Real Use of DICOM in the Domains

Radiology, Nuclear Medicine, Mammography and CAD

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Insights from a DICOM-based PACS-Implementation

- Infrastructure (Hospital / Radiology)
- DICOM Services used
- Mammography
- Structured Reporting
- Teleradiology
- Conclusions

– Experiences from a real implementation…
University Hospital Mainz and Department of Radiology

- 1500 beds, 104 wards
- 53,000 inpatients/year, 190,000 outpatients
- >30 examination rooms
- ~ 600 patients / d
- ~ 15 clinical conferences / d
- RIS since 1988
- PACS since 1996 (Radiology and Neurorad.)
  - with >30 modalities (e.g. 5 CTs, 5 MRs, 7 CRs, 2 DRs..)
  - ~ 20 -25 GB / d new data (incl. Cardiology)
  - ~ 30 TB online (around 50 million objects)
## Data Load per Exam

<table>
<thead>
<tr>
<th>Modality</th>
<th>Matrix</th>
<th>Depth</th>
<th>MB / image</th>
<th>Images / Exam.. (typical in Mz)</th>
<th>MB / Ex</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>512*512</td>
<td>12 bit</td>
<td>0,5</td>
<td>250 (up to 2000)</td>
<td>125</td>
</tr>
<tr>
<td>MRT</td>
<td>256<em>256 - 512</em>512</td>
<td>12 bit</td>
<td>0,13 – 0,5</td>
<td>197</td>
<td>~50</td>
</tr>
<tr>
<td>DSA/DL</td>
<td>1024*1024</td>
<td>10 bit</td>
<td>2</td>
<td>18</td>
<td>36</td>
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<tr>
<td>CR</td>
<td>1500<em>2000 - 2000</em>2500</td>
<td>10 – 14 bit</td>
<td>6 - 10</td>
<td>4</td>
<td>24 - 40</td>
</tr>
</tbody>
</table>
### Data volume per Year in 2004 (without Cardiology)

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studies / month</td>
<td>14400</td>
</tr>
<tr>
<td>Images / month</td>
<td>745,000</td>
</tr>
<tr>
<td>Gigabyte/month (uncompressed)</td>
<td>460 GB</td>
</tr>
<tr>
<td>Images per Study</td>
<td>52</td>
</tr>
<tr>
<td>MB per Study</td>
<td>32</td>
</tr>
<tr>
<td>KB per Image</td>
<td>617</td>
</tr>
<tr>
<td>Studies / year</td>
<td>173,000</td>
</tr>
<tr>
<td>Images / year</td>
<td>8,940,000</td>
</tr>
<tr>
<td>Gigabyte / year (uncompressed)</td>
<td>5,520 GB</td>
</tr>
</tbody>
</table>
Data Load per Modality (without Cardiology)

- CT: 56%
- MR: 23%
- X-Ray: 16%
- Others: 5%
Inhouse Imagedistribution

[Graph showing trends and data points for Summe, Bilderzeuger, Verbraucher, TrendSumme, Trend Erzeuger, and Trend Verbraucher from 30.06.2003 to 12.11.2004]
# Capacity and Costs for Archiving*

<table>
<thead>
<tr>
<th>Medium</th>
<th>Capacity (GB)</th>
<th>Costs (ca. €)</th>
<th>Costs / GB (ca. €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film (35*43/20 images)</td>
<td>äq. 0.01</td>
<td>2</td>
<td>200</td>
</tr>
<tr>
<td>MOD</td>
<td>0.65</td>
<td>45</td>
<td>70</td>
</tr>
<tr>
<td>CD</td>
<td>0.65</td>
<td>3</td>
<td>4.6</td>
</tr>
<tr>
<td>DVD-Ram</td>
<td>2.6</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>DVD-R</td>
<td>4.7 bds.</td>
<td>12</td>
<td>1.3</td>
</tr>
<tr>
<td>CD-Jukebox</td>
<td>325</td>
<td>21000</td>
<td>65</td>
</tr>
<tr>
<td>DVD-Jukebox</td>
<td>1456</td>
<td>27500</td>
<td>19</td>
</tr>
<tr>
<td>DVD-Jukebox 2</td>
<td>5640</td>
<td>48000</td>
<td>8.5</td>
</tr>
<tr>
<td>RAID</td>
<td>1.000 – 80.000</td>
<td>5.000 – 500.000</td>
<td>5 – 6.25</td>
</tr>
</tbody>
</table>

