Dose Management Software

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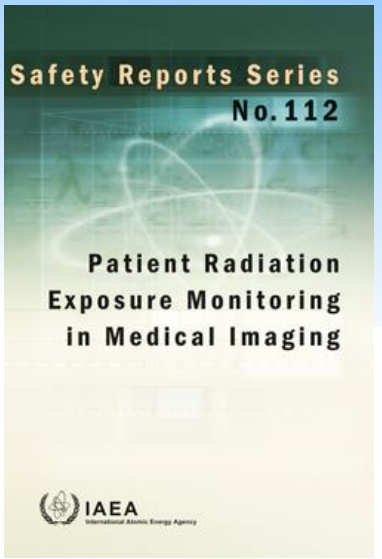
https://www.iaea.org/publications/14971/patient-radiation-exposure-monitoring-in-medical-imaging

Safety Report "Patient Radiation Exposure Monitoring in Medical Imaging", in collaboration with ICRP, WHO, UNSCEAR, IOMP, DICOM WG28 (Physics)

slide courtesy of Jenia Vassileva, ex NSRW, IAEA



NEW!

Patient exposure monitoring: A process including the mechanism and the operational elements related to collecting, interpreting, and acting upon quantities associated with clinical imaging operation

Tracking patient exposure data: An analysis process of ascertaining and monitoring *temporal trends* in individual or collective stored data

Managing patient exposure data: A process of *oversight* through exposure data recording, tracking, and analysis towards improvement of radiation protection and patient care

To understand what DMS offer, we have to go back in time, and remember what the situation in the past.

- *Most of the radiological units were non-digital (X-ray units were using screen/film cassettes and fluoroscopy units image intensifiers) and no record of the exposure factors used during examination was kept.*
- *Most of the units did not even have a kerma-area product (KAP) meter (referred in the past as dose-area product, DAP).*

What was the solution:

manual selection of patient dose related metrics in a limited number of exams (10-30 patients)

For fluoroscopy, an external KAP meter was used, and a medical physicist had to record (manually and in real-time) the KAP and fluoroscopy time (FT) readings, and also, indicative values of the exposure factors during the exam.

For DRL purposes, cumulative FT and KAP values were adequate.

Sample of relevant publications (courtesy of Ioannis Tsalafoutas)

The British Journal of Radiology, 72 (1999), 173–178 © 1999 The British Institute of Radiology

Patient doses from barium meal and barium enema examinations and potential for reduction through proper set-up of equipment

[1]E YAKOUMAKIS, PhD, [2]I A TSALAFOUTAS, MSc, [3]P SANDILOS, PhD, [2]H KOULENTIANOS, MD, [3]A KASFIKI, PhD, [3]L VLAHOS, MD and [1]Ch PROUKAKIS, MD

The British Journal of Radiology, 74 (2001), 727–734 © 2001 The British Institute of Radiology

Differences in effective dose estimation from dose–area product and entrance surface dose measurements in intravenous urography

[1]E YAKOUMAKIS, PhD, [2]I A TSALAFOUTAS, MSc, [2]D NIKOLAOU, MD, [2]I NAZOS, RT, [2]E KOULENTIANOS, MD, PhD and [1]Ch PROUKAKIS, MD, PhD

Pediatr Radiol (2003) 33: 236–240
DOI 10.1007/s00247-002-0861-x

ORIGINAL ARTICLE

Konstantinos A. Gogos
Emmanuel N. Yakoumakis
Ioannis A. Tsalafoutas
Triantafillia K. Makri

Radiation dose considerations in common paediatric X-ray examinations

The British Journal of Radiology, 80 (2007), 107–112

Radiation doses to patients undergoing standard radiographic examinations: a comparison between two methods

[1]V TSAPAKI, MSc, PhD, [1]I A TSALAFOUTAS, MSc, PhD, [2]I CHINOFOTI, Tec, [2]A KARAGEORGI, Tec, [3]E CARINOU, MSc, PhD, [3]V KAMENOPOULOU, MSc, PhD, [4]E N YAKOUMAKIS, MSc, PhD and [2]E D KOULENTIANOS, MD

Patient Doses from Noncardiac Diagnostic and Therapeutic Interventional Procedures

Ioannis A. Tsalafoutas, PhD, Helen Goni, PhD, Petros N. Maniatis, MD, Paris Pappas, MD, Nick Bouzas, MD, and George Tzortzis, MD

J Vasc Interv Radiol 2006; 17:1489–1498

Ioannis A. Tsalafoutas[1]
Virginia Tsapaki[2]
Charikleia Triantopoulou[3]
Christina Pouli[3]
Virginia Kouridou[1]
Ioanna Fagadaki[3]
John Papailiou[3]

AJR:191, November 2008

Comparison of Measured and Calculated Skin Doses in CT-Guided Interventional Procedures

PACE, Vol. 28 September 2005

Radiation Doses to Patients and Cardiologists from Permanent Cardiac Pacemaker Implantation Procedures

IOANNIS A. TSALAFOUTAS,* STAVROS G. SPANODIMOS,† PETROS N. MANIATIS,‡ GEORGE M. FOURNARAKIS,† ELIAS D. KOULENTIANOS,§ and DIMITRIOS L. TSIGAS†

Radiation dose in repeated CT guided radiofrequency ablations

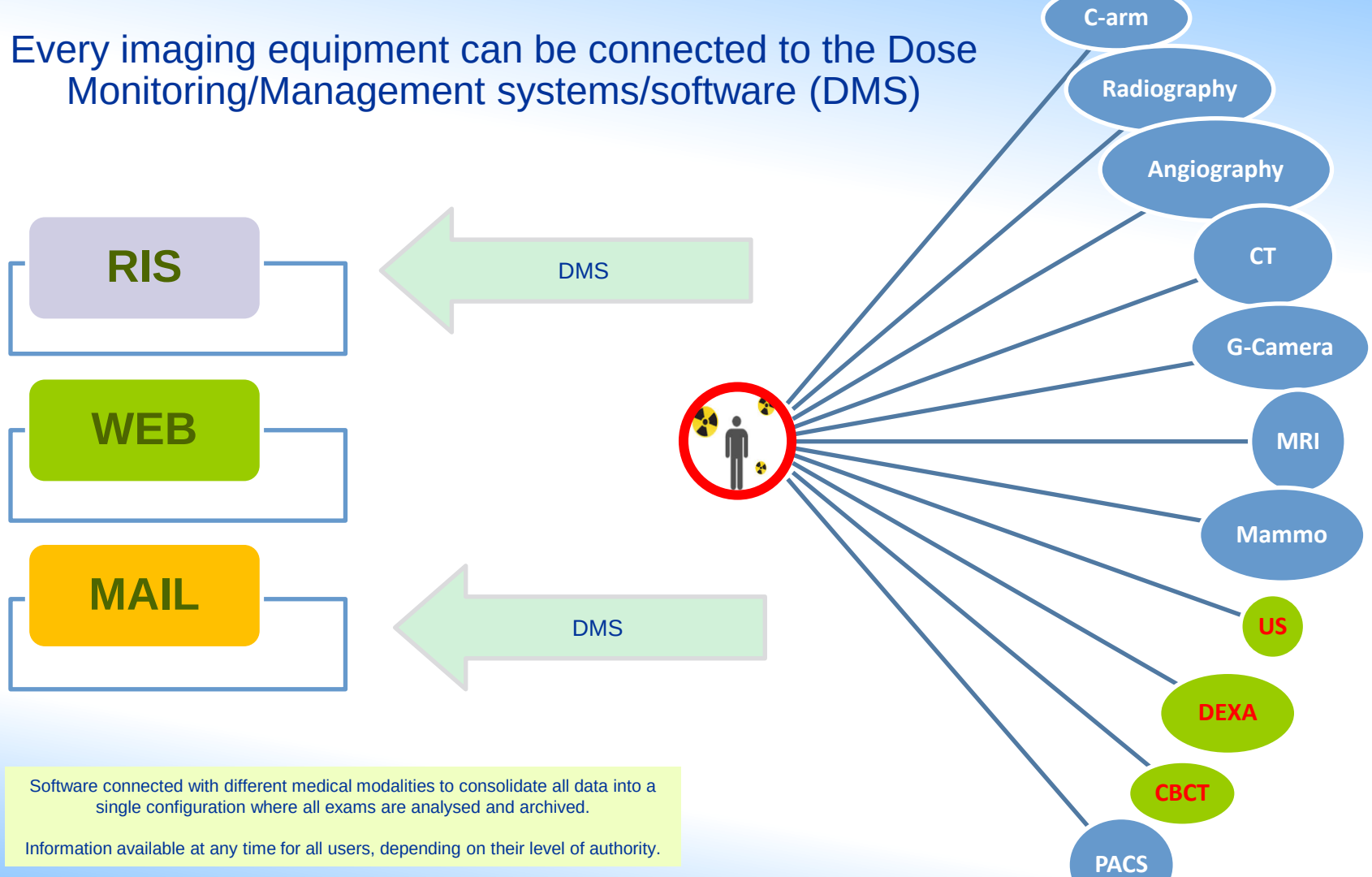
V. Tsapaki [a], I.A. Tsalafoutas [b,*], Ch. Triantopoulou [c], E. Kolliakou [c], P. Maniatis [c], J. Papailiou [c]

Physica Medica 30 (2014) 128–131

FROM MANUAL TO AUTOMATIC COLLECTION

- Tracking of dose data is proven invaluable (numerous publications)
- Manual method is not practical since monitoring all the examinations can be difficult due to their large number.
- Data acquisition process can lead to mistakes, usually by mistyping the information.
- Besides the above flaws, it can be very time consuming
- Due to above dedicated personnel just for the data acquisition and categorisation will be needed.
- For efficient dose optimisation process a lot of data should be collected.
- These difficulties can be overcome with the use of tracking software.

