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D 9.141 - Standards for digital dose reporting

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Abstract

In interventional cardiology (IC), patients may be exposed to high doses to the skin resulting in tissue reactions (e.g. skin burns) following single or multiple procedures. Assessing the maximum skin dose (MSD) to the patient together with the dose distribution during (or after) these procedures is, as recommended by the ICRP Committee 3, essential from patient radiation protection point of view. Several software tools (online or offline) have been developed to help medical physicists in assessing the MSD during or after the procedure; they are either commercialised by major X-ray equipment manufacturers or produced by independent companies (e.g. dose management software companies). The capabilities and accuracy of such skin dose calculation (SDC) software markedly differ among vendors; and the reporting of the MSD estimate as well as the related accuracy in the Radiation Dose Structured Report (RDSR) is neither systematic nor harmonised.

The VERIDIC project focuses on the harmonization of RDSR and on the validation of SDC software products, which will optimise radiation protection of patients. Among the overall project objectives, the Work Package 1 (WP1) dealt with the SDC harmonization issue in the view of proposing a possible standardisation of the digital dose reporting. Two different sub-tasks were carried out: (i) The review of existing software and (ii) the harmonization of dose reporting and tracking.

In the first subtask (i), 19 software tools claiming SDC capacities were identified in the literature and reviewed according to their SDC algorithms and their capabilities. Special attention was dedicated to their main features and limitations of interest for the clinical user. In the second subtask (ii), RDSRs from recent systems of the four main manufacturers (Philips, Siemens, GE and Canon) were compared with a view to identifying the availability and the completeness of the data necessary for the calculation. The ability of two dose management systems to extract RDSR data was also investigated by comparing their output with the original RDSR.

Although most SDC software tools use a comparable approach to estimate the skin dose, considerable differences in the implementation exist. While the accuracy of the 10 SDC products which were experimentally validated with measurements on phantoms, was acceptable (within ±25%); the agreement was poor for the two products which were also validated on patients (within ±43% and ±76%, respectively). In addition, no software has been validated on angiographic units from all manufacturers, though several software developer claimed vendor-independent transportability

Strong heterogeneities in examination related technical parameters encoded in RDSR by the manufacturers were found, especially important for all dose calculation related data; even more heterogeneities were pointed out when considering the DICOM fields exports through two dose management software products. This highlighted the need for harmonizing both RDSRs and their exports in order to be able to calculate MSD from these data in an easy and straightforward way.

Essential parameters for MSD calculation and dose mapping were listed and should be included in both RDSRs and exports. A public DICOM field to store MSD was suggested, as well as the use of the existing field to store final dose maps. To enhance harmonization, a flat representation of the skin dose map in addition the possible 3D representation was also suggested, in order that skin dose maps of multiple procedures on the same patient could easily be overlaid and the resulting MSD could be better estimated.

Contents

1. Harmonization of skin dose reporting

1.1 General framework

In interventional cardiology (IC), patients may be exposed to high doses to the skin resulting in tissue reactions (e.g. skin burns) following single or multiple procedures. Assessing the maximum skin dose (MSD) to the patient during (or after) these procedures together with 2D dose distribution is, as recommended by the ICRP Committee 3, essential from patient radiation protection point of view.

Several software tools (online or offline) have been developed to help medical physicists in assessing the MSD during or after the procedure; they are either commercialised by major X-ray equipment manufacturers or produced by independent companies (e.g. dose management software companies). The capabilities and accuracy of such skin dose calculation (SDC) software markedly differ among vendors; and the reporting of the MSD estimate as well as the related accuracy in the Radiation Dose Structured Report (RDSR) is neither systematic nor harmonised. The VERIDIC project focuses on the harmonization of RDSR and on the validation of SDC software products, which will optimise radiation protection of patients.

1.1.1 Description of work achieved in WP1

Among the overall VERIDIC project objectives, the Work Package 1 (WP1) dealt with the SDC harmonization issue in the view of proposing a possible standardisation of the digital dose reporting.

Two different sub-tasks were carried out during the considered reporting period (from the 1st of February to the end of November 2018):

- The review of existing software
- The harmonization of dose reporting and tracking

1.1.2 Review of existing software

The first sub-task started by identifying the physical parameters used for calculation of the MSD (tube voltage, filtration, beam orientation, table position, backscatter factor (BF), table attenuation, air KERMA-to-skin dose conversion coefficient, etc.). Indeed, depending on whether a given parameter is accurately considered in the MSD calculation of the available software product, significant dose differences can occur.

As a first step, a critical analysis of software was carried out by considering the following properties:

- their calculation algorithms (information was gathered from technical specifications, scientific literature, direct contacts with manufacturers and/or developers)
- the factors considered in the calculation of the MSD estimates (such as the backscatter, the table attenuation or the patient's body shape)
- their capabilities of providing users with a 2D or 3D-dose distribution (graphical dose representations were qualitatively compared from manufacturers leaflets, technical documents or published papers)

In order to gather all this information, the four major manufacturers of angiographic systems were contacted. Some of them provided us with their publications (not only published papers) and technical documents that detailed the way the MSD were assessed and the modelling used for simulating the patient body shape. Technical information associated to SDC software

developed by independent companies was also obtained through a literature review and/or personal contacts with the developers (Table 1).

Both online and offline software (*i.e.,* whether software provides the user with the MSD and possibly the dose distribution during or after the procedure, respectively) developed after 2000 were considered. Older software that is not available anymore like the program of den Boer et al. (2001) was left out.

Table 1: MSD calculation software

Software Name	References	Manufacturer	Contacted /answered
Dose Map**	Bordier et al. 2015 a; Bordier et al. 2015 b; Nilsson-Althen and Sandborg 2016	GE	Y/Y
Dosewatch*	Gardavaud et al 2018	GE	Y/Y
DTS**	Bednarek et al. 2011 ; Rana et al 2013 ; Rana et al 2016	CANON	Y/N
em.dose*	Greffier et al. 2017 ; Magnier et al. 2018	ESPRIMED	Y/Y
Radimetrics*		BAYER	Y/N
RDM*	Habib Geryes et al. 2018	MEDSQUARE	Y/Y
Dose*	Hintenlang et al. 2018	QAELUM	Y/Y
UF-RIPSA*	Johnson et al. 2011 ; Borrego et al. 2017 ; Borrego et al. 2018	Non-commercial	N
	Khodadadegan et al. 2011 ; Khodadadegan et al. 2013	Non-commercial	N
FDEIR*	Takata et al. 2017	Non-commercial	N
MCGPU*	Badal et al. 2013, Principi et al. 2018	Non-commercial	N
TeamPlay*		SIEMENS	Y/Y
Dosewise*		PHILIPS	Y/N
Dosetrack*		SECTRA	Y/N
Nexodose*	Rottoli et al 2018	BRACCO	Y/N
Dose monitor*		PACSHEALTH	N
Dosem*		INFINITT	N
OpenSkin *	https://bitbucket.org/openskin/openskin	Non-commercial (Cole J.)	Y/Y
	Hellström M. 2018	Open Source	Y/Y

*offline system - **online system

Most of the software tools are “offline” systems. Of course, from a radiation protection point of view, “online” systems are preferable since they allow optimization of the MSD during the procedure.

The MSD calculation formalism used by different manufacturers and non-commercial developers; is presented below even though it was not possible to obtain information about it for all the considered systems.

There is a clear agreement among the developers on how to assess the MSD value. Except for MC-GPU and FDEIR, which model the particle transport via Monte Carlo (MC) simulations, all listed software (Dose Map, DoseWatch, DTS, em.dose, Radimetrics, RDM, Dose, UF-RIPSA, Khodadegan et al., OpenSkin) uses a formalism comparable to the methodology proposed by Jones and Pasciak (2011) for systems compliant with IEC standards.

The displayed air kerma at the reference point ($K_{a,r}$) is corrected to account for the calibration of the $K_{a,r}$ against quality control measurements, the table and mattress attenuation, the contribution of the backscattered radiation, the distance between the reference point and the actual patient entrance point and the conversion of air KERMA to dose in tissue as follows:

$$Skin\ dose = K_{a,r} \times CF \times Att \times BSF \times \left(\frac{d_{ref}}{d_{perp}}\right)^2 \times f_{skin} \quad [1]$$

Where :

- *CF* is the calibration factor or the ratio between the measured and the displayed, $K_{a,r}$,
- *Att* is the attenuation coefficient of the table and the mattress,
- *BSF* is the backscatter factor,
- d_{ref} is the distance between the X-ray focal spot and the reference point,
- d_{perp} is the distance between the X-ray focal spot and the patient entrance reference point (PERP)
- f_{skin} is the ratio of mass-energy-absorption coefficients from skin-to-air.

In the definition of their calculation formalism, Jones and Pasciak (2011) did not include the scatter radiation from adjacent field. Neither does any of the previously listed software; however, it has a very limited influence (Borrego et al., 2018).

Table 2 details the parameters used in the SDC formula given above and allows the comparison between different developers.

Table 2 : Comparison of BSF, Att, CF, f-factors and patient model by developers

Software Name	Backscatter factor (BSF)	Attenuation coefficient of the table and the mattress (Att)	$K_{a,r}$ calibration factor (CF)	f-factor	Patient model
Dose Map	Logarithmic model BSF = a ln(area)+b; per event	Second order polynomial model vs kV; per event	Not Available	Not Available	Elliptical phantoms
Dosewatch	BSF	AF	Single value (1.2)	Not Available	ICRP anthropomorphic phantoms
DTS	From calibration measurements; per event	From calibration measurements and corrected for beam angulation; per event	From calibration measurements; per event	Single value	CAESER database patient modelling
em.dose	From literature (Benmakhlouf et al 2011); per event	Set by user for different beam qualities; per event	Single value set by user	Single value (1.06)	Elliptical phantoms
Radimetrics		Not Available	Single value set by user	Selectable by user	Choice between a list of different phantoms
RDM	From literature (Benmakhlouf et al 2011); per event	Set by user (PA) and corrected for beam angulation; per event	Single value set by user	From literature (Benmakhlouf et al 2011); per event	Rectangular parallelepiped with two half-cylinders on the side
Dose	From literature (Benmakhlouf et al 2011 and 2013); per event	From measurements on one system; per event	Not Available	Not Available	Elliptical phantoms
UF-RIPSA	From literature (ICRU Report 74); per event	From MC simulated coefficients for one system; per event	From KAP calibration curves set by user; per event	Source unknown; per event	University of Florida hybrid phantom library
Khodadadegan et al.	Single value set by user	Single value set by user	Single value set by user	No	Mathematical phantoms in the first version (2011); information unclear in the latest version (2013), likely elliptical phantoms
FDEIR	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Voxelized CT phantom
MC-GPU	Not Applicable	Not Applicable	Not Available	Not Applicable	Voxelized phantom
OpenSkin	From literature (Benmakhlouf et al 2011); per event	From measurements on one system	No	From literature (Benmakhlouf et al 2011); per event	Rectangular parallelepiped with two half-cylinders on the side
Hellström	From literature (Benmakhlouf et al 2011); per event	From measurements on one system; per event	From calibration measurements; per event	From literature (Benmakhlouf et al 2011); per event	No patient representation

Some variations in the choice of BSF values were found (see Table 2). One software tool used a fixed value per procedure (Khodadadegan et al.), whereas most software (Dose, RDM, em.Dose, Hellström, OpenSkin) used tabulated values or interpolation of those values selected according to technical parameters (possibly beam quality, field size and phantom thickness). The most used BSF source is clearly the simulation work of Benmakhlouf et al (2011, 2013). It is obvious that the choice of BSF has a strong influence on the accuracy of MSD calculation since the MSD is directly proportional to it, as illustrated in Table 3.