*without compression or mirroring*
Actual Use of the PACS in Mainz

- Radiography, CT, MRT, DSA
- Sonography
- Szintigrapy, PET
- Visible Light
  - Endoscopy, Ophthalmology, Digital Photography, Microscopic Slides)
- Cardiology
Image Sources

**Radiology 505:**
- CT Siemens
- CT Philips
- MR Siemens
- PCR Philips, CR Agfa
- Flat-detektor Philips
- Angio Philips
- Ultrasoun GE L7
- RF Philips
- Filmscanner
- CD-Import, JPEG Import
- SecTelmed

**Radiology 210:**
- CT Siemens
- MR Siemens
- Angio Siemens
- Thoravision
- CR Agfa
- 2 * PCR Philips
- 3 x Ultrasound
- Mammography

**Radiology 701:**
- 2 x MR Siemens
- CT Siemens
- PCR Philips

**Radiology 503:**
- PCR Philips
- Flat-detektor Philips

**Nuklear Medicine:**
- Gamma-Kameras
- Ultrasound, PET, SR_generator

**Neuroradiology:**
- CT Picker
- Angio Philips
- MF-Platz (Myelo) Philips

**Endoscopy:**
- SR-Generator
- Endoscopy

**Dental Clinic**
- Digital X-Ray
- Sidicom

**Urology:**
- Uroskop Siemens

**Orthopedics:**
- OP-PCs with Arthro, RF

**Surgery:**
- Endoscopy

**Cardiology:**
- Cathlab, Ultraschall

**Neurosurgery:**
- OP-CT

**Angiology:**
- Capillar-mikroscp

**Pneumology:**
- Bronchoskop

**Neurology:**
- Ultraschall

**Child-Surgery:**
- RF

**HTG:**
- RF

**Gynecology:**
- OP-Endoskop

**Ophthalmology:**
- Ultrasound
Workflow Support
Modality Worklist / Performed Procedure Step

MWL:

Name, Birth date
Accession number
UIDs et al.

Conventional procedure: manual entry in RIS with different pitfalls
Modality Worklist / Performed Procedure Step

**MWL:**
Name, Date of Birth
Accession number
UIDs et al.

**RIS**

**MPPS** with automatic transfer of:
- Exposure Time
- Total dose
- Exposure dose
- Fluoro dose
- Number frames
- Fluoro time
- Number series

**Acq. modality**
Consistency and Completeness of Image Archiving

- ~ 25000 images / d
- ~ 600 studies / d
- manual control takes 10 - 30 min / modality
- ~ 5h/d for the complete department
Storage Commitment

Acq modality

Please take responsibility for safekeeping of data

O.k., commitment for archiving images permanently

PACS

PACS

DVD
DICOM Print

- Standard for all new equipment
- Usable at modalities and workstations
- Easy way for backup-up solutions
  (configuration of two or more printers, e.g. laser film and paper printer)
- Avoids specific and costly interfaces
- Mainz: reduction of film print >90%, reduction of printers (8 of 14)
Mammography
Mammography

- X-ray Mammography (3000/year)
- Preoperative marking (90% <1 cm)
- Ultrasound
- Biopsy (>100/year, Treffer >90%)
- Digital Stereotaxie
- MRT
Dynamic contrast imaging

% Signal intensity vs time for malignant, benign, and normal tissues.
Digital Mammography