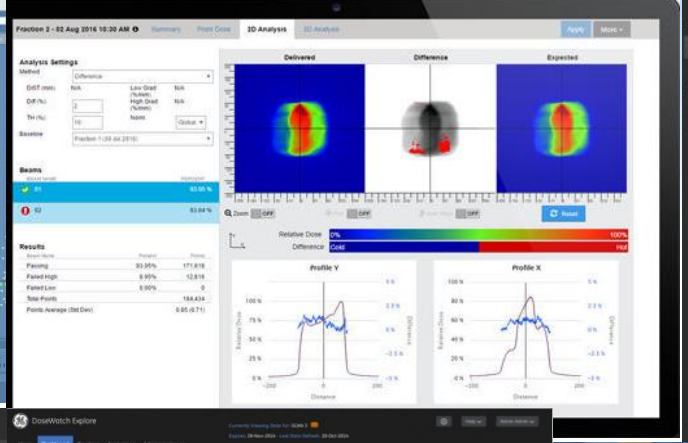
Every imaging equipment can be connected to the Dose Monitoring/Management systems/software (DMS)

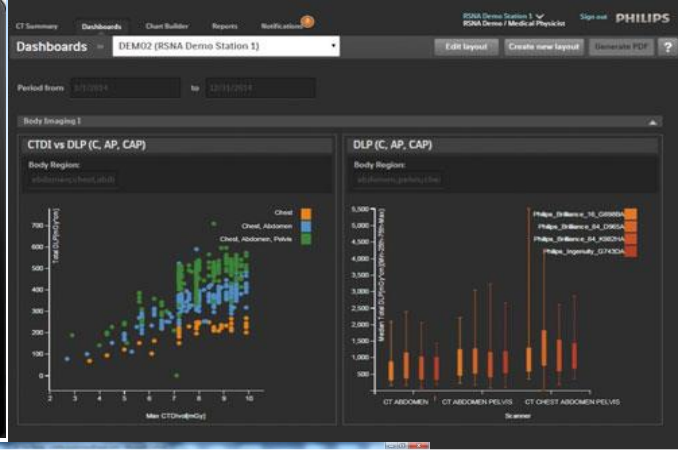


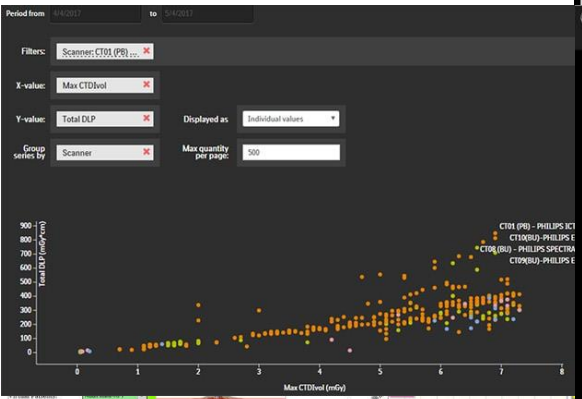
Software connected with different medical modalities to consolidate all data into a single configuration where all exams are analysed and archived.

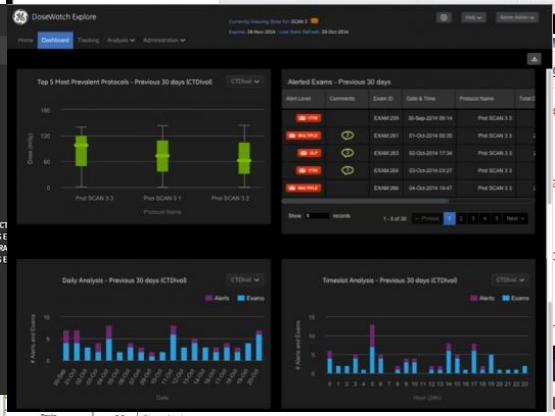
Information available at any time for all users, depending on their level of authority.

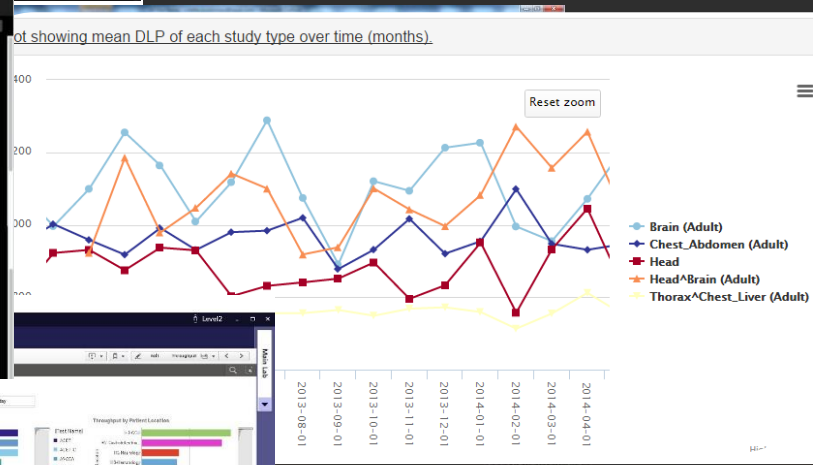

Scatter - CCABD
Clear Selection
US - TX - ARL - ER
CT - CCABD
Calculation based on 16,143 studies
DDB: 950 mGy*cm
Adult
Paediatrics

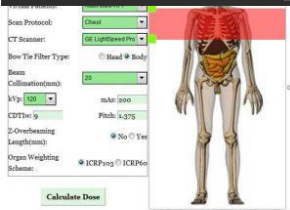

2D Analysis
Delivered
Difference
Expected
Analysis Settings
Beams
Results
Profile Y
Profile X

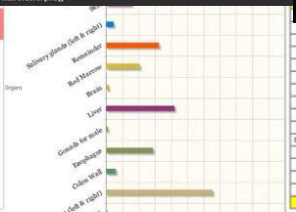

Dashboards
DEMO2 (RSNA Demo Station 1)
CTDI vs DLP (C, AP, CAP)
DLP (C, AP, CAP)
Body Region:
Chest
Chest, Abdomen
Chest, Abdomen, Pelvis
CT ABDOMEN
CT ABDOMEN PELVIS
CT CHEST ABDOMEN PELVIS


Filters:
Scanner: CT01 (P8) ...
X-value:
Max CTDIvol
Y-value:
Total DLP
Displayed as
Individual values
Group series by
Scanner
Max quantity per page:
500
Total DLP (mGy*cm)
Max CTDIvol (mGy)


DoseWatch Explore
Top 5 Most Prevalent Protocols - Previous 30 days (CTDIvol)
Alerted Exams - Previous 30 days
Daily Analysis - Previous 30 days (CTDIvol)
Timeslot Analysis - Previous 30 days (CTDIvol)

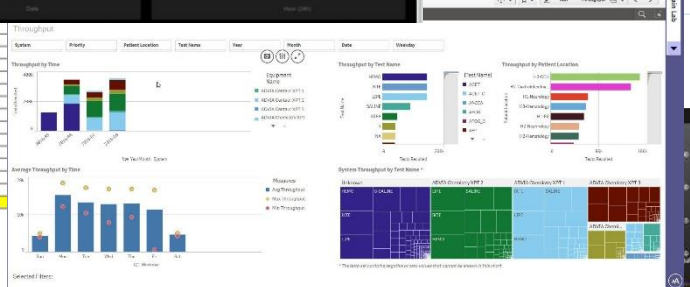

ot showing mean DLP of each study type over time (months).
Reset zoom
Brain (Adult)
Chest_Abdomen (Adult)
Head
Head^Brain (Adult)
Thorax^Chest_Liver (Adult)

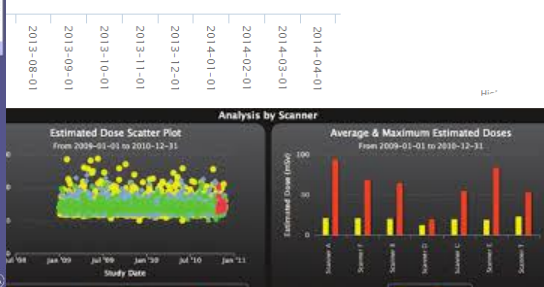

Scan Protocol:
Chest
CT Scanner:
GE LightSpeed Pro
Calculate Dose




Salivary Glands (left & right)
Remainder
Red Marrow
Brain
Liver
Gonads for male
Esophagus
Colon Wall
Breast (left & right)
Urinary Bladder Wall
Bone endosteum
Dose (mGy)

Brain 0.3
Breast (left & right) 14.3
Colon Wall 1.3
Esophagus 6.3
Gonads for male 0.2
Liver 9.0
Lungs (left & right) 18.6
Red Marrow 4.5
Remainder 7.1
Salivary glands (left & right) 1.0
Skin 3.4
Stomach Wall 8.2
Thyroid 2.3
Urinary Bladder Wall 0.2
Total Effective Dose (mSv): 7.0


Throughput
Throughput by Time
Throughput by Test Name
Throughput by Patient Location
Average Throughput by Time
System Throughput by Test Name


Analysis by Scanner
Estimated Dose Scatter Plot
From 2009-01-01 to 2010-12-31
Average & Maximum Estimated Doses
From 2009-01-01 to 2010-12-31
Study Date