Not many software tools use different approaches to estimate BSF. DoseMap uses the irradiated area as unique input in a logarithmic model developed for a specific angiographic unit. Measurements on the very same unit showed that this approach would not cause more than 4% dose uncertainty. The more complete method (FDEIR MC-GPU), based on Monte Carlo, inherently takes the contribution of the scattered photons into consideration.

As far as table and pad attenuations are concerned, many options are possible and different ones are chosen by each provider, like data taken from the literature or a fixed value. As a general rule, table/mattress attenuations are either based on results of physical measurements or on mathematical simulations (UF-RIPSA,) for different X-ray beam projection angulations. Attenuation values are often defined according to procedure X-ray beam qualities and considering presence or absence of the table in the beam. Ideally, the beam angulation should also be considered, since it affects the path travelled by the X-rays in the table and mattress (Dose Map).

From measurements on a table with a 5-cm thick mattress, Bordier et al (2015) observed about 10% difference in the beam intensity comparing PA and RAO40° projections. It should be noted that, in addition to the mattress attenuation, Dose Map accounts explicitly for the contribution of the scatter originating from the mattress.

As for the CF, most vendors did not specify the value used in their systems, did not define it clearly or did not use it (OpenSkin). However, this is of crucial importance owing to the permissive European acceptability criterion which states that the accuracy of the displayed $K_{a,r}$[1] shall not be higher than 35% above 100 mGy (EC, 2012). The CF values can be fixed (DoseWatch) or varying according to the beam energies considered (UF-RIPSA) and to both acquisition and fluoroscopic imaging modes (DTS, Khodadadegan et al.).

In any case, currently the RDSR provides the user with a single calibration factor. Such a single calibration factor is probably not sufficient for an accurate calculation of skin dose, since it has to take into account the calibration of displayed $K_{a,r}$ at different energies, which can vary. For example, heavier filtered beams (0.1–0.2 mm Cu) exhibit a higher dependence as compared to less filtered beams in the range of 10%–15% for 70–90 kVp beams (Lin et al. 2015).

As for how the anatomy of the patient is taken into account, the simplest approaches rely on elliptical or super-elliptical models (scalable or not with real patient height and weight) or just consider the patient as a 2D flat surface. Other approaches use physical anthropomorphic phantoms referring to ICRP recommendations, anthropomorphic phantoms from the digital human modelling project, which corresponds to a voxelized CT phantom derived from a standard patient, or hybrid phantoms from the University of Florida library.

In order to illustrate how the use of either fixed or variable BSF and attenuation coefficient may influence SDC results, Table 3 compares two examples of cardiac procedures concerning two different average patient diameters of 20 and 35 cm respectively. For the whole procedure and

[1] Actually, the European acceptability criterion refers to the Kerma-Area product, but a similar accuracy can be extrapolated to the Ka,r,. An identical criterion is also proposed by the IEC (2010).

for each patient thickness, three kVp ranges were considered for the assessment of the total skin dose according to equation [1] while BSF as well as table attenuation coefficients were alternatively considered as fixed or variable. Therefore, the same IC procedure resulted in two cumulative skin dose values, the difference of which is detailed in Table 3.

As expected, the influence of the correction of the BS is greater for thicker patient, higher kVp and heavily filtered X-ray beams, thus resulting in a dose difference between both methods reaching 20 %. Conversely, the influence of such a correction is significantly smaller for thinner patient, the dose difference between both methods in this case being around 6 %.

Knowing that an interventional cardiology procedure may result in a skin dose level of a few Gy, the appropriateness of considering physical parameters such as BSF and/or table attenuation in a as realistically as possible manner plays an essential role. The thicker the patient, the greater the dose difference.

Table 3: Comparison of skin dose calculations with fixed or variable parameters

<table>
<tr><td></td><td>Parameter</td><td colspan="2">< 80 kVp</td><td colspan="2">80 to 110 kVp</td><td colspan="2">> 110 kVp</td></tr>
<tr><td rowspan="5">Patient diameter = 20 cm
HVL = 3.12 mm Al @ 80 kV</td><td></td><td>Fixed</td><td>Variable</td><td>Fixed</td><td>Variable</td><td>Fixed</td><td>Variable</td></tr>
<tr><td>BSF</td><td>1.4</td><td>1.3</td><td>1.4</td><td>1.4</td><td>1.4</td><td>1.45</td></tr>
<tr><td>ATT</td><td>0.8</td><td>0.75</td><td>0.8</td><td>0.8</td><td>0.8</td><td>0.9</td></tr>
<tr><td>Skin Dose ATT + BSF (Fixed)</td><td colspan="2">7.12 (Gy)</td><td colspan="4" rowspan="2">% difference between both SDC results: 5.9</td></tr>
<tr><td>Skin Dose ATT + BSF (Variable)</td><td colspan="2">7.56 (Gy)</td></tr>
<tr><td rowspan="5">Patient diameter = 35 cm
HVL = 5.94 mm Al @ 80 kV</td><td>BSF</td><td>1.4</td><td>1.5</td><td>1.4</td><td>1.57</td><td>1.4</td><td>1.6</td></tr>
<tr><td>ATT</td><td>0.8</td><td>0.75</td><td>0.8</td><td>0.8</td><td>0.8</td><td>0.9</td></tr>
<tr><td>Skin Dose ATT + BSF (Fixed)</td><td colspan="2">11.03 (Gy)</td><td colspan="4" rowspan="2">% difference between both SDC results: 19.1</td></tr>
<tr><td>Skin Dose ATT + BSF (Variable)</td><td colspan="2">13.31 (Gy)</td></tr>
</table>

According to the information presented in Table 2, each considered software may allow an accurate MSD calculation if integrating either physical, calibration measurements or input on patient's characteristics. Nevertheless, the most interesting point of the software review for the final user is the comparison of their major key features, limitations and accuracy (Table 4). This is a difficult exercise owing to the incompleteness of available information about the capacities of certain software products.

Most of the software tools are "offline" systems and extract the data necessary to the MSD calculations from the dose report or from the radiation dose structured reports (RDSR); only two tools (Dose Map and DTS) provide "online" dose mapping, collecting data directly from the modality. Obviously, from a radiation protection point of view, "online" systems are preferable since they allow monitoring and optimizing the MSD during the procedure. However, collecting data from the modality is cumbersome and system-specific, while the

RDSR, though not always available as streaming data during the procedure, should follow specific DICOM standards and, hence, should be accessible to all software developers.

It appeared that most software tools use ray-tracing techniques to identify the irradiated area, which should allow them to account correctly for the contribution of overlapping beams to the MSD. Since ray tracing algorithms have become widely accessible thanks to the increasing availability of powerful graphics workstations in the scientific and computing communities, it is reasonable to believe that all the listed software systems use such algorithms, even if such information was not available for all.

The most frequent shortcoming of the reviewed systems is surely the lack of clarity on the CF and Att used for the MSD calculation: sometimes the method applied is not clearly defined and uncertainties are not available; some developers use a single CF without any beam quality correction; others used a CF and/or a Att measured or simulated for one single system, which limits the transportability of the system. Same comments apply to the backscatter factors.

Very few developers (Dose, DTS, Khodadegan) mentioned the shape and the uniformity of the irradiation field, owing to the presence of wedge filters or to the heel effect, as a source of uncertainty; it is unclear whether other accounted for those. Since that information is not available in the RDSR, that issue was probably not addressed. Furthermore, none of the reviewed software products reports the uncertainty associated with the MSD estimation to the user.

Output data completeness and dose reporting interactivity of each system are very dependent on developer's capability or willingness to display relevant dosimetric information: maximum skin dose, skin dose map, dose map resolution, angular distribution of different parameters like DAP, $K_{a,r}$, number of events etc.

Graphical representation of skin dose mapping as well as the intrinsic map resolution is also varying from one developer to another. Images representing the mapping of skin doses for the different software tools are also given in Table 3. These representations range from sophisticated colour codes on a 3D representation of the patient to a simple grey-scale 2D distribution on a flat representation of the patient's back, possibly including a gauge of maximum skin dose difficultly modifiable. This, again, underlines the lack of harmonisation the content display, and makes an overlay of procedures performed on different systems or in different centres quite difficult. That is why the availability of a minimal set of parameters and the possibility to revert back more complex representations to an harmonized 2D mapping should be advised.

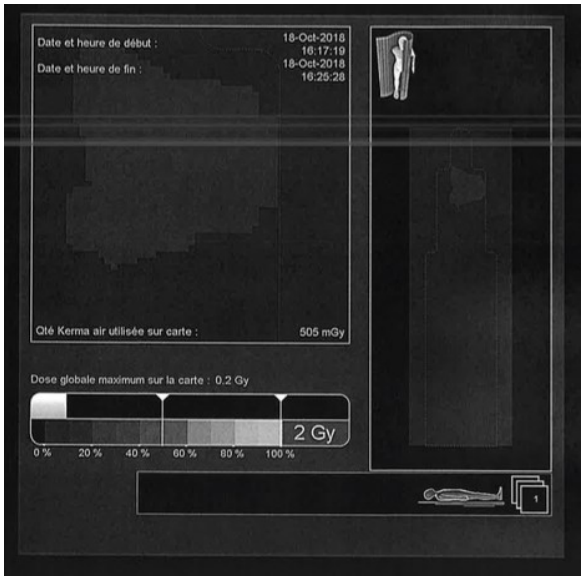
Transportability of the software tool is an essential point, which is frequently claimed by independent, commercial software developers (em.dose, Radimetrics, RDM, Dose), while software from angiographic system manufacturers, such as DTS from Canon and Dose Map from GE, is system-specific. The transportability of Dosewatch from GE is not clear from the available information. The same information for non-commercial software was usually not available. Only one software tool is available in open access (OpenSkin) but is not transportable on all angiographic systems at the present time.

