Dose Management Systems in Radiology

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Medical Radiation (US data)

1980: medical radiation < 25 %

2006: medical radiation ca. 50 %
CT alone ca. 25 %
Häufigkeit und Dosis
diagnostischer und
interventioneller
Röntgenanwendungen
Trends zwischen 2007 und 2014

Abb. 2 ▶ Prozentuale Beiträge der verschiedenen Röntgenanwendungen zur Gesamthäufigkeit (a) und kollektiven effektiven Dosis (b) für die Jahre 2007 bis 2014. VT Verdauungstrakt, UGT Urogenitaltrakt

Abb. 3 ▶ Vergleich der Häufigkeiten von CT- und MRT-Untersuchungen für die Jahre 2007 bis 2014 gesamt sowie getrennt für den ambulanten und stationären Bereich
Evolution of CT technology

1994
1-Slice: 0.75 sec/R
Collimation: 3 mm
6 cm

1998
4-Slices: 0.5 sec/R
Collimation: 4x2.5 mm
30 cm

2002
16-Slices: 0.5 sec/R
Collimation: 16x1.5 mm
72 cm

2004
64-Slices: 0.5 sec/R
Collimation: 64x0.6mm

Whole Body Imaging
Data from German Trauma Registry

Use of whole body CT for polytrauma patients in Germany
Data from the German Trauma Registry
Dose ‘Enemies’

• Angiography (incl. Coronarography)
• CT-Imaging
  – „ER-Imaging“ – whole body CT
  – CT Angio for Pulmonary Embolism
  – Head CT / Neuroperfusion imaging
  – Dynamic Contrast Enhanced CT of other body regions
  – Increasing use of Coronary CT
• +/- Screening examinations (mammography)
Suzanne Sloan also suffered hair loss after receiving a CT perfusion scan at a hospital in Huntsville, Ala. Ms. Sloan, a fifth-grade teacher, began to piece together what had happened to her after seeing a photograph in a newspaper of someone who had experienced the same distinctive hair loss.

H. Michael Heuser lost clumps of hair and had other problems after receiving a radiation overdose at Cedars-Sinai Medical Center in Los Angeles. Mr. Heuser, a 52-year-old executive producer of films, received CT perfusion scans after exhibiting stroke symptoms.

From then on, as the accounting of overdoses at Cedars-Sinai reached 269 over a period of 18 months, Mr. Heuser would be known in government reports simply as “Patient 1.”
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California Tightens Oversight of CT Scans

By WALT BOGDANICH OCT 1, 2010

California’s governor has signed tough new legislation tightening oversight of diagnostic CT scans, largely in response to the overdosing of hundreds of patients who underwent brain scans for stroke in 2008 and 2009.

Gov. Arnold Schwarzenegger signed a bill on Wednesday that will require hospitals and clinics to record radiation doses for CT scans and to report any overdoses to patients and their doctors.

The brain scan overdoses surfaced last year at Cedars-Sinai Medical Center in Los Angeles, where 269 patients received up to eight times the radiation that was expected. The overdoses continued for 18 months before the hospital discovered them.
Changes brought by 2013/59/Euratom

- **Art 58.a:** written protocols for every type of standard medical radiological procedure and for each piece of equipment, but also “for relevant categories of patients”, must be established

- **Art 58.b:** Information relating to patient exposure forms part of the report of the medical radiological procedure.

- **Art 58.c:** imposes establishment of “referral guidelines for medical imaging”
Article 61

Special practices
1. Member States shall ensure that appropriate medical radiological equipment, practical techniques and ancillary equipment is used in medical exposure:
   (a) of children;
   (b) as part of a health screening programme;
   (c) involving high doses to the patient, which may be the case in interventional radiology, nuclear medicine, computed tomography or radiotherapy.

Special attention shall be given to quality assurance programmes and the assessment of dose or verification of administered activity for these practices.
Article 63

Accidental and unintended exposures
Member States shall ensure that:

(a) all reasonable measures are taken to minimise the probability and magnitude of accidental or unintended exposures of individuals subject to medical exposure;

...

(c) for all medical exposures the undertaking implements an appropriate system for the record keeping and analysis of events involving or potentially involving accidental or unintended medical exposures, commensurate with the radiological risk posed by the practice;
CT Dose Reduction Techniques

- Limitation of Field of view / avoiding overscanning
- Positioning of Patient (center, arm position)
- **Tube Current Modulation / AEC**
- Dynamic Collimators reducing z-overscanning
- **Low kV scanning / Automatic voltage selection (Care kV Siemens, kV Assist GE)**
- Use of DECT with virtual non-contrast imaging
- **Using modern Image Reconstruction Algorithms**
  - Iterative reconstruction is a black box to most users (AIDR, AIDR-3D, Toshiba, IRIS, SAFIRE, ADMIRE, Siemens)
Dose Reduction – Iterative Reconstruction

- Meyer et al. EJR 2014
- Whole Body CT: half-dose imaging using iterative reconstruction
- No significant difference in IQ with HDI compared to FDS
Example: Chest-CT

Chest CT 2017 IR

Chest CT 2008
Example: Chest-CT

Chest CT 2017

DLP = 123 mGy.cm

60 % Dose reduction

Chest CT 2008

DLP = 303 mGy.cm
Large variations in Dose

• Smith-Bindmann (2011): „… we found 10- to 100-fold differences in DLP for CT scans for the same clinical indication among thousands of examinations we have reviewed …“

• Attention to dose reduction and dose management at the institutional level is likely to have the greatest effect on improved optimization
Dose Management Systems

• DMS = System intended to collect, manage, aggregate and analyze radiation dose data of examinations of a given population to allow continuous dose optimization

• Main components:
  – Set of examination protocols / procedures
  – IT System collecting and storing the dose data
  – Dose team

• Can operate at local, regional, or national level
Where do the dose data come from?