ALARA PRIICPLES CAN BE ADDRESSED TODAY WHEN USING RDMS

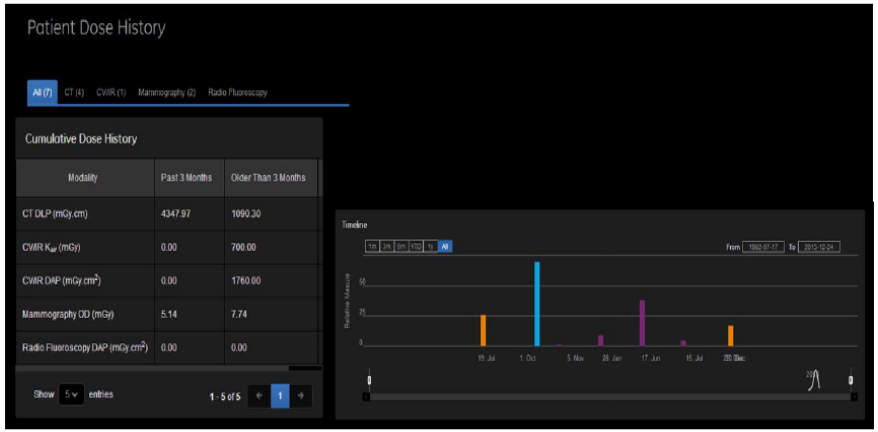
- JUSTIFICATION

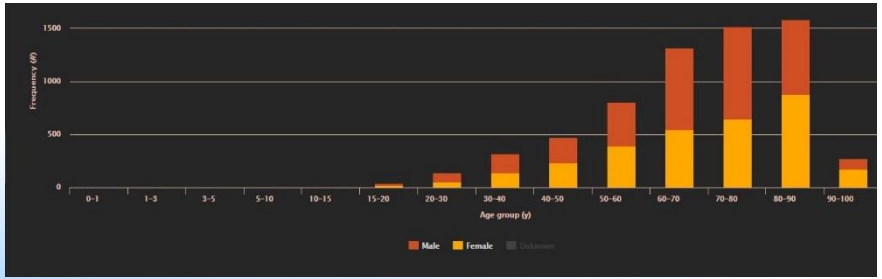
- Exam history
- Exam analysis in terms of time and type
- analysis in terms of type
- Dose simulation before exam
- Unexpected variations from routine procedures

- OPTIMIZATION

- Patient dose estimation and comparison
- Benchmarking
- DRLs
- Dose alerts
- Incident and accidental exposure easily identified

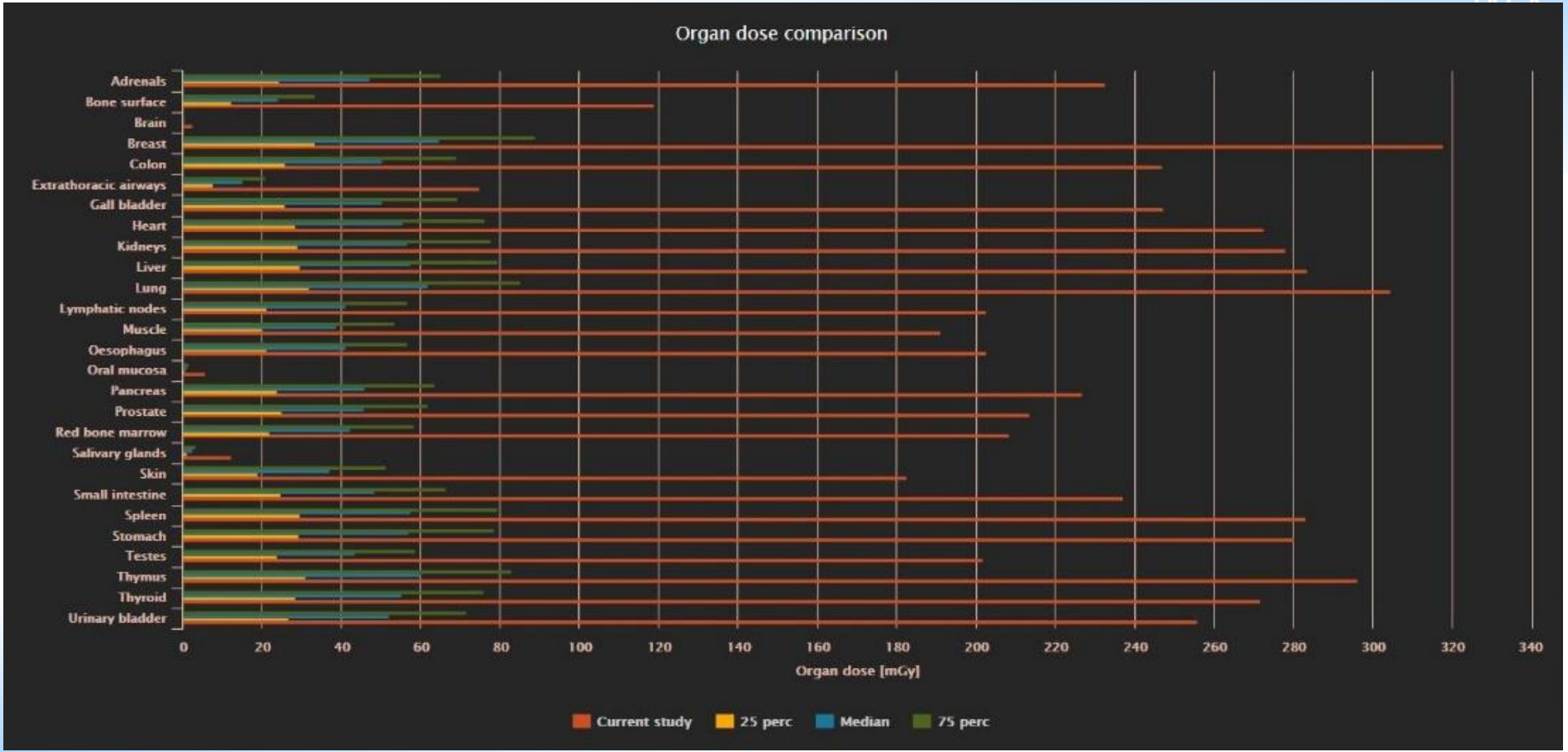
DMS can provide dose trends, utilization, high dose examinations



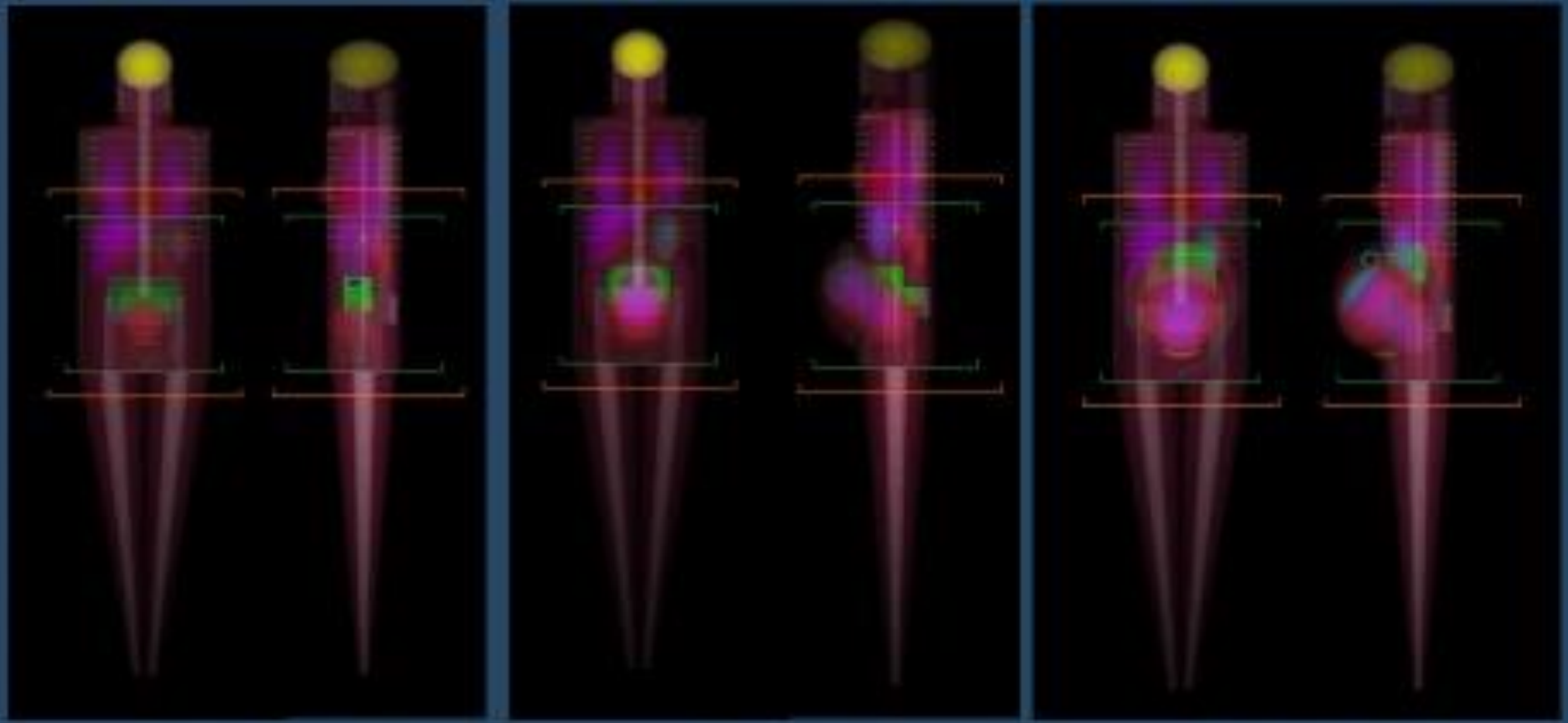


- Provide a “history” of examinations
- Analysis in terms of time, exam type, etc that would help in overall assessment of the exam type.
- Can give dose trends, device utilization, high dose studies and detailed X-ray exam information.
- The dose management software simulates patient dose before the X-ray exam is performed.