Apart from OpenSkin, Hellström and DoseWatch that have not been validated against physical measurements yet, all systems have been validated in clinical set-ups against measurements with thermoluminescent (TL) dosimeters, optically stimulated luminescence (OSL) dosimeters, radio- photoluminescence (RPL) dosimeters or, most frequently, gafchromic films. Most validation measurements were performed using phantoms (PMMA, water, tissue equivalent or anthropomorphic); only 2 systems (Dose Map and em.dose) were validated on patients. For phantom measurements, the calculated MSD agreed with the measurements within ±25%. For

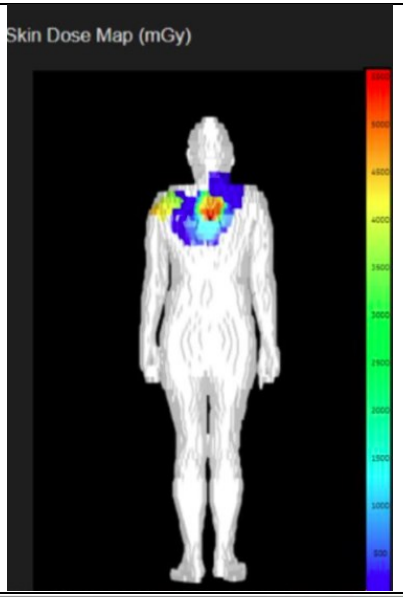
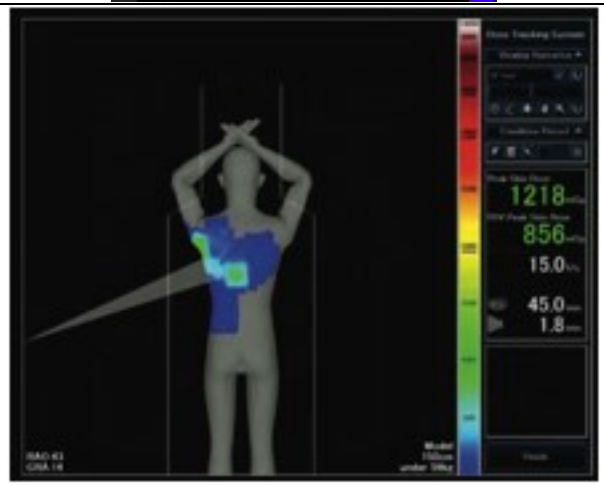
patient measurements, the agreement was poorer and the MSD agreed with the measurements within ±76% for Dose Map and within ±43% for em.dose. It should be noted that MC-GPU and FDEIR were only validated for limited beam projections (PA and PA and RAO30°, respectively), whereas some systems were validated for several projections or sequences of projections. Few systems were also validated against MC simulations (FDEIR, MC-GPU, UF-RIPSA) and agreed within ±6%. DoseWatch, though not validated against physical measurements, was compared against Dose Map and em.dose during real procedures and showed agreement within 10% on average.

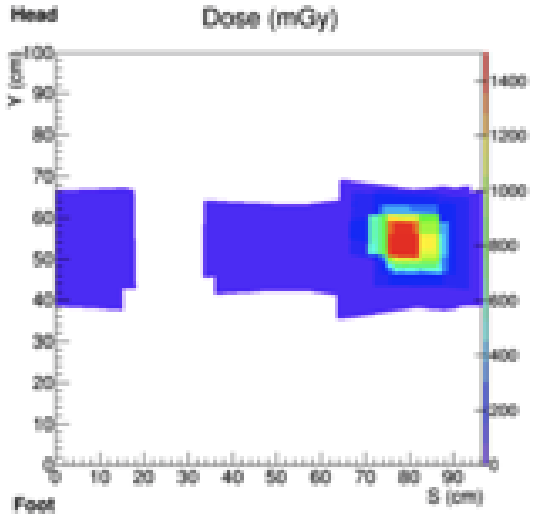
It is worth noting that no software was actually physically validated on angiographic units from all vendors, though several software developer claimed vendor-independent transportability. Software was usually validated on one, maximum two, types of angiographic units. Those wide discrepancies in the validation methods highlight the need for extended physical validation of the software tools.

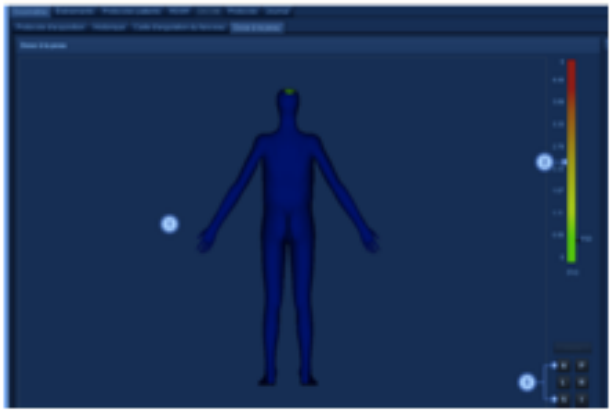
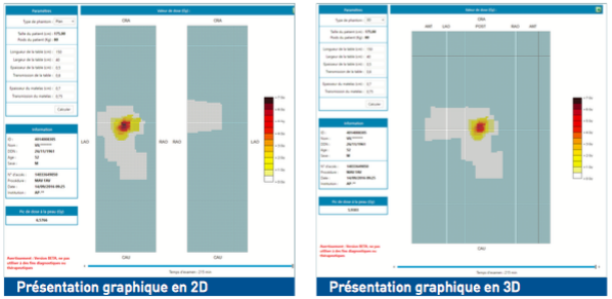
Table 4: Comparison of key features, limitations, benchmarking results and output examples by developers

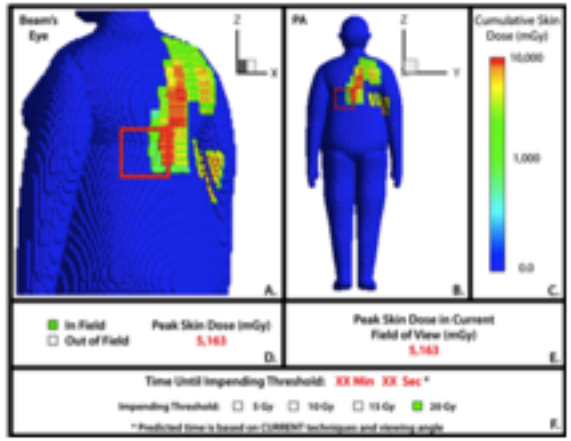
Software Name	Key features	Limitations	Benchmarking[2]	Output examples
Dose Map	- Ray tracing to identify irradiated area - Online dose mapping - On patient validation - - Map resolution 1 cm²	- Vendor-specific - Simplistic patient representation - CF unclear - Grey color scale difficult to read ; MSD provided as a % of 3 Gy (or 2 Gy) with 10% steps	Study 1 (Bordier et al 2015 a) - MSD agreement with Gafchromic film within [-8.6%;25%] - On water phantom and anthropomorphic phantom - On GE system Study 2 (Bordier et al 2015 b) - MSD agreement with Gafchromic film [-14%;13%] - On GE Innova IGS 530 - On anthropomorphic phantom Study 3 (Nilsson-Althen and Sandborg 2016) - MSD agreement with Gafchromic film [-53%;76%] (average : -32%) - On GE Innova IGS 540	- 

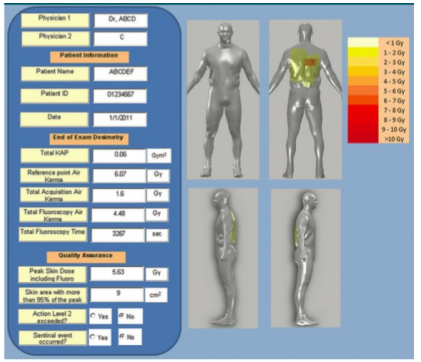
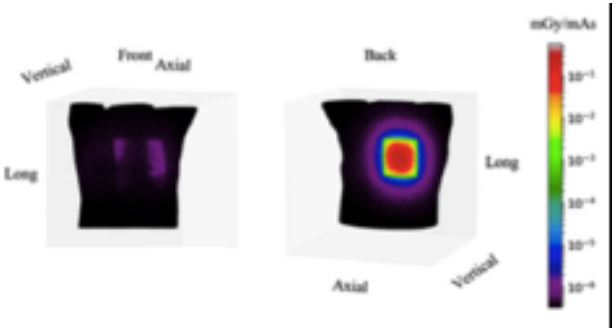
[2] Differences between measured and calculated skin doses are presented as (Calculated-Measured)/Measured

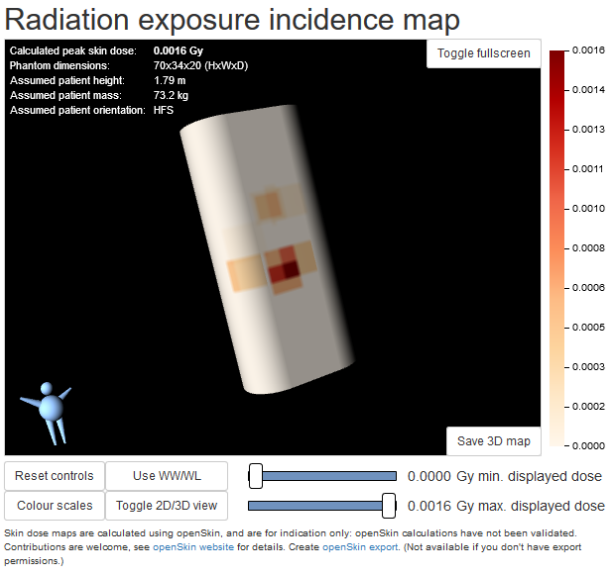
Software Name	Key features	Limitations	Benchmarking[2]	Output examples
Dosewatch	- Not available	- No validation measurements - Single patient representation	- MSD agreement with emdose and Dosemap on average 9.5% and 8.3%, respectively - On patients - Non-cardio procedures - On GE Innova IGS 540	
DTS	- Ray tracing to identify irradiated area - Online dose mapping - Various patient representations	- Vendor-specific - System-specific calibration procedure	- MSD agreement with gafchromic films [-5% ;2%] - Overlap dimensions agree within [-3% ;3%] - On PMMA phantom - On Toshiba/Canon Infinix-i Bi-plane	