- Flat detector and CR-based available
- Higher dynamic of images (1:4000 vs. 1:200)
- Constant and consistent image quality
- Increased productivity
- Image postprocessing
- Evolving and new functionality:
  - CAD, Tomosynthesis, Energy subtracted imaging, mammography with contrast media, Telemammography
DICOM SR in Breast Care

- Supplement 50 Mammography CAD is official part of the standard since 2001
- CAD-Systems providing SR are available
- part of the European Screen Trial (Mevis, R2...)
- Further developments
  - Patient Clinical History (Supp 75)
  - Breast Imaging Report (Supp 79)
Nuclear Medicine
Nuclear Medicine

• Integrated since the beginning
• Use for Scintigraphy, SPECT, PET
• Image fusion
STRUCTURED REPORTING
Conventional Radiological Reporting

Characteristics

– Different types

  • Prose without images
  • Structured reports without images
  • Prose with embedded images
  • Structured reports with embedded images

– “Good” report (Hall, AJR 2000)

  • Brief statement on exam indication, concise description of findings, no defensive posturing, accepted terminology and acronyms, summarize observations and assessment of clinical significance
Conventional Radiological Reporting

“Reality”
- Rapid technological improvement in imaging technology (display, processing, storage, 3D-acquisition..)
- But:
  - Reports not transmitted in timely fashion
  - contain ambiguous terms
    - opacity, density, infiltrate, consolidation...
    - tumor, lesion, focus, neoplasm...
  - do not address the key clinical question
  - contain clinically important errors
Expectations to Radiological Reporting

- Shortage of turnaround time
  - 19% same day, 42% 1 – 2 days (Naik, AJR, 2001)

- Design of reports
  - 86% clinicians prefer computer-generated itemized reports
  - Only 12% prefer prose
  - Also 64% of radiologists using PACS prefer computer-generated reports due to ease of reading, ease of extracting information, focused and organized nature..

- Structured reports with images (Reiner et al., 2004)
  - content, clarity, completeness, consistency, confidence
Reasons for Structured Reporting (SR)

- Ease of reading and extracting relevant informations included in hospital information systems
- Documentation of quantitative measurements
  - e.g. US, CT, MRT; CAD-Tools
- Comparability for follow-up studies
- Teaching and scientific research
  - automatically index and retrieve reports for online teaching
  - measure and improve the performance of radiologists
    - e.g. number of recommended additional tests
- with realtime use, decision support would become available
  - diagnostic suggestions for unusual cases
Different ways to Structured Reports

Computer supported / generated

– manual measurement, e.g. Ultrasound
– computer assisted measurements
  • Calcium Scoring
  • Functional analysis
  • Quantification of stenosis, organ volumes...
– CAD
  • Breast, Chest, Colon...
Computer supported / generated manual measurement, e.g. Ultrasound

<table>
<thead>
<tr>
<th>Carotid Bulb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Modifier: Topographical modifier = Distal (G-A119, SRT)</td>
</tr>
<tr>
<td>End Diastolic Velocity:</td>
</tr>
<tr>
<td>0.77708441 m/s</td>
</tr>
<tr>
<td>Peak Systolic Velocity:</td>
</tr>
<tr>
<td>1.2273264 m/s</td>
</tr>
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<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Concept Modifier: Topographical modifier = Mid longitudinal (G-A128, SRT)</td>
</tr>
<tr>
<td>End Diastolic Velocity:</td>
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<tr>
<td>0.84378693 m/s</td>
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<tr>
<td>Peak Systolic Velocity:</td>
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<tr>
<td>1.394029 m/s</td>
</tr>
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</table>

<table>
<thead>
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<th>Carotid Bulb</th>
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<tbody>
<tr>
<td>Concept Modifier: Topographical modifier = Proximal (G-A118, SRT)</td>
</tr>
<tr>
<td>End Diastolic Velocity:</td>
</tr>
<tr>
<td>0.56030121 m/s</td>
</tr>
<tr>
<td>Peak Systolic Velocity:</td>
</tr>
<tr>
<td>1.1939752 m/s</td>
</tr>
</tbody>
</table>