Some DMS use dose data to calculate organ doses



21 Pregnant Anthropomorphic Models: 3 Regular – 18 Bariatic



I TRIMESTER

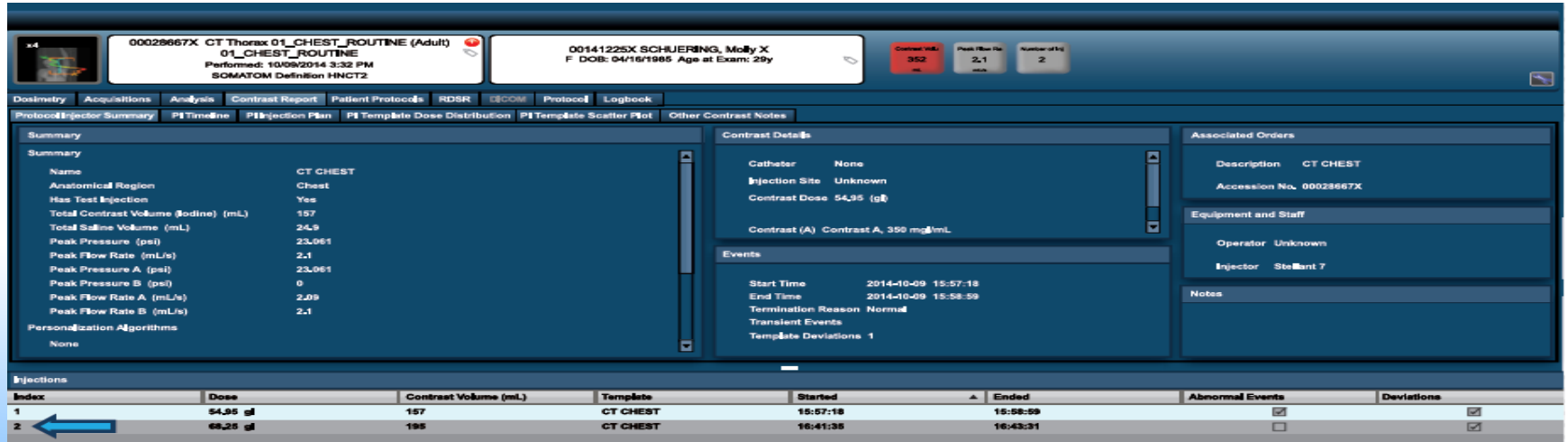
II TRIMESTER

III TRIMESTER

CT Contrast information

Score card displays patient radiation dose, CT and MR contrast dose

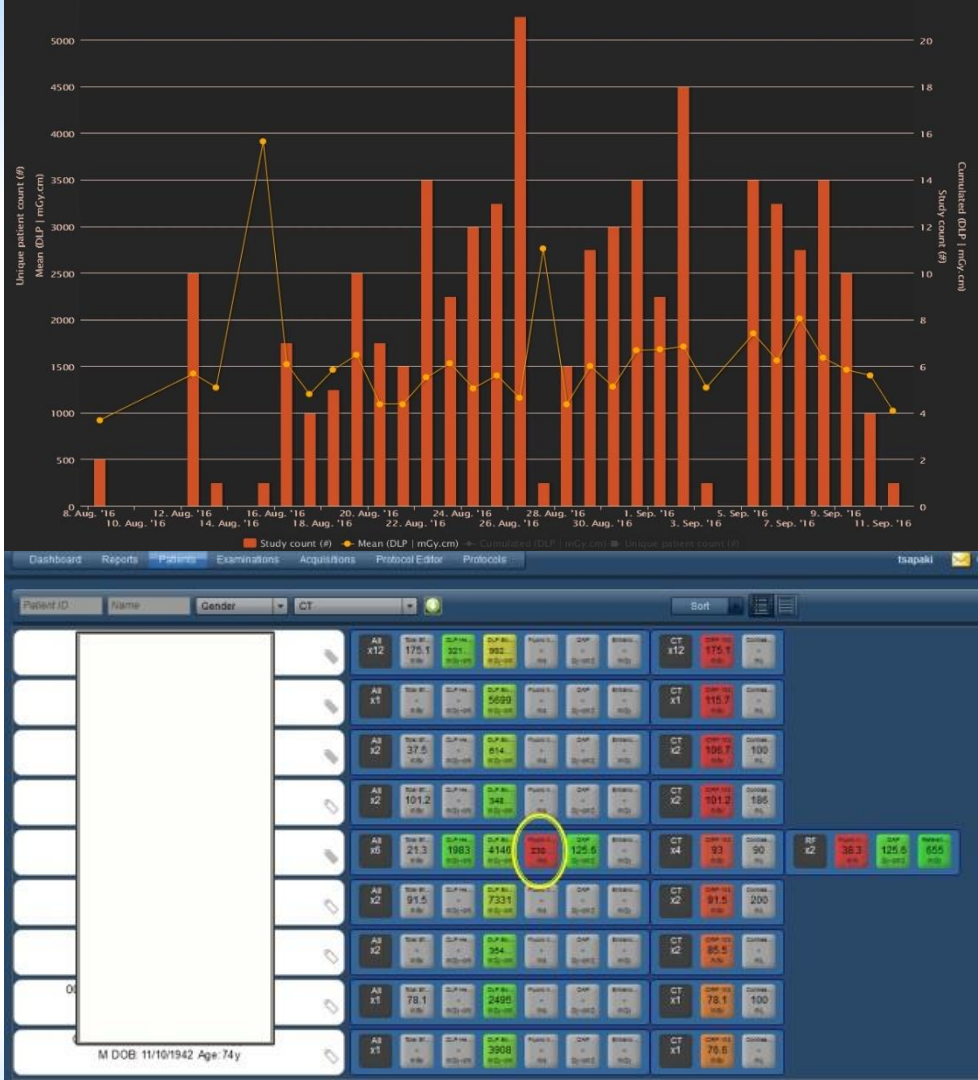
Patients total contrast volume for this procedure (352 mL)



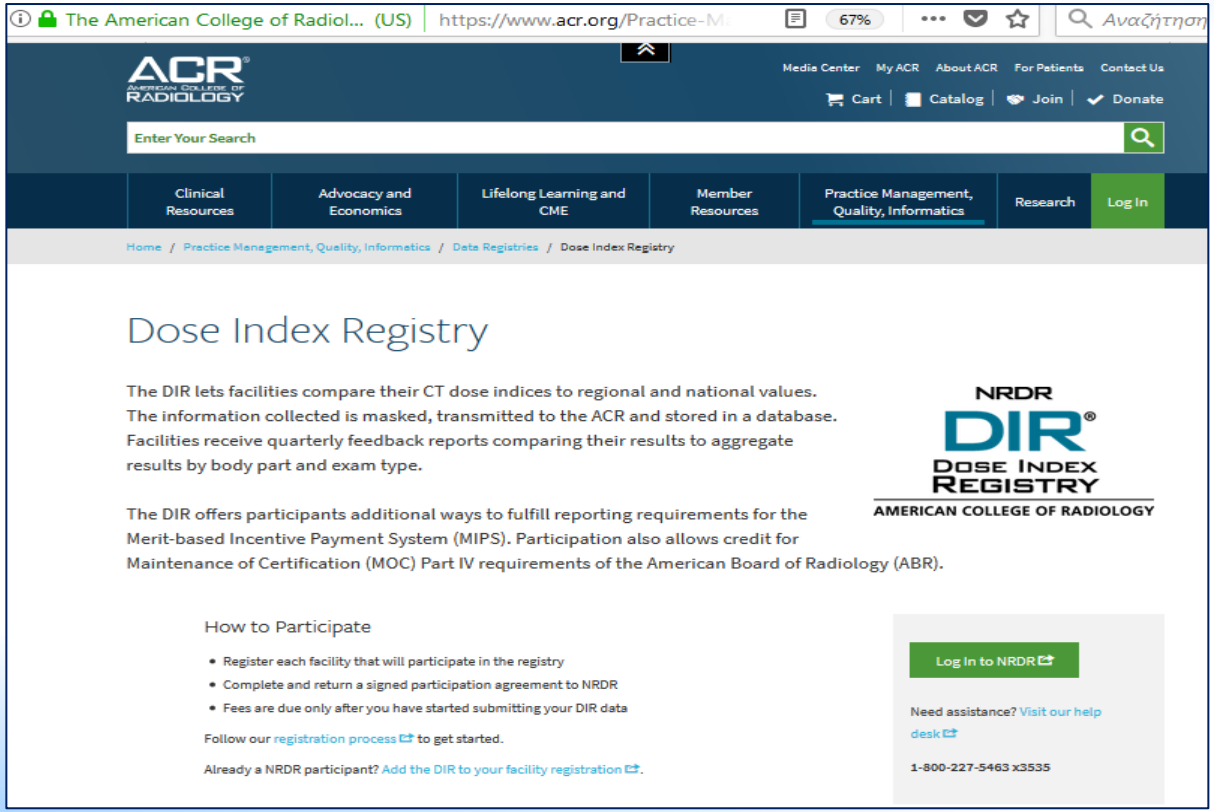
DMS and OPTIMIZATION

Facilitates easy, quick, and immediate estimation, calculation and analysis of:

- *Patient doses*
- *Diagnostic reference levels*
- *Dose alerts*
- *Compares with national and international standards*