Software Name	Key features	Limitations	Benchmarking[2]	Output examples
em.dose	- Available for all vendors - On patient validation	- Simplistic patient representation - Software cannot handle projections > 60° - Att correction unclear	Study 1 (Greffier 2017) - MSD agreement with Gafchromic films within [- 36%;53%] (average : 3.4%) - On patients - On Siemens Artis Zeego without RDSR Study 2 (Magnier 2018) - MSD agreement with Gafchromic films within [-6.3%;25%] (average : 4.7%) and within [-43% ;34%] (median : 2.3%) - On anthropomorphic phantom and on patients, respectively - On Siemens Artis Zeego - Non-cardiac procedures	 -

Software Name	Key features	Limitations	Benchmarking[2]	Output examples
Radimetrics	- Various patient representations - - Available for all vendors	Not available	Not available	
RDM	- Ray tracing to identify irradiated area - Map resolution 1 cm² - Available for all vendors - - Skin dose map reconstruction in time	- Single CF, single Att (no beam quality correction) - Simplistic patient representation	- MSD agreement with gafchromic films within [-19%;21%] and [-24%;3%] (average: 10% and 9%) - Overlap dimensions agree within 1-3 cm - On PMMA phantom - On GE Innova IGS 540 and Siemens Artis Zee VC21, respectively	

Software Name	Key features	Limitations	Benchmarking[2]	Output examples
Dose	- Ray tracing to identify irradiated area - Map resolution 1 cm² - - Available for all vendors	- No CF - Att measured for one system	- MSD agreement with simulation and gafchromic films measurements within ±20% - On few Siemens Artis and Philips Allura - On PMMA phantom	
UF-RIPSA	- Ray tracing to identify irradiated area. - Various patient representations - Library of MC simulated table attenuation coefficients - Organ dosimetry	- Att simulated (MC) for one system - CF curves for one system	- MSD agreement with OSL dosimeters within [-14%;-6.2%] (average: 5%) - On tissue-equivalent phantom - On Siemens Artis zee	

Software Name	Key features	Limitations	Benchmarking[2]	Output examples
Khodadadegan et al.	- Ray tracing to identify irradiated area - Map resolution 1 cm²	- Simplistic patient representation (for calculations)	- MSD agreement with gafchromic films within [-9.0%;-5.9%] - Overlap dimensions agree within ±17% - On PMMA phantom	
FDEIR	- GPU-based MC simulations (derived from Penelope code) - Potential for online organ dosimetry	- Not available	- MSD agreement with RPL dosimeters and PHITS within ±6% for PA and RAO30° irradiations - On water phantom	
MC-GPU	- GPU-based MC simulations (derived from Penelope code) - Potential for online organ dosimetry	- Not available	- MSD agreement with TL dosimeters and Penelope for PA irradiation within ±6% and ±1%, respectively - On slab phantom	Information not available

Software Name	Key features	Limitations	Benchmarking[2]	Output examples
OpenSkin	- Ray tracing to identify irradiated area - OpenSource (GNU General Public License) useable as standalone or within OpenREM suite	- No CF - Att measured for one system - Simplistic patient representation - Does not work for all systems - No validation measurements	No	
Hellström	-	- MSD calculation only (no mapping) - No ray tracing algorithm - Irradiation field position not considered (all projections are assumed to be situated on the same skin region) - CF and Att measured for one system - No validation measurements	No	No

2. Harmonization of dose reporting and tracking

2.1 Radiation dose structured report and patient dose structured report

The scope of DICOM structured reporting (SR) is the standardization of structured data and clinical observations in the imaging environment. It is the most accepted standard used to transfer medical images. It allows sending, querying, retrieving, storing or printing images from all modalities using this standard.

SR documents are encoded using DICOM standard data elements. SR uses DICOM Patient/Study/Series information model (DICOM header), plus hierarchical tree of "Content Items". Extensive use of coded nomenclature allows the use of vocabulary/codes from non-DICOM sources (even text, external database elements and scanned images can be used). Templates define content constraints for specific types of documents / reports (figure 1). For example, the "accumulated dose data" (TID 10002) in "projection X-ray" (TID 10001) is split into 5 sub-items defining the imaging modality used. At the "irradiation event" level (TID10003), data related to the event are described by a number of other TIDs.

Two different SR objects are underpinning the harmonization of the dose reporting approaches: **RDSR** (**R**adiation **D**ose **S**tructured **R**eport) and **PDSR** (**P**atient **D**ose **S**tructured **R**eport) need to be defined:

- The RDSR is a DICOM object that records observations made for an imaging-based diagnostic or interventional procedure, particularly those that describe or reference images, waveforms, or specific regions of interest.
- The PDSR is a DICOM object similar to the RDSR but dedicated to patient dose. It is being discussed among the manufacturers but not implemented in practice yet.

DICOM RDSR were created to allow an easy recall of all dose related parameters for a given radiological procedure, while PDSR were created for storing the results of an estimation of actual radiation dose to a patient.

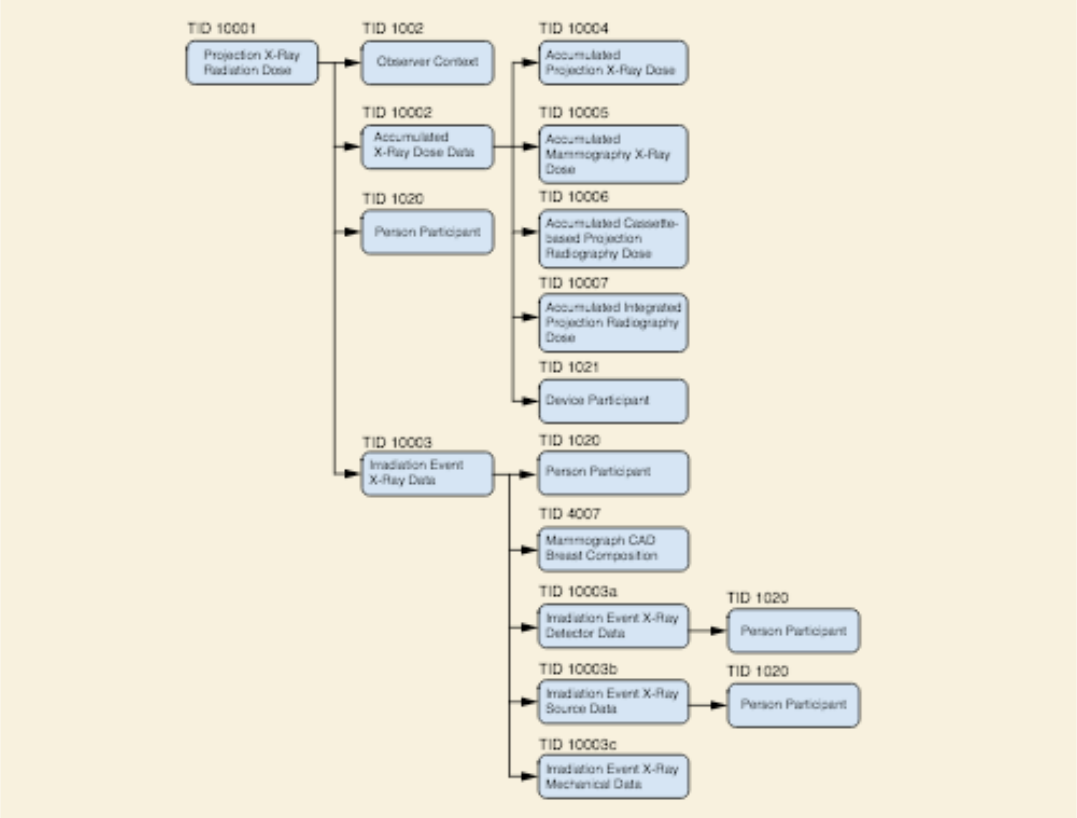


Figure 1: Template, which defines content constraints

The way all procedure parameters are encoded in the RDSR is presented in Table A3.1 in the Annex 3 where DICOM Tags (associated with given parameters in each image, DICOM headers), corresponding RDSR items and DICOM code sequences (associated with fixed or selectable parameters in RDSR) are related to each other. An extract of this table is given below (Table 5).

Table 5: Extract of DICOM Tags, Corresponding RDSR Items and DICOM Code Sequences

DICOM Tag (DICOM header)	Corresponding RDSR Items	DICOM Code Sequence
	X-Ray Radiation dose report	
(0008),(0080)	Location/hospital name	
	Observer type = Device	(121007,DCM)
	Device Observer UID	
	Device Observer Name	
(0008),(1090)	Device Observer Manufacturer Name	
(0008),(1090)	Device Observer Model Name	
(0018),(1000)	Device Serial Number	
	Observer type = Person	(121006,DCM)
(0008),(1050)	Person Observer Name	
	Person Observer Role in the organization	(131081,DCM)
	Person Observer Role in this procedure	(121094,DCM)

To each DICOM tag, one or more RDSR items can be associated, and a DICOM code sequence may be defined. There is ambiguity between DICOM tags from irradiation events and RDSR items when they are fixed (modality…), detectable from the machine parameters (kV, mA…) or selectable from a pre-defined list (physicians…). When there is no such list, no DICOM tag can be defined but a DICOM code sequence is set if the item is generic (Observer type = Device, Observer type = Person, Person Observer Role in the organization, Person Observer Role in this procedure…). When the RSDR item is fully dependent on the complete procedure, neither DICOM tags nor DICOM code sequence can be defined (Total dose, Total DAP, etc…).

Such a system is very well defined and consistent and it has been forced on manufacturers after long debates in the DICOM committees. However, each manufacturer has taken advantage of the possibility to adapt this standard with so-called "private fields", thus introducing many differences in the structured reports.

The RDSR has been compulsory since 2007 for all cathlabs. It is the report that all offline SDC systems use for their skin dose calculation, since it gives information on all dose-related parameters (kV, filtration, field size, as well as air-KERMA at PERP, which is the basis for all dose calculation models).

Unfortunately, as already mentioned above, many fields are private and difficult to interpret; some information might simply be missing. DICOM RDSRs from four different manufacturers for 5 systems have been compared. An extract is presented in Table 6.