Common Carotid Artery
Computer Assisted Measurements

Risk Factors
- Diabetes Mellitus
- Hypertension
- Hypercholesterolemia
- Smoker
  - Present
  - Former
- Positive Family History
- Obesity
- Sedentary Lifestyle

Clinical History
Symptoms
- Asymptomatic
- Unstable Angina Pectoris
- Stable Angina Pectoris
- Atypical Angina Pectoris
- Atypical Chest Pain
- Dyspnea
- Other
- Previous Myocardial Infarction
- Previous Coronary Revascularization
  - Bypass Surgery
  - Balloon Angioplasty
  - Coronary Stenting
Computer Assisted Measurements
• CAD output for quantitation DSA, CTA, MRA

• Awaiting Suppl. 97

DICOM SR Example - Vascular
Radiologischer Befund

Observation Context: Recording Observer's Name = Oliver Mohrs
Observation Context: Recording Observer's OrganizationName = Radiologie, Mainz

Untersuchung:
Oberes Sprunggelenk rechts in 2 Ebenen vom 31.01.02:

Anamnese:
Weber B Fraktur re.

Ergebnis:
Zum Befundvergleich liegt die Voruntersuchung vom 23.01.02 vor.
Plattenosteosynthese sowie mittels Zusatzschraube versorgte Weber B Fraktur.
Im Vergleich zur VU unverändert achsgerechte Stellungsverhältnisse.

Arzt:
DICOM SR Standardization Process

- Part 16 - Content Mapping Resource (2001)
- Supp 36 - Codes and Controlled Terminology (1999)
- Supp 50 - Mammography CAD (2001)
- Supp 75 - Patient History (2004)
- Supp 78 - Fetal and Pediatric Echocardiography SR (preliminary)
- Supp 86 - Digital Signatures for Structured Reports (Early Draft)
- Supp 94 - Radiation Dose Report (Early Draft)
- Supp 97 - CT/MR Cardiovascular Analysis Report (Public comment)
- Supp 104 - DICOM Encapsulation of PDF Objects (Public comment)
Teleradiology
Request with / for Teleradiology

- Radiological consultation
- Radiological research
  - FTP or HTTP transfer possible, but uncomfortable and not user-friendly
- Normally teleradiology tools are not part of the various PAC-Systems
- Security, privacy aspects
- Interoperability with different vendors
Telemedicine via e-mail

DICOM Conference Budapest 2005
Members of the Telemedicine-Initiative

- Ärztliche Stelle Hessen
- AGFA
- Charité Berlin
- Chili
- ConVis
- Curagita AG
- DKFZ
- FH Würzburg-Schweinfurt
- GeSIT
- GI Gesundheitsinformatik
- Gesundheitsnetz-R
- Image Devices
- Medical Communications
- OFFIS
- Siemens
- Steinhart Medizinsysteme
- University Mainz
- University Freiburg
- University Mannheim
Limitations in Implementations

- Order / Entry
- Selection of relevant images (Key Objects)
- Access to images and reports
  - Compression
- Enterprise-wide patient identification
- GSDF
- DICOM-SR
National Recommendations in Germany

• DFG (German Science Foundation)
  – Image Management Systems to cover all imaging applications in hospitals
  – DICOM Services
    • DICOM Basic Services, MWL, MPPS, St.C.,
    • Print (opt.)
  – IHE – Profiles
    • For RFPs

• DRG (German Roentgen Society)
  – Teleradiology
    • DICOM eMail
Summary

- DICOM-based PACS opens many different opportunities to use optimal solutions for given requests (modalities, workstations, other domains...)
- Basic DICOM-services essential to improve the quality of data consistency, documentation, or workflow improvement
- DICOM-SR is evolving, used for quantified data and for report access through network or CDs
- DICOM eMail is a common approach for teleradiology between independant health care enterprises or PACS-solutions
Somewhere, something went terribly wrong

Thank you for your attention!

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