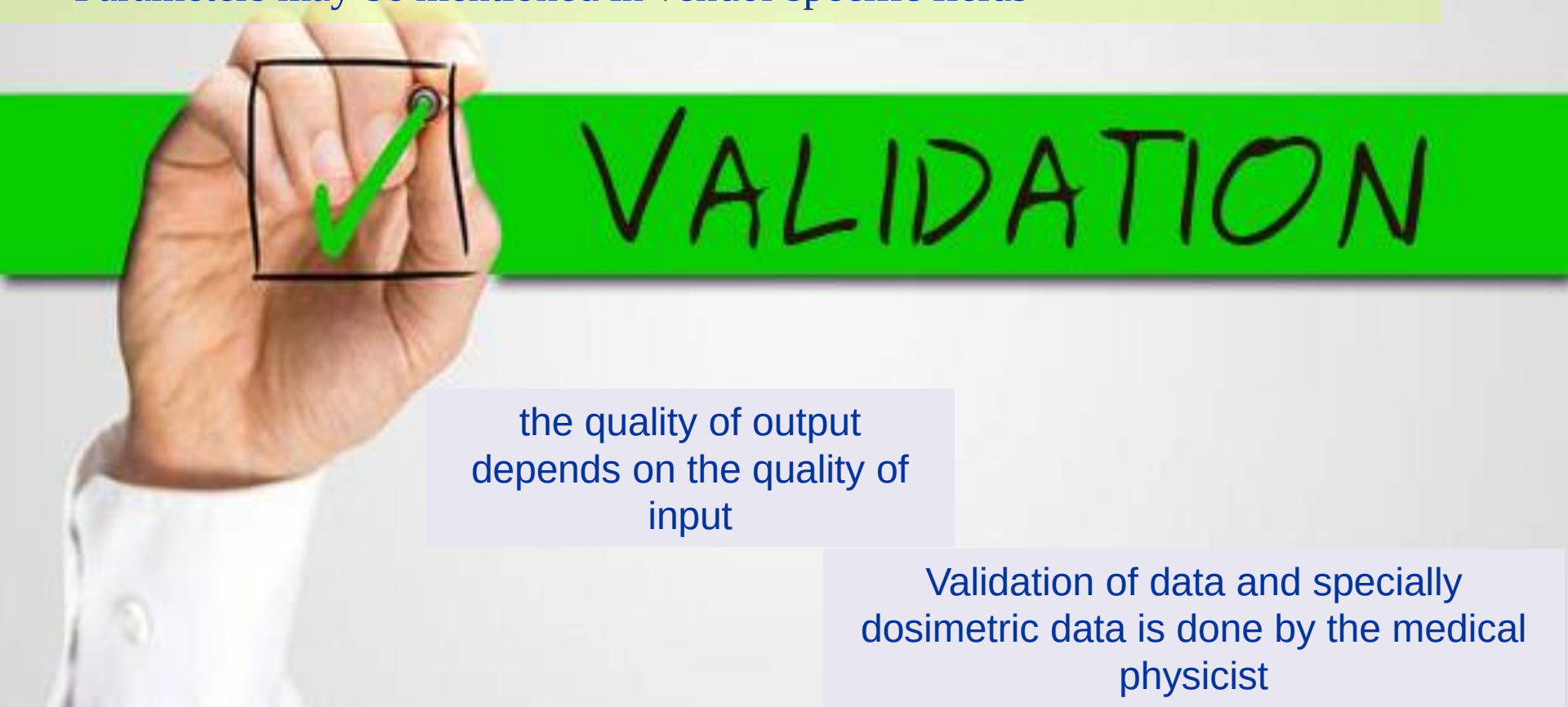
Estimates of population doses; Example of a dose registry



September 2017

48 million exams from more than 2100 facilities

- After data are collected they must be validated
- Parameters are occasionally mentioned in the wrong DICOM field
- Parameters may be mentioned in vendor specific fields



the quality of output depends on the quality of input

Validation of data and specially dosimetric data is done by the medical physicist

Challenge 1 Enormous variety in machines (possible connectivity issues)

- So many different modalities (CT, mammography, radiography, fluoroscopy, interventional, nuclear medicine, MRI, etc)
- So many vendors in each modality.
- So many models per vendor
- All of them will have different way of implementation
- Older machines may not provide dose reports
- Older machines do not even report dose

Institution must be certain that the X-ray machines CAN be connected to the software.

Challenge 2: Enormous amount of data

- In one hospital it can be thousands of exams
- In many hospitals it can be millions of exams
- Hundreds of protocols for example for CT
- Mixture of old and new exams (data)

Every time you change something in the protocol or you change the protocol name there will be a permanent trace in the history of the record. This is another important reason why we have so many data

Challenge 3: Enormous variety in clinical protocol nomenclature

Different CT scanners have different protocol names.

- Before actual use of DMS, protocols should be standardized in terms of nomenclature.

- If not, then protocol mismatches and overlapping errors will happen between different CT scanners. For example, errors such as using same name for a single-phase contrast-enhanced protocol on one scanner and a triple-phase contrast-enhanced protocol on another scanner would lead to miscalculation of the average radiation dose of certain protocols.
- One can use the RadLex Playbook: http://playbook.radlex.org/playbook/SearchRadlexAction

This is the biggest challenge after procurement and better be done at a imaging device level.

Challenge 4: Various dosimetric quantities for all modalities

$CTDI_w$

SSDE

MGD

CTDI

AGD

$CTDI_{vol}$

DLP

MSD

$CTDI_{air}$

KAP

DAP

Kar

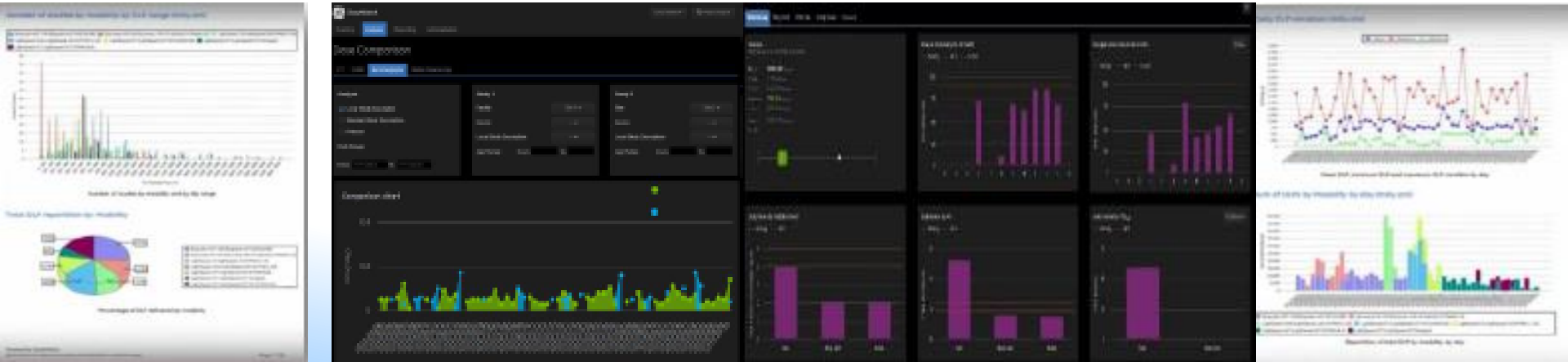
P_{KA}

ESAK

Challenge 5: Enormous amount of information

- The clinicians are bombarded with tons of graphs, figures, statistics and other info ..
- This tons of data do not necessarily lead to knowledge, innovation, insights

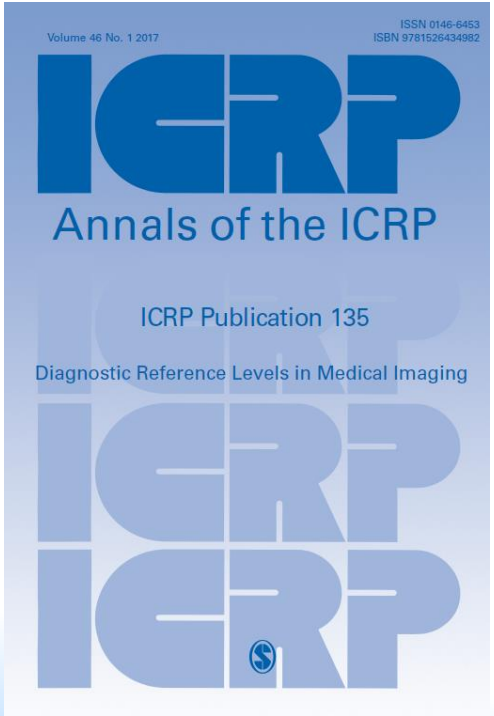
One has to scrutinize this data and be able to dig out meaningful information for the user



Challenge 6: Notification values are fixed and independent of patient size.

- Appropriate doses for bariatric patients may inappropriately trigger notification events
- This can lead today to unnecessary incident reviews required by authorities.
- Even worse, when the alert value is exceeded, the workflow may stop on the scanner until a user with the proper credentials authorizes scan continuation.

International Commission on Radiological Protection (ICRP), 2017. Diagnostic reference levels in medical imaging. ICRP Publication 135. Ann. ICRP 46(1).



Patient dose management systems are helpful in fulfilling legal requirements or to identify unintended overexposures.

…the validity of the dosimetric indicators must be verified by medical physics experts, and corrected, if necessary, prior to their incorporation into patient dose management systems.

Radiation dose management systems; requirements and recommendations for users from the ESR EuroSafe Imaging initiative.

- Basic requirements
- Standard requirements
- High-level solutions

- DMS which can be tailored to the size and workload of a clinic/institution.
- If calculated organ or effective doses are provided, the uncertainties should always be considered.

During installation and subsequent operation of a DMS, the inclusion of an MPE is strongly recommended, especially in larger institutions or complex installations.