Table 6: Extract of Information provided in RDSR from five different systems

Single plane	**Philips**	**Philips**	**GE**	**Siemens**	**Canon**
	Clarity FD25	**Allura FD48**	**Innova 520**	**Artis ZEE**	**(Toshiba)**
Location/hospital name					
Observer type = Device					**Y**
Device Observer UID	**Y**	**Y**	**Y**	**Y**	**Y**
Device Observer Name	**Y**	**Y**	**Y**	**Y**	**Y**
Device Observer Model Name	**Y**	**Y**	**Y**	**Y**	**Y**
Device Observer SN	**Y**	**Y**	**unknown**	**Y**	**Y**
Study instance UID					**Y**
Accumulated Dose Data					
Calibration date			**Y**	**Y**	**Y**
Calibration factor			**100%**	**1**	**1%**
Calibration uncertainty			**35%**	**5%**	**0%**
Calibration responsible			**unknown**	**name**	**Toshiba**
Calibration protocol					**Toshiba**

*See Table A3.2 in Annex 3 for the full dataset

From this comparison it appears that only a minimal harmonization exists. Many of the useful fields are "private" which means their content can differ from manufacturer to manufacturer and it is quite difficult to extract data in a systematic fashion. For example, the MSD if displayed on the machine is not necessarily in the RDSR

Not all RDSR give the same information: many fields are left blank, even the most obvious ones like institution name. Of course, the device serial number (which is always present) is unequivocal and it is thus possible to relate it to a given institution.

Below are listed other examples of discrepancies in the RDSR, which might have an effect on the skin dose estimate or its optimisation:

- At general procedure level :
  - *Completion flag* : the study is not marked as completed after the procedure is finished for Siemens and Canon (Toshiba). The reason given by the manufacturers is that they claim it is then possible to put the patient on the table again a bit later and "continue" the procedure, i.e. it is not mandatory to open a new procedure for this patient. In reality, this is very seldom done and a new procedure is created each time the patient is installed on the table. On the other hand, it can be very confusing when dose management software are used as it can cause collection of incoherent data or loss of data.

  - *Calibration factor and uncertainty*: although there is only room for one calibration factor to be input from QC results (and changed once per year), only 3 manufacturers use this possibility. Besides, they interpret the uncertainty very differently. GE sets the maximum tolerable uncertainty of 35% according to IEC, Siemens sets a reasonable uncertainty of 5%, and Canon (Toshiba) reports an impossible uncertainty of 0%. As for the calibration factor itself, it is even more difficult to understand since GE and Canon (Toshiba) give a percentage ranging from 1 to 100%, whereas Siemens give a number, of which they cannot explain the significance.

  - *DAP total; DAP fluoro total; Acq DAP total*: for all equipment, DAP is expressed in Gy.m² in the RDSRs, following standards; however, the values displayed on the console in the cathlab are usually expressed in other units. This can be confusing for the physicians (and the physicists too) and can be an obstacle to optimization of practice.

  - *Fluoro time total; Acquisition time total:* time is always expressed in seconds in the RDSRs, following standards; however, the values displayed on the console in the cathlab are sometimes expressed in minutes. This can be confusing for the physicians (and the physicists too) and can be an obstacle to optimization of practice.

  - *Fluoro time total; Acquisition time total*:
    - "irradiation duration" is the total time of a fluoroscopy series also known as the "pedal time" or the time during which the operator presses the fluoroscopy pedal. In fluoroscopy mode, this includes the intervals between the pulses of a same series, when no X-Rays are used. In figure 2, the irradiation duration following that definition would be 50 ms.
    - Conversely, "exposure time" is the sum of the X-Ray pulse durations; only the time during which the X-Ray beam is ON is used, the time between the pulses is

not. In Figure 2, the acquisition time following that definition would be 30 ms. For optimization purpose, the "exposure time" is obviously useful, while the "irradiation duration" is of limited interest.

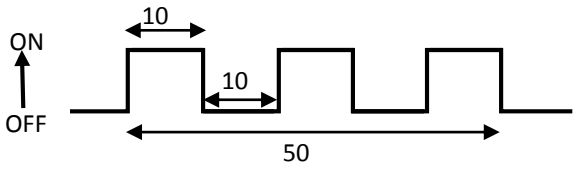


Figure 2: Pulsed fluoroscopy waveform

Fluoro time total and *Acquisition time total* are not the total of all the event irradiation durations or exposure times in Canon (Toshiba).

- At event level :
  - *Fluoro time per event; Acquisition time per event*: Unfortunately, the definitions of "irradiation duration" and "exposure time" are not exactly the same as above when used in each separate event. According to manufacturer, one or the other or both are in the RDSR.

    For Canon (Toshiba), exposure time is the real X-Ray emission time, whereas irradiation duration is unrealistic as it is expressed in seconds, so that the times are impossibly long (Figure 3).

Exposure Time:
2960.65 ms
Pulse Width:
7.69 ms
Irradiation Duration:
5120.77 s

Figure 3: screenshot of part of an event (Canon)

In this example 1 event would correspond to 1,42 hours of pedal time fluoroscopy, while the sum of all irradiation durations from all 15 fluoro events would be 9,43 hours!

For Philips, exposure time is not given in RDSR and irradiation duration is the pedal time.

For GE and Siemens, irradiation duration is not provided and exposure time is the real x-ray emission time.

- *Number of frames total* : Siemens does not provide the total number of acquisition frames in the accumulated dose data paragraph, while the others do

- *Maximum Skin Dose :* no DICOM tags are visible for the input of this data for GE and Canon (Toshiba), while one private field is foreseen by Philips and Siemens. However, the provided value is not an estimate of the patient dose, but the maximum cumulative KERMA at the reference point. Hence, nor the backscatter contribution nor the table and mattress attenuation are accounted for. GE and Canon (Toshiba) could use the field

concept name EV (121342, DCM, "Dose Image")[3] to store the image of their calculated dose maps. However this is not achieved in the versions we had access to.

- *PERP definition* : all follow IEC recommendations ("15 cm from isocentre"); however, the isocentre position is difficult to position with respect to the patient surface.
- *Source Object Distance (SOD)*: it is defined as the distance in mm from source to isocentre (centre of field of view). It represents the distance between the focal point of the X-ray source and the 'Point Of Interest' of the patient (Figure 4). However, since the system does not know this point of interest, an assumption is to be made. This assumption is system-specific. The point of interest is assumed to coincide with the beam isocentre. The isocentre is constant even when the table moves

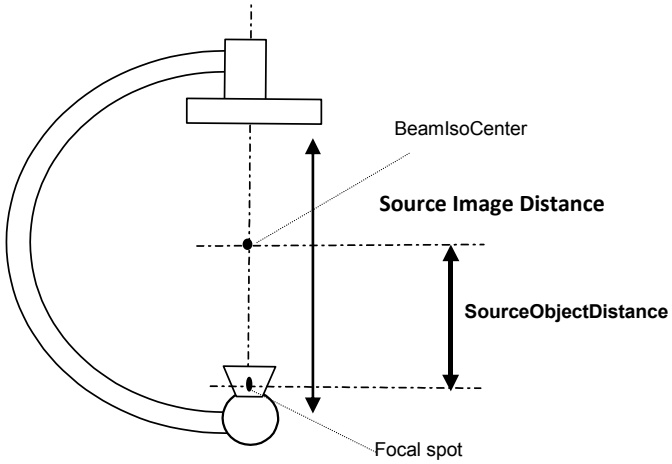


Figure 4: SID and SOD representation

- *Filter type; Filter material; Filter thickness min; Filter thickness max:* the information on filtration is partly missing for GE, it should be added as parameter necessary for MSD calculation. This information is useful for determining the beam quality and, thus, for backscatter and attenuation determination.

- *Type of grid:* the presence or absence and type of grid are not available in Philips, GE and Canon (Toshiba).

- *Number of pulses* : unavailable on the oldest Philips, although it is useful information for optimization of practice.

- *Name of fluoro or acq protocol:* unavailable in Philips RDSR although it is useful if the procedure is to be repeated for educational purposes.

- *kV, mA, mAs…:* these parameters are averages of the respective values during the event.

[3] As described in the DICOM standard: "The Dose Image references a graphic representation of the radiation dose distribution. This may be a Secondary Capture scan of a dosimetry film".

- *Collimated field height, Collimated field width*: although this value is needed to recalculate the MSD, it is unavailable in Siemens and Philips reports, but information isavailable in fields "Bottom shutter, Left shutter, Right shutter and Top shutter" for Philips.

- *Detector size* : detector size is not available in RDSR but would be useful for optimization of practice.

2.3 Harmonization of the radiation dose structured reports

In order to facilitate the calculation and the reporting of the skin dose, harmonization of the use of the RDSRs seems necessary.

In addition to "Event type (fluoroscopy or fluorography)", which is necessary to determine whether most of the dose is due to cine mode or fluoroscopy and is therefore an essential data to be able to target the optimization process, the necessary data for an accurate maximum skin dose calculation for each irradiation event (highlighted in orange in Table 7) are:

1) for manual calculation :
   - KAP or Air-KERMA at PERP
   - Primary and secondary angles
   - Actual field size at skin (collimation, source-to-skin distance, source-to-isocenter distance, source-to image detector distance)
   - Calibration factors (AK, table attenuation)
   - kV
   - Filtration

2) for Monte Carlo simulation :
   - KAP or Air-KERMA at PERP
   - Primary and secondary angles
   - Actual field size and shape at skin (collimation, source-to-skin distance, source-to-isocentre distance, source-to image detector distance)
   - kV
   - Filtration (inherent and additional, including wedge filters)
   - Patient modelling

A dedicated, public field should be created to store the MSD value, along with a field dedicated to store the uncertainty in the MSD estimation.

In order to allow for an easy MSD calculation, it would be useful to report:

- The field size at the PERP in the plane perpendicular to the beam (Figure 5)
- The distance between the X-Ray source and the patient (Figure 5)
- The attenuation of the table and the pad, ideally for different beam qualities (combinations of filters and kVp)
- The backscatter factor of the patient, ideally for different beam qualities (combinations of filters and kVp) and field size at patient entrance plane.

For calculation of the cumulative MSD following multiple procedures, harmonized information on the patient position and orientation would be necessary too.