PACS / Modality

DICOM-Header

Data extraction

CT-Dose-Page

OCR

DMS

DICOM-Header

Data extraction

CT-Dose-Page

OCR

DMS

DICOM-Header

Data extraction

CT-Dose-Page

OCR

DMS

DICOM-Header

Data extraction

CT-Dose-Page

OCR

DMS

X-ray Radiation Dose Report
DICOM Dose SR
CT / A00233
Specials*61a_Polytrauma (Adult)

Geräte
CT
SIEMENS / SOMATOM Definition Flash

Untersuchungsbeschreibung

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<th>Sequenzbeschreibung</th>
<th>kV</th>
<th>mAs</th>
<th>Phanomen Type</th>
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<th>CTObrol</th>
<th>DLP</th>
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Medium Type

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<th>Fluss</th>
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DICOM-Data
(Basic) Functions of a DSM

• Mapping of modality protocol names to DMS master protocols
• Management of Dose Reference Levels
• Configurable Dashboards
• Management of Dose Alerts
• Individual view of a patient
• View of an individual examination
• Analysis of dose / protocol / time / modality
Dashboard
Detailed Analysis: organ dose
CT Exposure Modulation
Peak Skin Dose
Check dose alerts
Check dose distribution and outliers
Check outliers
Incident alert
Dose alert at Tech Workplace
Dose alert at Tech Workplace
Dose alert at Tech Workplace
Dose alert at Tech Workplace
Protocol mapping / management

• In Germany, there is no standard naming for examination protocols, every department has its own naming conventions (RadLex in the future)
• Names might event be different for the same examinations on different machines (and RIS and OES)
• DMS needs mapping of procedure names ➔ very work intensive!!!
• Central Protocol management ... also needed for order entry and for CDS
Deep Learning resulted in automatic mapping of 7443 out of 11289 examination protocols

Input: DICOM Header, RDSR, Dose Reports
Collect and extract of examination information
Labeling of testdata
System is ordering and prioritizing given information
Output: DRL-Examination type

Mapping on image level (CR/DX/DR/MG)
series level (CT)
study level (XA)
Advantages of using a DMS

• Automatic and complete collection of all dose data
• Supports tracking and analysis of dose data at individual, average and cumulative level
• Analysis by patient, patient groups, modalities, users, clinical indications (protocols)
• Evolution of dose over time
• Track outliers with regard to DRL
• Allows easy visual analysis of dose 'big data'
What about image quality?

- ALARA: „As low as reasonably achievable“ → depends on the task:
  - Lung and high contrast examinations → noise acceptable
  - Parenchymal organs of the abdomen → less noise
- No universal metrics for radiology image quality exists
- „Image Quality Score“ → radiologists rate during the reporting process
- Relate image quality to the indication of the examination
Clinical Decision Support for Order Entry

Knowledge Database

Inference Engine

Integration with IS
Challenges when introducing CDS

• Integration with Order Entry system
• Getting it used in clinical routine
  – Motivation of physicians
  – Think about rewards and penalties
• System has to be fast: „every click and every second counts“
• Introducing radiology CDS is not a radiology project, but a project involving many clinical and administrative partners.
WIP: Integration ESR iGuide to OES

**Clinical Question**

-肿瘤是否仍然存在？
-既往病史。

**Additional Info**

-问诊。
-家族史。

**Clinical Request**

- CT Head with iv contrast

**Examination ordered**

- CT Head with iv contrast
Appropriateness ranking
Appropriateness ranking

Jump back to OrderEntry

Selection
Seamless integration

Continuation in Order Entry System
Effects of implementing CDS

Raja et al. 2013:
793-bed academic medical center
Number and RVU of imaging studies in ED
10 years, 48,000 to 61,000 Pat.

Fig. 6—Run chart shows timing of illustrative institutional initiatives to reduce inappropriate use of high-cost imaging (CT and MRI) in emergency department (ED). RVUs = relative value units, CPOE = computerized physician order entry system, CDS = clinical decision support.
Benefits of CDS

• Improved appropriateness of imaging referrals
• Reduction of (unnecessary) radiation exposure
• Better use of sparse resources, i.e. radiologists, technicians, and modalities
• Shorter way to diagnosis → better clinical workflow, overall better efficiency
• Better justification of resources needed in radiology
Conclusion

• Dose Management Systems are necessary
  – to continuously educate the radiology team
  – to monitor and optimise dose at different levels

• Most important factor to reduce dose: appropriateness of the examination → Clinical Decision Systems

• Image Quality Score is missing today
Outlook – DMS and AI

• Mapping of examinations (vs. standardized coding)
• Determination of examined body region
• Evaluation of image quality