European Radiology
https://doi.org/10.1007/s00330-020-07290-x

RADIOLOGICAL EDUCATION

Radiation dose management systems—requirements and recommendations for users from the ESR EuroSafe Imaging initiative

Reinhard W. Loose[1,2] · Eliseo Vano[3] · Peter Mildenberger[4] · Virginia Tsapaki[5] · Davide Caramella[6] · Johan Sjöberg[7] · Graciano Paulo[8] · Alberto Torresin[9] · Sebastian Schindera[10] · Guy Frija[11] · John Damilakis[12] · on behalf of the European Society of Radiology (ESR)[13]

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Abstract
The European Directive 2013/59/Euratom requires member states of the European Union to ensure justification and optimisation of radiological procedures and store information on patient exposure for analysis and quality assurance. The EuroSafe Imaging campaign of the European Society of Radiology created a working group (WG) on "Dose Management" with the aim to provide European recommendations on the implementation of dose management systems (DMS) in clinical practice. The WG follows Action 4: "Promote dose management systems to establish local, national, and European diagnostic reference levels (DRL)" of the EuroSafe Imaging Call for Action 2018. DMS are designed for medical practitioners, radiographers, medical physics experts (MPE) and other health professionals involved in imaging to support their tasks and duties of radiation protection in accordance with local and national requirements. The WG analysed requirements and critical points when installing a DMS and classified the individual functions at different performance levels.

Key Points
- *DMS are very helpful software tools for monitoring patient exposure, optimisation, compliance with DRLs and quality assurance.*
- *DMS can help to fulfil dosimetric aspects of the European Directive 2013/59/Euratom.*
- *The EuroSafe WG analyses DMS requirements and gives recommendations for users.*

Keywords Dose management systems · Radiation protection · Optimisation · Quality assurance

Abbreviations

ADT	Admission, discharge and transfer
ALARA	As low as reasonably achievable
CR	Computed radiography
CT	Computed tomography
DICOM	Digital Imaging and Communication in Medicine

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[10] Institute of Radiology, Cantonal Hospital, Aarau, Switzerland
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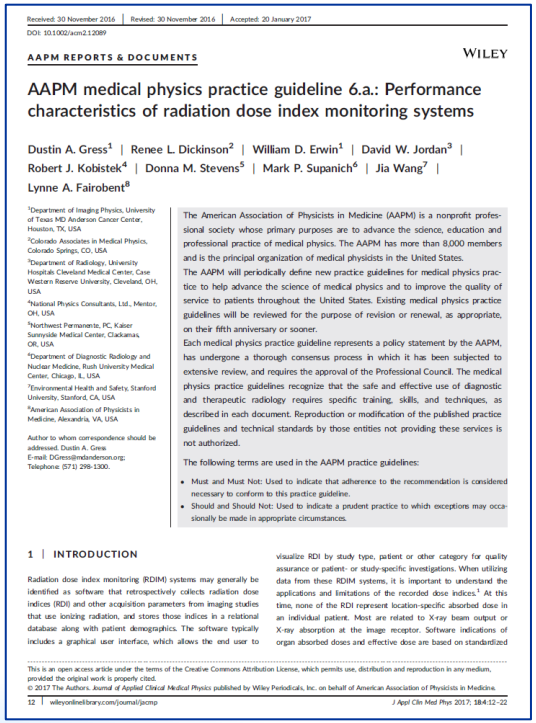
AAPM guidelines



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DOI: 10.1002/acm2.12089

AAPM REPORTS & DOCUMENTS

WILEY

AAPM medical physics practice guideline 6.a.: Performance characteristics of radiation dose index monitoring systems

Dustin A. Gress[1] | Renee L. Dickinson[2] | William D. Erwin[1] | David W. Jordan[3] | Robert J. Kobistek[4] | Donna M. Stevens[5] | Mark P. Supanich[6] | Jia Wang[7] | Lynne A. Fairobent[8]

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The American Association of Physicists in Medicine (AAPM) is a nonprofit professional society whose primary purposes are to advance the science, education and professional practice of medical physics. The AAPM has more than 8,000 members and is the principal organization of medical physicists in the United States.
The AAPM will periodically define new practice guidelines for medical physics practice to help advance the science of medical physics and to improve the quality of service to patients throughout the United States. Existing medical physics practice guidelines will be reviewed for the purpose of revision or renewal, as appropriate, on their fifth anniversary or sooner.
Each medical physics practice guideline represents a policy statement by the AAPM, has undergone a thorough consensus process in which it has been subjected to extensive review, and requires the approval of the Professional Council. The medical physics practice guidelines recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice guidelines and technical standards by those entities not providing these services is not authorized.

The following terms are used in the AAPM practice guidelines:

- Must and Must Not: Used to indicate that adherence to the recommendation is considered necessary to conform to this practice guideline.
- Should and Should Not: Used to indicate a prudent practice to which exceptions may occasionally be made in appropriate circumstances.

1 | INTRODUCTION

Radiation dose index monitoring (RDIM) systems may generally be identified as software that retrospectively collects radiation dose indices (RDI) and other acquisition parameters from imaging studies that use ionizing radiation, and stores those indices in a relational database along with patient demographics. The software typically includes a graphical user interface, which allows the end user to visualize RDI by study type, patient or other category for quality assurance or patient- or study-specific investigations. When utilizing data from these RDIM systems, it is important to understand the applications and limitations of the recorded dose indices.[1] At this time, none of the RDI represent location-specific absorbed dose in an individual patient. Most are related to X-ray beam output or X-ray absorption at the image receptor. Software indications of organ absorbed doses and effective dose are based on standardized

These systems have potential to revolutionize quality assurance in imaging and present unique research opportunities.
The data from DMS may be useful in assisting the medical physicist in such tasks as ongoing Quality assurance, Practice Quality Improvement and patient or fetal dose estimation.

estimated organ and effective dose values must only be used with the direction and involvement of a Qualified Medical Physicist, and with careful consideration and understanding of limitations of the quantities

Dose Management Systems (publication)

There is little guidance on how to set up and assess the accuracy of a DMS, including a lack of standardization of procedures related to acceptance testing and periodic quality control tests.

IAEA Expert meeting
Date: 30 May-3 June 2022

The purpose of the meeting was to discuss the current status on dose management systems use, identify gaps and challenges and finally define the contents of guidelines for medical physicists on the content, analysis, and evaluation of these systems to help Member States understand, set up and use them appropriately.

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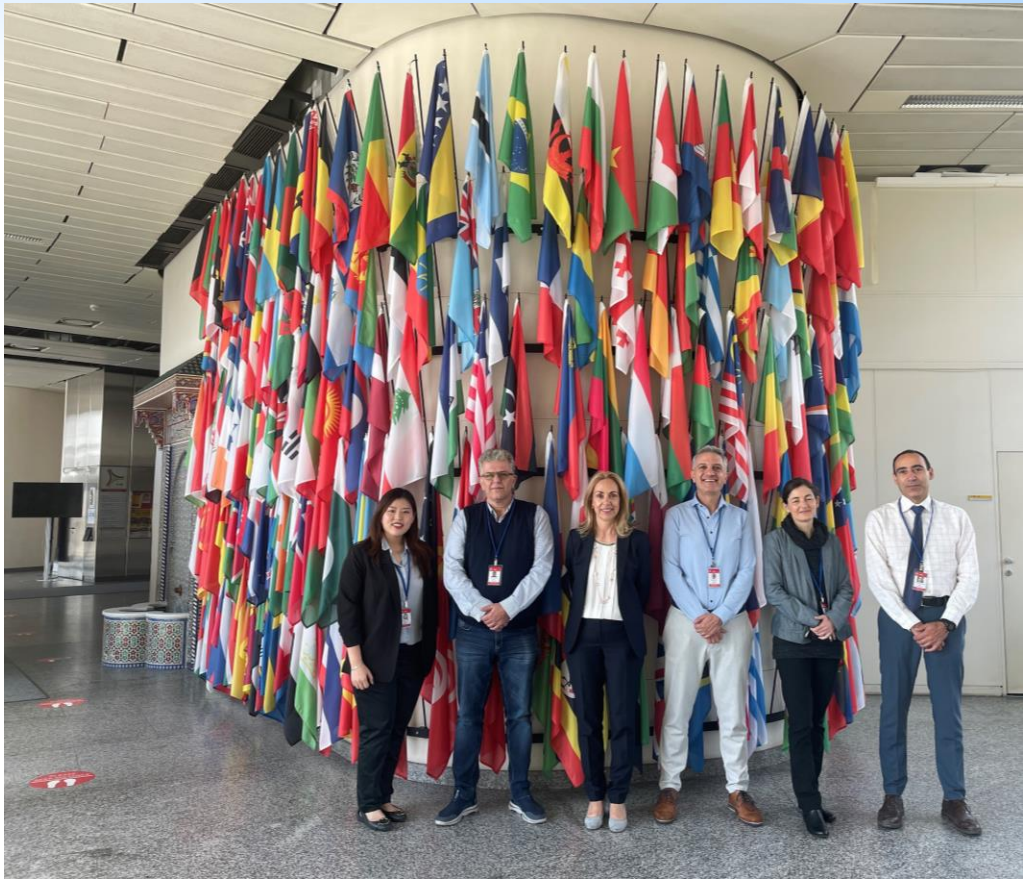