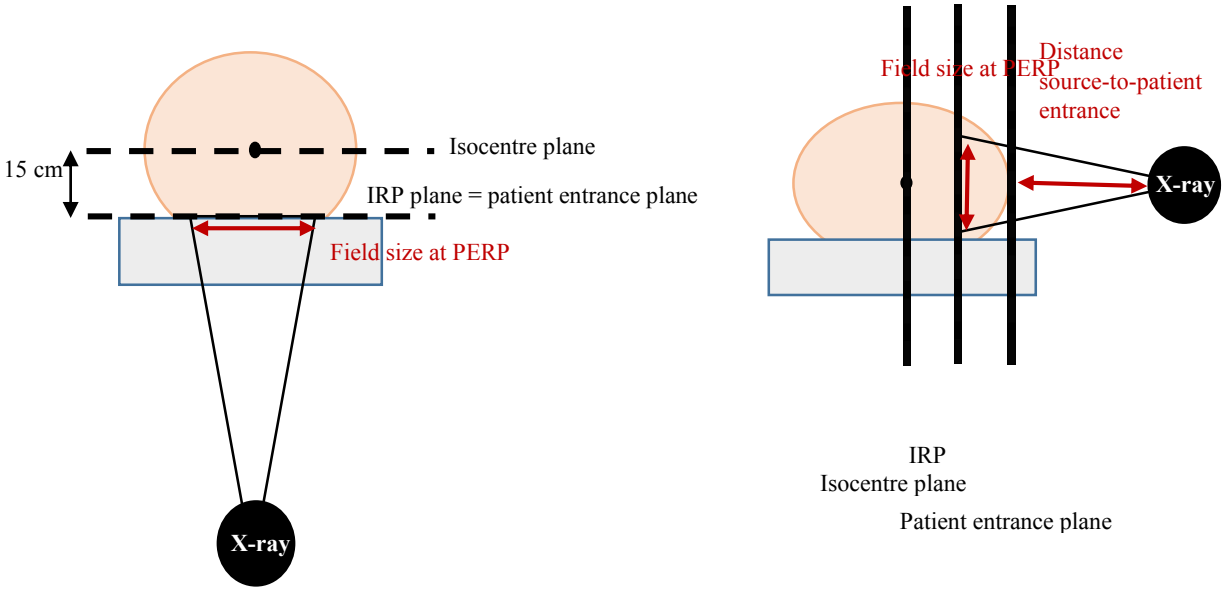


Figure 5: isocentre, PERP (IRP) and patient entrance plane (frontal and lateral views)

The dose map as calculated by the system (whether 2D or 3D) should be stored in private fields at examination or RDSR level (not at event level) at the end of the examination, each manufacturer could use its own method to calculate the MSD and display the dose map. They can use the concept name EV (121342, DCM, "Dose Image"), which is already part of the RDSR, to store the final image of the map.

The harmonized version of the dose map could be a simplified flat (2D) map, with the centre of the map width being the patient spine and the top and bottom being indicated.

A resolution of 1 cm² per pixel could be used. It is the area recommended by ICRP (2007) for the dose limit to the skin in case of planned exposure situations; in addition, the tissue reactions observed in IC cover a considerably greater area. From a practical point of view, the resolution would also allow the storage of the map using limited space. The grey level of the image could be scaled according to the MSD value stored in a public DICOM tag, as mentioned above; the position of the MSD on the map (x,y) and its uncertainty should also be stored in specific DICOM tags. Doses from several procedures could easily be cumulated by superimposing the map.

If the SDC product does not provide directly a 2D, the 3D patient representation (should it be a type of cylinder or a more realistic phantom) could be split following patient's sternum and unwind as proposed by Bordier et al. (2015 a and b) or Geryes et al (2018) (Figure 6), for instance. The limitation of that method would be a less accurate dose reporting on the patient's side.

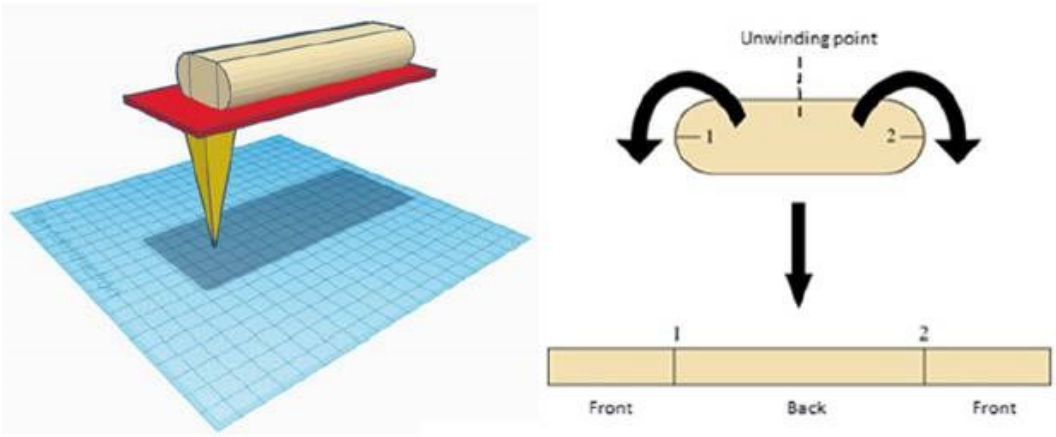


Figure 6: Flattened skin dose map representation. Reproduced from Geryes et al. (2018)

In the future, if most SDC tools provide skin dose distribution on phantoms and if phantom auto-scaling technologies (Sands et al. (2017)) become widely available, the dose could be reported on a standard phantom (from ICRP family, for example) and easily cumulated over many procedures. Alternatively, the dose distribution from previous procedures could be scaled to the most recent version of the patient representation.

2.4 Radiation dose structured reports and dose management software

Many dose management systems allow the export of DICOM data. A comparison of the content of these exports with the original RDSR has been performed for two systems, Dosewatch and Radimetrics (extract in Table 7; complete dataset in annex 3 – Table A3.3)

Table 7: Extract of RDSR and Radimetrics comparison

	Radimetrics excel	**RDSR PDF**
Series	6	Not on RDSR
Images	11	on RDSR = 290
Modality	XA	
kVp	75	Not on RDSR
Mean mAs		on RDSR = 85.6
Code Acquisition plane (RF)	Plane A	Not on RDSR
Code Event type	P5-06000	Not on RDSR
Irradiation event	Fluoroscopy	Not on RDSR
Irradiation time	5120770	in RDSR + Exposure Time
Acquisition protocol (RF)	Coro/Dilatation 7.5f/s Low	Not on RDSR
PERP definition (RF)	15cm from Isocenter toward Source	Not on RDSR
Primary angle	0	Not on RDSR
Secondary angle	0	Not on RDSR
Code filter	C-127F9	Not on RDSR
Filter thickness min	0,3	Not on RDSR
Filter thickness max	0,3	Not on RDSR
Fluoro mode	Pulsed	Not on RDSR
Pulse rate	7,5	Not on RDSR

Pedal activation time		
Number of pulses	385	Not on RDSR
Pulse length	7,69	Not on RDSR

Surprisingly, the information extracted by the two systems is not exactly the same and also differs significantly from the information in the RSDR.

For example, site, institution name, study instance UID, PSD, to cite the most significant parameters are not included in the RDSR. Name of operator, name of physician, series number, modality generic name, patient BMI, patient age at moment of examination, fluoroscopy time are missing data in the RDSR but can be found in the Radimetrics export.

Another important information can only be found in the GE export, the patient water equivalent thickness. It relates the weight, height and BMI data to a water equivalent thickness that can be used to classify patients into categories and to evaluate the risk of skin injuries.

3. Conclusions

This report, although the first deliverable of WP1, will be subject to additions and modifications within the timeframe of the VERIDIC project, because more and more papers are published on the subject of dose mapping for interventional cardiology procedures and missing information at the present date might be obtained before the completion of the project.

However, this document represents the state of current knowledge on available dose calculation software and a review of key features and weak points made clear that work remains to be done before an accurate and reliable skin dose mapping can be achieved for all patients.

The same kind of work was carried out for radiation dose structured reports which, as recommended by the international institutions, may serve as input to assess patient skin dose received by patient undergoing interventional examinations.

A critical analysis of RDSR contents of four major manufacturers was carried out with a view to identifying both the completeness of data stored in the DICOM fields and their consistency.

Strong heterogeneities in examination related technical parameters encoded in RDSR by the manufacturers were found, especially important for all dose calculation related data; even more heterogeneities were pointed out when considering the DICOM fields exports through two dose management software tools.

This highlighted the need for harmonizing both RDSRs and their exports in order to be able to calculate MSD in an easy and straightforward way from these data.

Essential parameters for MSD calculation and dose mapping were listed and should be included in both RDSRs and exports

A public DICOM field to store MSD was suggested, as well as the use of the existing field to store final dose map images. To enhance harmonization, a flat representation of skin dose map in addition the possible 3D representation was also suggested, in order that skin dose maps of multiple procedures on the same patient could easily be overlaid and the resulting MSD could be better estimated.

List of acronyms

BMI: body-mass index

BSF: backscatter factor

CF: calibration factor

DCM: DICOM defined code

DICOM: digital imaging and communications in medicine

IC: interventional cardiology

ICRP: international commission on radiological protection

ICRU: International commission on radiation units and measurements

IEC : international electrotechnical committee

KAP: KERMA-area product

$K_{a,r}$: cumulative air KERMA at interventional reference point

KERMA: kinetic energy released per unit mass

kVp: kilovoltage peak

MSD: maximum skin dose P-RDSR: Patient Radiation Dose Structured Report

OSL: optically stimulated luminescence

PERP: patient entrance reference point

QC: quality control

RDSR: radiation dose structured report

RPL: radio-*photoluminescence*

SDC: skin dose calculation

SID : source image distance

SOD : source object distance

SR: structured reporting

SRT: SNOMED (Systematized Nomenclature of Medicine)

TID: template identification

TL: thermoluminescence

WP: work package

References

Bednarek, Daniel R., Jeffery Barbarits, Vijay K. Rana, Srikanta P. Nagaraja, Madhur S. Josan, and Stephen Rudin. 2011. 'Verification of the performance accuracy of a real-time skin-dose tracking system for interventional fluoroscopic procedures', *Proceedings of SPIE--the International Society for Optical Engineering*, 7961: 796127_1.

Benmakhlouf, H., H. Bouchard, A. Fransson, and P. Andreo. 2011. 'Backscatter factors and mass energy-absorption coefficient ratios for diagnostic radiology dosimetry', *Phys Med Biol*, 56: 7179-204.

Benmakhlouf, Hamza,, Fransson Annette, and Andreo Pedro. 2013. 'Influence of phantom thickness and material on the backscatter factors for diagnostic x-ray beam dosimetry', *Physics in Medicine & Biology*, 58: 247.

