ACQUISITION
- DISPLAY/OUTPUT
- NETWORK/COMMUNICATIONS
- ARCHIVE/STORAGE
- DATABASE

H.K. Huang “Elements of Digital Radiology”
WHAT WE ARE

LEAP OF FAITH

WHAT WE WANT TO BE

MAKE THE JUMP.