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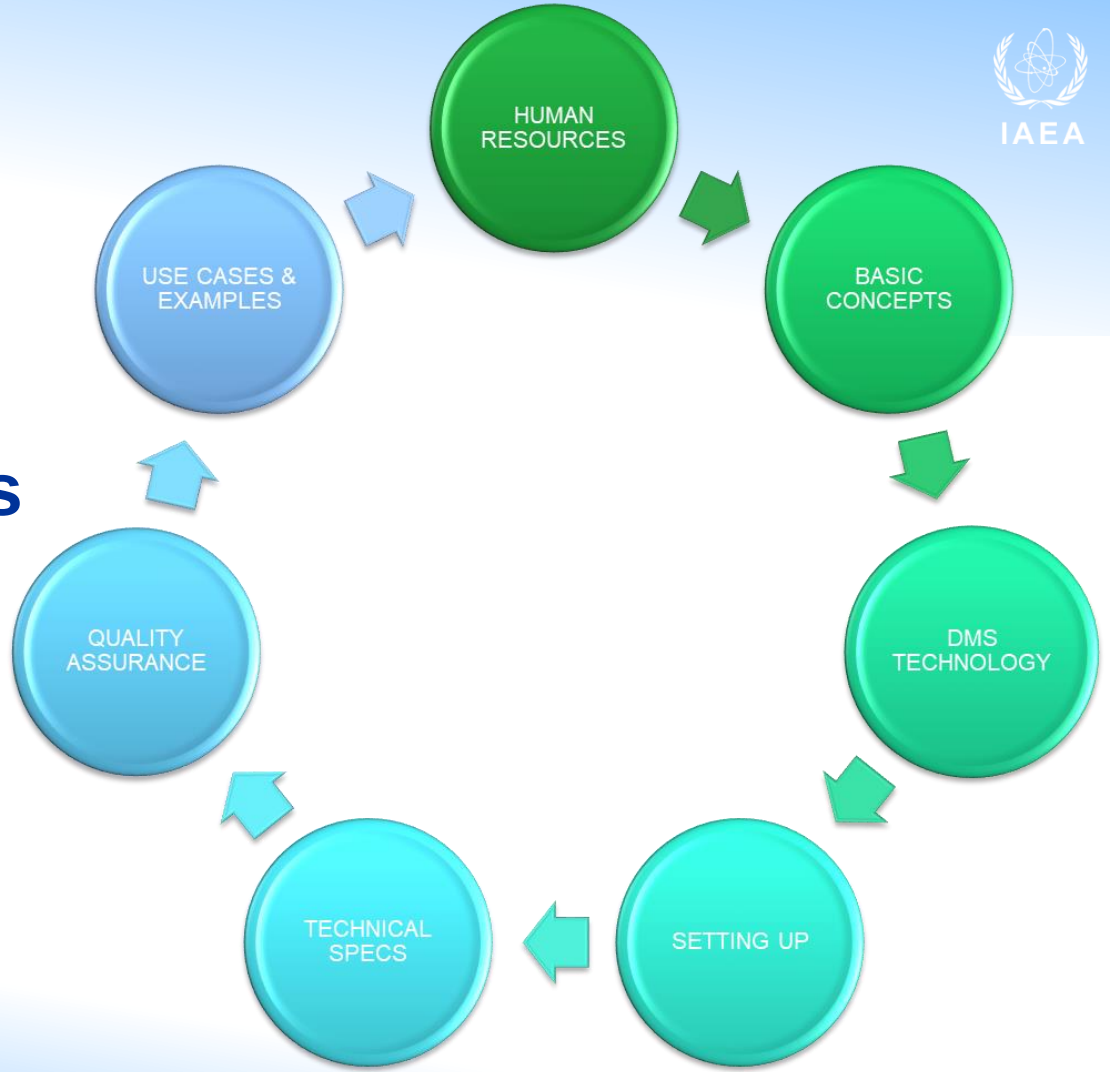


Information Collected

1. Certifications

FDA, CE, Joint Commission
other Certification

2. Data Transfer Methods, Patient/Facility Information

Data connection & Collection
Examination/Patient/Facility Records
Unit Conversion & Calibration Factors

3. Modalities, Metrics & Methods Supported

Acquisition & Reconstruction Parameters Collected
Dose Metrics & Parameters Calculated
Image Quality Evaluation Tools
Occupational Dose Tracking

4. Statistical Analysis Capabilities

Information Dashboard
Export Capabilities
Analysis of data collected & calculated

5. Customization

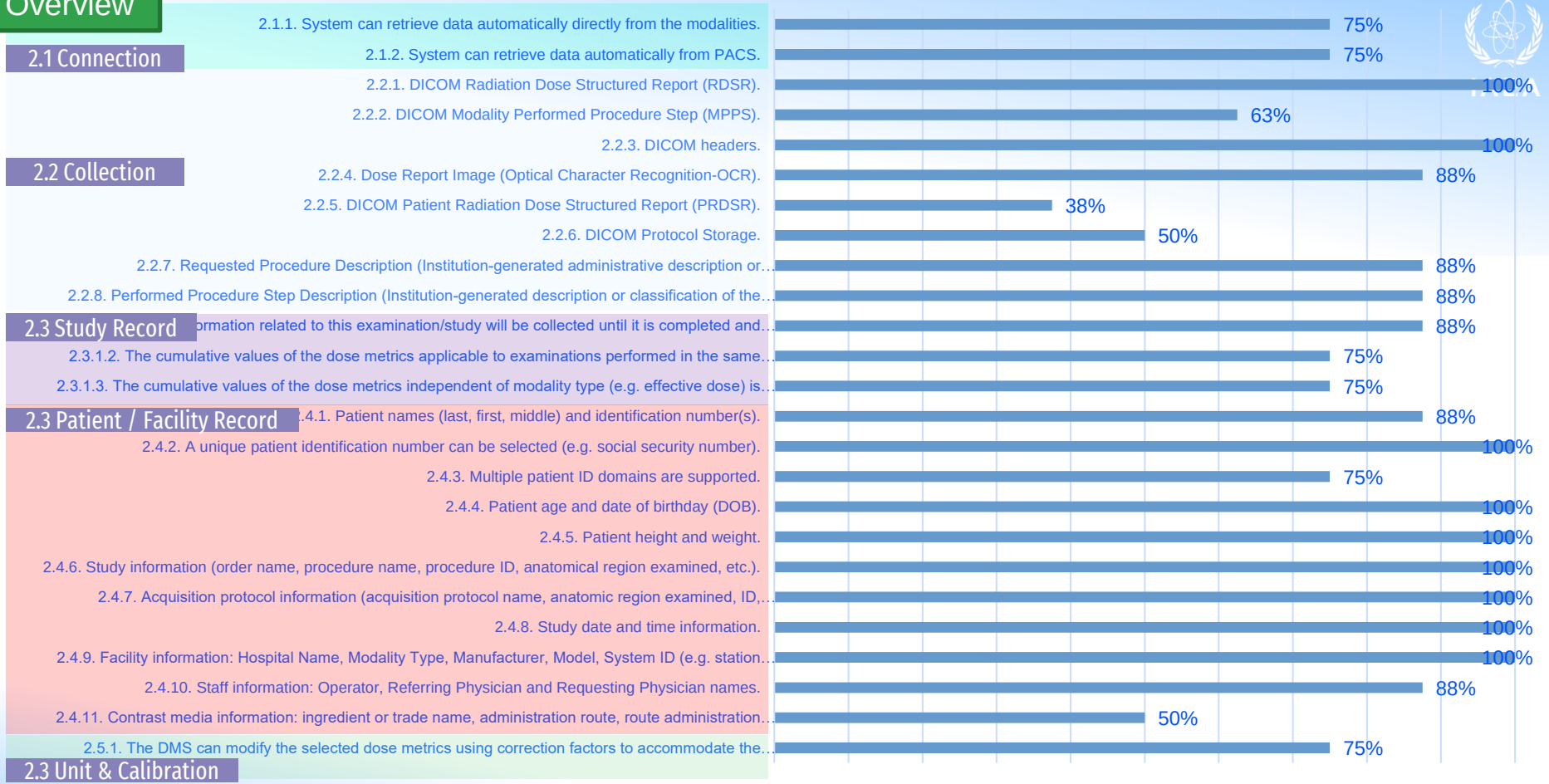
Setting Alerts
Master Protocols
DRL Libraries
User Rights

6. Implementation Process

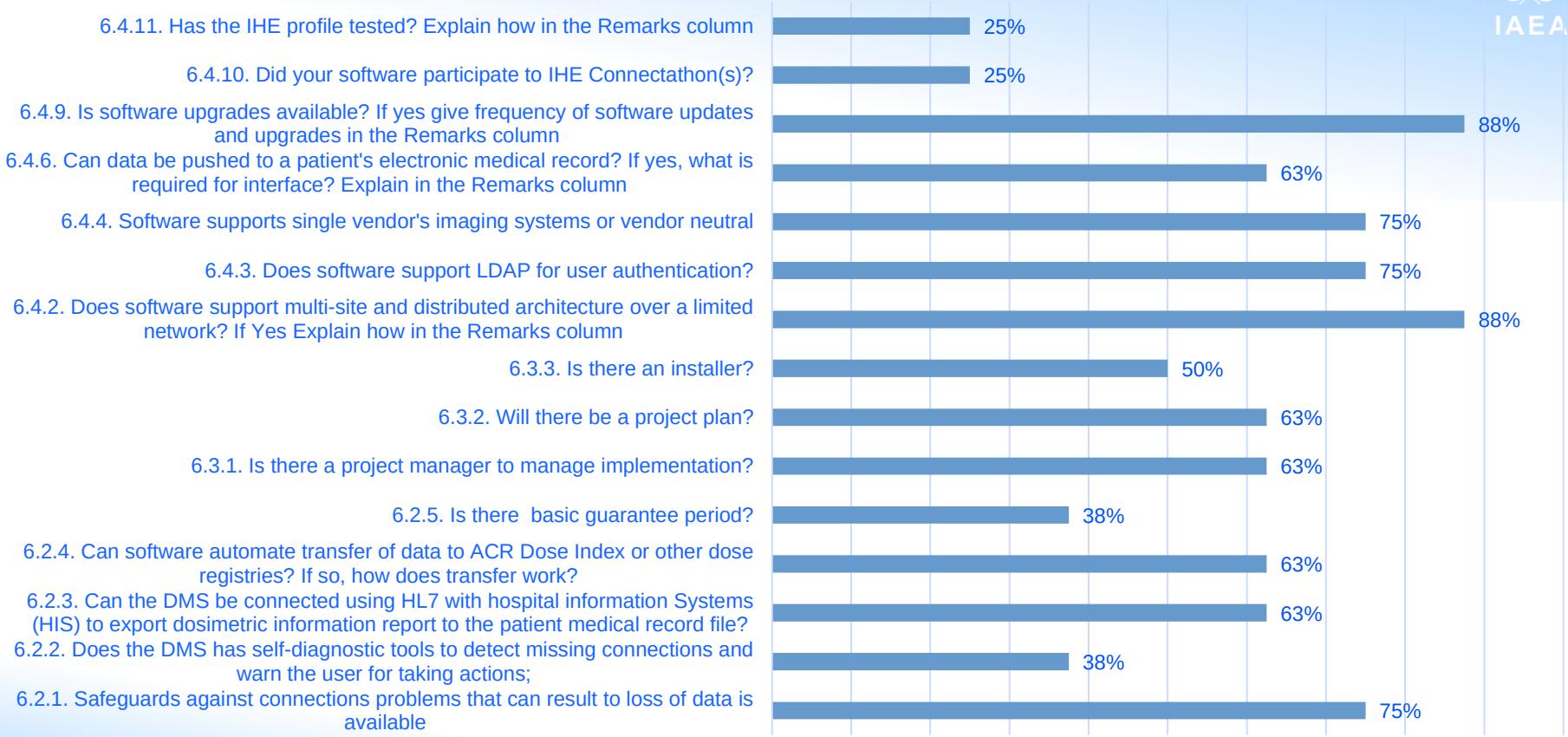
IT installation requirements
Support & Functionalities
Implementations