Bordier, C., R. Klausz, and L. Desponds. 2015a. 'Accuracy of a dose map method assessed in clinical and anthropomorphic phantom situations using Gafchromic films', *Radiat Prot Dosimetry*, 165: 244-9.

Bordier, C., R. Klausz, and L. Desponds. 2015b. 'Patient dose map indications on interventional X-ray systems and validation with Gafchromic XR-RV3 film', *Radiat Prot Dosimetry*, 163: 306-18.

Borrego, D., E. L. Marshall, T. Tran, D. A. Siragusa, and W. E. Bolch. 2018. 'Physical validation of UF-RIPSA: A rapid in-clinic peak skin dose mapping algorithm for fluoroscopically guided interventions', *J Appl Clin Med Phys*, 19: 343-50.

Borrego, D., D. A. Siragusa, S. Balter, and W. E. Bolch. 2017. 'A hybrid phantom system for patient skin and organ dosimetry in fluoroscopically guided interventions', *Med Phys*, 44: 4928-42.

den Boer, A., Ad den Boer, de Feijter, PJ Patrick W. Serruys and Jos R.T.C. Roelandt. 2001. 'Real-Time Quantification and Display of Skin Radiation During Coronary Angiography and Intervention'. Circulation 104(15): 1779-1784.

Gardavaud, F., S. Tavolaro, N. Grussenmeyer-Mary, F. Cornelis, and F. Boudghène. 2018. 'Evaluation de la dose pic a la peau pour des procédures cliniques vasculaires en radiologie interventionnelle : une comparaison entre trois solutions numériques de calcul', 57èmes Journées Scientifiques de la SFPM. Toulouse, France.

Greffier, J., C. Van Ngoc Ty, G. Bonniaud, G. Moliner, B. Ledermann, L. Schmutz, L. Cornillet, G. Cayla, J. P. Beregi, and F. Pereira. 2017. 'Assessment of peak skin dose in interventional cardiology: A comparison between Gafchromic film and dosimetric software em.dose', *Phys Med*, 38: 16-22.

Habib Geryes, B., L. Hadid-Beurrier, M. J. Waryn, A. Jean-Pierre, and J. Farah. 2018. 'Benchmarking the DACS-integrated Radiation Dose Monitor(R) skin dose mapping software using XR-RV3 Gafchromic(R) films', *Med Phys*.

Hellström M, 2018. Thesis „Estimatng patient peak skin dose with fluoroscopic procedures – department of radiation Science, Umea University – Sweden.

Hintenlang D, K. Little, X. Jiang, X. Yang and N. Fitousi. 2018. 'Evaluation of Fluoroscopic Dose MetricsPredicted by Dose Management Software', *60th annual meeting of the American Association of Physicists in Medicine*, Nashville, Tennessee, USA.

ICRU. 2005. 'Patient dosimetry for x rays used in medical imaging'. *J ICRU.*

IEC 60601-2-43. 2010. 'Medical Electrical Equipment–Part 2-43: Particular Requirements for the Basic Safety and Essential Performance of X-ray Equipment for Interventional Procedures', International Electrotechnical Commission, Geneva, 2010.

IEC 61910-1. 2015. 'Medical electrical equipment – radiation dose documentation – Part 1 : Radiation Dose Structured Report for radiography and radioscopy', International Electrotechnical Commission, Geneva, 2015.

ICRP. 2007. 'ICRP publication 103: The 2007 Recommendations of the International Commission on Radiological Protection.' Annals of the ICRP 37(2-4).

Johnson, P. B., D. Borrego, S. Balter, K. Johnson, D. Siragusa, and W. E. Bolch. 2011. 'Skin dose mapping for fluoroscopically guided interventions', *Med Phys*, 38: 5490-9.

Jones, A. K., and A. S. Pasciak. 2011. 'Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods (vol 12, pg 231, 2011)', *Journal of Applied Clinical Medical Physics*, 15: 402-02.

Khodadadegan, Y., M. Zhang, W. Pavlicek, R. G. Paden, B. Chong, B. A. Schueler, K. A. Fetterly, S. G. Langer, and T. Wu. 2011. 'Automatic monitoring of localized skin dose with fluoroscopic and interventional procedures', *J Digit Imaging*, 24: 626-39.

Khodadadegan, Yasaman, Muhong Zhang, William Pavlicek, Robert G. Paden, Brian Chong, Eric A. Huettl, Beth A. Schueler, Kenneth A. Fetterly, Steve G. Langer, and Teresa Wu. 2013. 'Validation and Initial Clinical Use of Automatic Peak Skin Dose Localization with Fluoroscopic and Interventional Procedures', *Radiology*, 266: 246-55.

Lin, P. J., B. A. Schueler, S. Balter, K. J. Strauss, K. A. Wunderle, M. T. LaFrance, D. S. Kim, R. H. Behrman, S. J. Shepard, and I. H. Bercha. 2015. 'Accuracy and calibration of integrated radiation output indicators in diagnostic radiology: A report of the AAPM Imaging Physics Committee Task Group 190', *Med Phys*, 42: 6815-29.

Magnier, F., M. Poulin, C. Van Ngoc Ty, E. Osmond, G. Bonniaud, J. Coulot, B. Pereira, L. Boyer, J. Guersen, and L. Cassagnes. 2018. 'Comparison of Patient Skin Dose Evaluated Using Radiochromic Film and Dose Calculation Software', *Cardiovasc Intervent Radiol*, 41: 762-71.

Nilsson Althen, J., and M. Sandborg. 2016. 'Verification of Indicated Skin Entrance Air Kerma for Cardiac X-Ray-Guided Intervention Using Gafchromic Film', *Radiat Prot Dosimetry*, 169: 245-8.

Rana, V. K., S. Rudin, and D. R. Bednarek. 2013. 'Updates in the real-time Dose Tracking System (DTS) to improve the accuracy in calculating the radiation dose to the patients skin during fluoroscopic procedures', *Proc SPIE Int Soc Opt Eng*, 8668: 86683z.

Rana, V. K., S. Rudin, and D. R. Bednarek. 2016. 'A tracking system to calculate patient skin dose in real-time during neurointerventional procedures using a biplane x-ray imaging system', *Med Phys*, 43: 5131.

Principi, S., A. Merino, M. Amor Duch, and M. Ginjaume**.** 2018. **'**Preliminary validation of the MC-GPU Monte Carlo code against PENELOPE/penEasy code system for interventional radiology and cardiology', *5th European IRPA Congress*, The Hague, The Netherlands.

Rottoli, Federica, Cristina De Mattia, Marina Sutto, Paola Enrica Colombo, Carmelo Migliorisi, and Alberto Torresin. 2018. '[OA097] Comparison between skin dose values of a software tool and gafchromic films using test fields and clinical cases', *Physica Medica*, 52.

Sands, M. M., D. Borrego, M. R. Maynard, A. A. Bahadori, and W. E. Bolch. 2017. 'Comparison of methods for individualized astronaut organ dosimetry: Morphometry-based phantom library versus body contour autoscaling of a reference phantom', *Life Sci Space Res (Amst)*, 15: 23-31.

Takata, T., J. Kotoku, H. Maejima, S. Kumagai, N. Arai, T. Kobayashi, K. Shiraishi, M. Yamamoto, H. Kondo, and S. Furui. 2018. 'Fast skin dose estimation system for interventional radiology', *J Radiat Res*, 59: 233-39.

Annexes

Annex 1 : letter to manufacturers

Dear Sir, Madam,

A European project, VERIDIC (**Validation and Estimation of Radiation skin Dose in Interventional Cardiology)** started on February 1st 2018 for 2 years.

This project comprises partners from 8 European countries and a number of medical physicists especially interested in patient dosimetry in interventional cardiology.

As described in the attached document, 2 main goals will be pursued :

a) harmonization of the available technical information in DICOM RDSRs
b) validation of MSD display and/or dose map display offered by different equipment manufacturers and software providers (university, companies…)

During the project, existing documents will be analysed (published papers, technical documents, etc…) and all available data will be reviewed.

As independent researchers and knowing that patient dosimetry in interventional cardiology is an important challenge both in the scientific and public health domains, it seems straightforward to join forces with all the companies responsible for putting sophisticated radiological equipment on the market.

A scientific review of all methods used for estimation of doses and of all available parameters will be produced at the end of the project.

Technical improvements will also be suggested at a European level, stressing the involvement of each partner in his efforts to optimize radiation protection of the patient.

We are sure you will appreciate the importance of this research topic and of the European dimension of the efforts that will be carried out.

We hope to be able to meet you in the next few weeks in order to discuss all these issues and the way forward in collaborating with you.

Annex 2 : List of papers describing SDC software

GE-DOSEMAP

Bordier, C., Klausz, R., Desponds, L. 2015. Accuracy of a dose map method assessed in clinical and anthropomorphic phantom situations using Gafchromic films. Radiat. Prot. Dosim. 165(1–4), 244–249.

Bordier C, Klausz R and Desponds L. 2015. Patient dose map indications on interventional x-ray systems and validation with Gafchromic® XR-RV3 film. Radiat Prot Dosimetry. 163(3), 306-318.

Nilsson Althen, J., and M. Sandborg. 2016. 'Verification of Indicated Skin Entrance Air Kerma for Cardiac X-Ray-Guided Intervention Using Gafchromic Film', Radiat Prot Dosimetry, 169: 245-8.

GE-DOSEWATCH

Gardavaud, F., S. Tavolaro, N. Grussenmeyer-Mary, F. Cornelis, and F. Boudghène. 2018. 'Evaluation de la dose pic a la peau pour des procédures cliniques vasculaires en radiologie interventionnelle : une comparaison entre trois solutions numériques de calcul', 57èmes Journées Scientifiques de la SFPM. Toulouse, France.

CANON-DTS

Bednarek DR, Barbaritis J, Rana VK, Nagaraja SP, Josan MS, Rudin S. 2011. Verification of the performance accuracy of a real-time skin-dose tracking system for interventional fluoroscopic procedures. Proc SPIE Int Soc Opt Eng. 7961(796127): 796127_1.

Rana, V. K., S. Rudin, and D. R. Bednarek. 2013. 'Updates in the real-time Dose Tracking System (DTS) to improve the accuracy in calculating the radiation dose to the patients skin during fluoroscopic procedures', Proc SPIE Int Soc Opt Eng, 8668: 86683z.