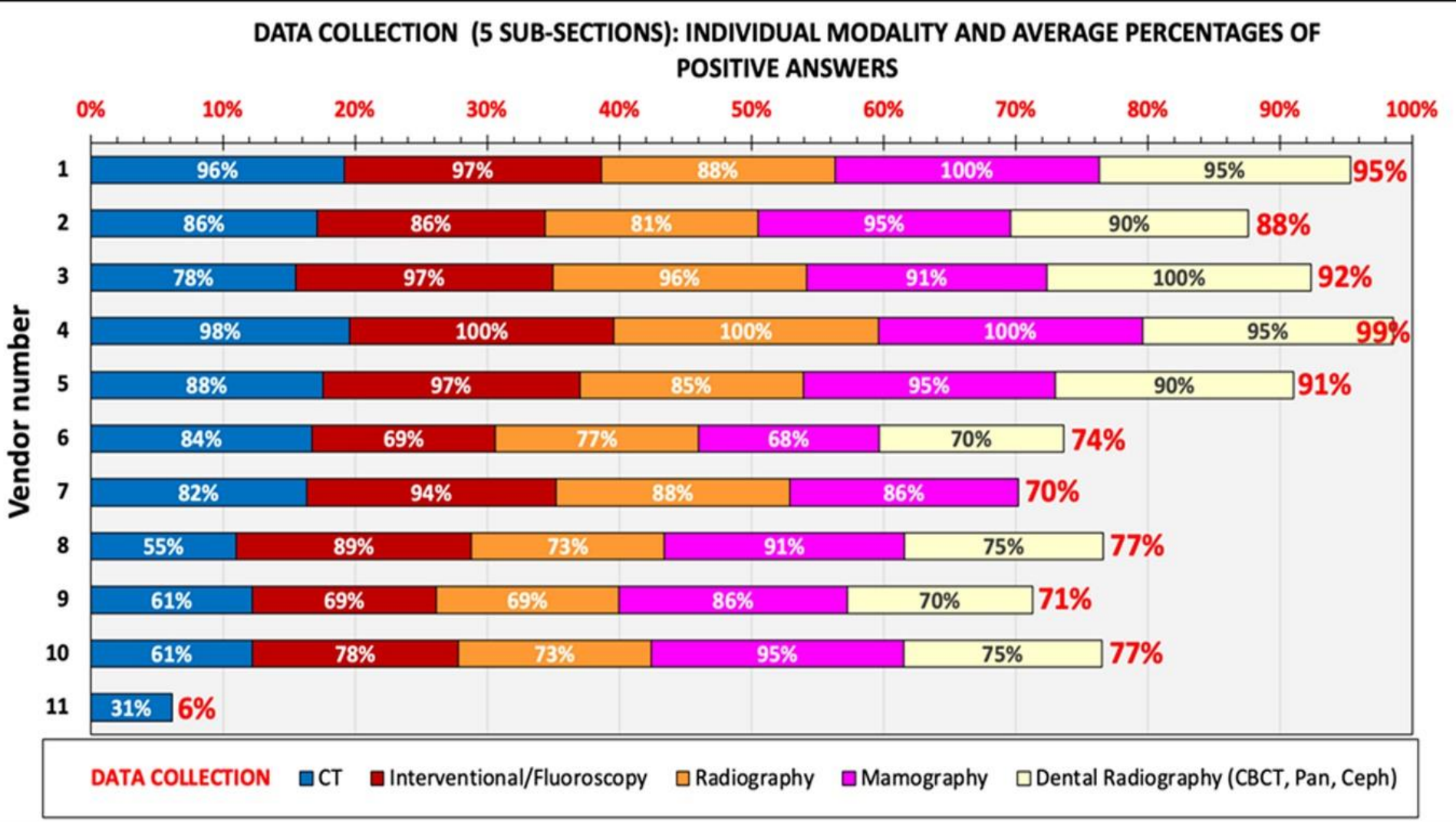
Courtesy Mrs Laurentcia Arlany, member of the IAEA DMS expert group

Overview


2.1 Connection
2.2 Collection
2.3 Study Record
2.3 Patient / Facility Record
2.3 Unit & Calibration
2.1.1. System can retrieve data automatically directly from the modalities. 75%
2.1.2. System can retrieve data automatically from PACS. 75%
2.2.1. DICOM Radiation Dose Structured Report (RDSR). 100%
2.2.2. DICOM Modality Performed Procedure Step (MPPS). 63%
2.2.3. DICOM headers. 100%
2.2.4. Dose Report Image (Optical Character Recognition-OCR). 88%
2.2.5. DICOM Patient Radiation Dose Structured Report (PRDSR). 38%
2.2.6. DICOM Protocol Storage. 50%
2.2.7. Requested Procedure Description (Institution-generated administrative description or… 88%
2.2.8. Performed Procedure Step Description (Institution-generated description or classification of the… 88%
ormation related to this examination/study will be collected until it is completed and… 88%
2.3.1.2. The cumulative values of the dose metrics applicable to examinations performed in the same… 75%
2.3.1.3. The cumulative values of the dose metrics independent of modality type (e.g. effective dose) is… 75%
.4.1. Patient names (last, first, middle) and identification number(s). 88%
2.4.2. A unique patient identification number can be selected (e.g. social security number). 100%
2.4.3. Multiple patient ID domains are supported. 75%
2.4.4. Patient age and date of birthday (DOB). 100%
2.4.5. Patient height and weight. 100%
2.4.6. Study information (order name, procedure name, procedure ID, anatomical region examined, etc.). 100%
2.4.7. Acquisition protocol information (acquisition protocol name, anatomic region examined, ID,… 100%
2.4.8. Study date and time information. 100%
2.4.9. Facility information: Hospital Name, Modality Type, Manufacturer, Model, System ID (e.g. station… 100%
2.4.10. Staff information: Operator, Referring Physician and Requesting Physician names. 88%
2.4.11. Contrast media information: ingredient or trade name, administration route, route administration… 50%
2.5.1. The DMS can modify the selected dose metrics using correction factors to accommodate the… 75%

Section 6. Implementation Process




DATA COLLECTION (5 SUB-SECTIONS): INDIVIDUAL MODALITY AND AVERAGE PERCENTAGES OF POSITIVE ANSWERS
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Vendor number
1
96%
97%
88%
100%
95%
95%
2
86%
86%
81%
95%
90%
88%
3
78%
97%
96%
91%
100%
92%
4
98%
100%
100%
100%
95%
99%
5
88%
97%
85%
95%
90%
91%
6
84%
69%
77%
68%
70%
74%
7
82%
94%
88%
86%
70%
8
55%
89%
73%
91%
75%
77%
9
61%
69%
69%
86%
70%
71%
10
61%
78%
73%
95%
75%
77%
11
31%
6%
DATA COLLECTION
CT
Interventional/Fluoroscopy
Radiography
Mamography
Dental Radiography (CBCT, Pan, Ceph)

Conclusions from the study

- Healthcare institutions contemplating the acquisition of a DMS solution should comprehensively explore the available DMS solutions, regarding the features and functionalities that the offer, to make sure that they align with their specific needs.

- Subsequently interested institutions must identify which of those advanced features, which may be optional and come at an extra cost, are either essential or desirable for their specific organization, considering the available budget.

- Finally, it should be confirmed whether the existing infrastructure and information technology personnel available are compatible with the proposed DMS installation, operation, and service support requirements. This approach could potentially optimize expenditure, ensuring a balance between operational efficiency and budgetary constraints.

Conclusions

- DMS are considered important tools for supporting the process of justification and optimisation at a health institutional level and for compliance with the regulation on radiation protection.
- More efforts are needed to eliminate the connectivity issues related to modality, varying clinical protocol nomenclature, identifying notification values for various patient sizes, etc.
- Advanced DMS must be used under the supervision of a qualified medical physicist.

For the future

Image quality assessment in relation to radiation dose for effective optimization tailored to each individual patient’s needs