Rana VK, Rudin S, Bednarek DR. 2016. A tracking system to calculate patient skin dose in real-time during neurointerventional procedures using a biplane x-ray imaging system. Med. Phys. 43 (9), 5131-5144.

ESPRIMED-emDOSE

Greffier J, Van Ngoc Ty C, Bonniaud G, Moliner G, Ledermann B, Schmutz L, Cornillet L, Cayla G, Beregi JP, Pereira F. 2017. Assessment of peak skin dose in interventional cardiology: A comparison between Gafchromic film and dosimetric software em.dose. Phys Med. 38, 16-22.

Magnier F, Poulin M, Van Ngoc Ty C et al. 2018. Comparison of Patient Skin Dose Evaluated Using Radiochromic Film and Dose Calculation Software Cardiovasc Intervent Radiol 41, 762-771.

MEDSQUARE-RDM

B Habib Geryes, L Hadid-Beurrier, MJ Waryn, A Jeanpierre and J Farah. 2018. Benchmarking the DACS-integrated Radiation Dose Monitor® skin dose mapping software using XR-RV3 Gafchromic films. Med. Phys

QAELUM-DOSE

Hintenlang D, Little K , Jiang X , Yang X , Fitousi N. 2018. "Evaluation of Fluoroscopic Dose Metrics Predicted by Dose Management Software". 60th annual meeting of the American Association of Physicists in Medicine, AAPM 2018, 29 July – 2 August 2018, Nashville, Tennessee, USA.

UF-RIPSA

Borrego D, Marshall, T Tran, D Siragusa, W Bolch. 2018. Physical validation of UF-RIPSA: A rapid in-clinic peak skin dose mapping algorithm for fluoroscopically guided interventions, J Appl Clin Med Phys 19:3:343–350

Johnson PB, Borrego D, Balter S, Johnson K, Siragusa D, Bolch WE. 2011. Skin dose mapping for fluoroscopically guided interventions. Med Phys. 38(10), 5490-5499.

KHODADADEGAN et al.

Khodadadegan, Y., M. Zhang, W. Pavlicek, R. G. Paden, B. Chong, B. A. Schueler, K. A. Fetterly, S. G. Langer, and T. Wu. 2011. 'Automatic monitoring of localized skin dose with fluoroscopic and interventional procedures', *J Digit Imaging*, 24: 626-39.

Khodadadegan, Yasaman, Muhong Zhang, William Pavlicek, Robert G. Paden, Brian Chong, Eric A. Huettl, Beth A. Schueler, Kenneth A. Fetterly, Steve G. Langer, and Teresa Wu. 2013. 'Validation and Initial Clinical Use of Automatic Peak Skin Dose Localization with Fluoroscopic and Interventional Procedures', *Radiology*, 266: 246-55.

FDEIR

T Takata, J Kotoku, H Maejima, S Kumagai, N Arai, T Kobayashi, K Shiraishi, M Yamamoto, H Kondo and S Furui. 2017. Fast skin dose estimation system for interventional radiology. Journal of Radiation Research, pp. 1–7

MC-GPU

Principi, S., A. Merino, M. Amor Duch, and M. Ginjaume**.** 2018. **'**Preliminary validation of the MC-GPU Monte Carlo code against PENELOPE/penEasy code system for interventional radiology and cardiology', *5th European IRPA Congress*, The Hague, The Netherlands.

HELLSTRÖM et al.

Hellström M. 2018. Thesis. Estimating patient peak skin dose with fluoroscopic procedures – department of radiation Science, Umea University – Sweden.

BRACCO-NEXODOSE

Rottoli F, De Mattia C, Sutto M, Colombo PE, Migliorisi C, Torresin A. 2018. Comparison between skin dose values of a software tool and gafchromic films using test fields and clinical cases

Annex 3 : DICOM and RDSR structures

Table A3.1 : DICOM Tags, Corresponding RDSR Items and DICOM Code Sequences

DICOM Tag (DICOM header)	Corresponding RDSR Items	DICOM Code Sequence
	Patient	
(0010),(0010)	Name	
	Sex	
(0010),(0030)	Date of Birth	
(0010),(0020)	ID	
	Manufacturer	
(0008),(0070)	Manufacturer	
	Completion flag	
	Verification flag	
	Date/time	
(0008),(0020)	Study Date	
(0008),(0021)	Series Date	
(0008),(0022)	Acquisition Date	
(0008),(0030)	Study Time	
(0008),(0031)	Series Time	
(0008),(0032)	Acquisition Time	
	Study	
(0008),(1030)	Study Description	
(0020),(0010)	Study ID	
(0008),(103e)	Series Description	
(0020),(000d)	Study instance UID	
	X-Ray Radiation dose report	
(0008),(0080)	Location/hospital name	
	Observer type = Device	(121007,DCM)
	Device Observer UID	
	Device Observer Name	
(0008),(1090)	Device Observer Manufacturer Name	
(0008),(1090)	Device Observer Model Name	
(0018),(1000)	Device Serial Number	
	Observer type = Person	(121006,DCM)
(0008),(1050)	Person Observer Name	
	Person Observer Role in the organization	(131081,DCM)
	Person Observer Role in this procedure	(121094,DCM)
	Accumulated Dose Data	
	Calibration date	
	Calibration factor	
	Calibration uncertainty	
	Calibration responsible	
	Calibration protocol	

	DAP total	
	Dose RP total	
	DAP fluoro total	
	Dose RP fluoro total	
	Fluoro time total	
	Acquisition DAP total	
	Acquisition dose RP total	
	Acquisition time total	
	Number of frames total	
	MSD	
	Height of system	
	Reference Point Definition	(113860,DCM)
	Events	
	Acquisition Plane	(113622,DCM)
(0008),(0031) Series Time (0008),(0032) Acquisition Time	Time started	
(0018),(1155)	Event type	(P5-0600,SRT)
	XA image (acquisition)	
(0018),(1030)	Acquisition protocol name	
(0020),(000d) Study Instance UID (0020),(000e) Series Instance UID	Event UID	
(0018),(115e) Image Area Dose Product	DAP	
	Dose Reference Point	
	Filter type	(113653,DCM)
	Filter material	(C-127F9,SRT)
	Filter thickness min	
	Filter thickness max	
(0018),(1166)	Grid (IN or NONE)	
	Type of grid: fixed	(111641,DCM)
	Type of grid: focused	(111642,DCM)
(0018),(115a)	Fluoro mode	(113631,DCM)
(0018),(0040)	Pulse rate	
	Nr of pulses	
(0018),(1151)	Tube current	
(0018),(0060)	kVp	
(0018),(1150)	Exposure time	
(0018),(1154) Average Pulse Width	Pulse width	
(0018),(1152) Exposure	mAs	
	Irradiation duration	
(0018),(0040)	Frame rate	
(0028),(0008)	Nr of frames	
	Subimages per frame	
(0018),(1190)	Focal spot size	

(0018),(1510)	Primary angle	
(0018),(1511)	Secondary angle	
	Collimated field area	
	Collimated field height	
	Collimated field width	
(0018),(1600)	Shutter shape	
(0018),(1608)	Bottom shutter	
(0018),(1602)	Left shutter	
(0018),(1604)	Right shutter	
(0018),(1606)	Top shutter	
(2003),(1003) [private] (0018),(1149)	FOV	
(0018),(1162)	Detector size	
(0021),(1017) [private]	Distance source to isocenter	
(0018),(1110)	Distance source to detector	
(0040),(0306)	Distance source to entrance	
(0018),(1111)	Distance source to reference point	
(300a),(0129) (0019),(1022) [private] (0021),(1057) [private]	Table longitudinal position	
(300a),(012a) (0019),(1023) [private] (0021),(1057) [private]	Table lateral position	
(300a),(0128) (0019),(1021) [private] (0021),(1057) [private]	Table height position	
(0018),(9470)	Table head tilt angle	
(0018),(9469)	Table horizontal rotation angle	
(0018),(9471)	Table cradle tilt angle	
(0018),(5100)	Patient position	(F-10340,SRT)
(0020),(0020)	Patient orientation	(F-10450,SRT)
	Patient table relationship	(F-10470,SRT)
	Target region	(T-32000,SRT)
	Threshold	
	Source of dose info	
	Annex 1	
	Procedure reported	
	Projection X-Ray	(113704,DCM)
	Combined Diagostic and Therapeutic	(R-002E9,SRT)
	Annex 2	
	Scope of accumulation	
	Performance procedure step	(113016,DCM)
	Perfomance procedure step SOP instance UID	

Table A3.2 Information provided in RDSR from 5 different systems (4 manufacturers)

Single plane	Philips Clarity FD25	Philips Allura FD48	GE Innova 520	Siemens Artis ZEE	Canon (Toshiba)
Patient					
Name	Y	Y	Y	Y	Y
Date of Birth	Y	Y	Y	Y	Y
ID	Y	Y	Y	Y	Y
Study					
Study	name/nr	name/nr	name/nr	name/nr	name/nr
Series	RDI	RDI		exam protocol SR	
Manufacturer	Y	Y	Y	Y	Y
Completion flag	complete	complete	complete	partial	partial
Verification flag	unverified	unverified	unverified	unverified	unverified
Date/time	Y	Y	Y	Y	Y
Study Description					
Series Description					
Radiation dose report					
Location/hospital name					
Observer type = Device					Y
Device Observer UID	Y	Y	Y	Y	Y
Device Observer Name	Y	Y	Y	Y	Y
Device Observer Model Name	Y	Y	Y	Y	Y
Device Observer SN	Y	Y	unknown	Y	Y
Study instance UID					Y
Accumulated Dose Data					
Calibration date			Y	Y	Y
Calibration factor			100%	1	1%
Calibration uncertainty			35%	5%	0%
Calibration responsible			unknown	name	Toshiba
Calibration protocol					Toshiba
DAP total	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$
Dose RP total	Gy	Gy	Gy	Gy	Gy
DAP fluoro total	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$
Dose RP fluoro total	Gy	Gy	Gy	Gy	Gy
Fluoro time total	s	s	s	s	s
Acq DAP total	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$
Acq dose RP total	Gy	Gy	Gy	Gy	Gy
Acq time total	s	s	s	s	s
Nb frames total	Y	Y	Y	Y (comment)	Y
MSD				Y (comment)	

Height of system	1065 mm	1075 mm			
Events					
Plane	Y	Y	Y	Y	Y
Time started	Y	Y	Y	Y	Y
Event type	Y	Y	Y	Y	Y
IRP definition	15 cm from isocenter	15 cm from isocenter	15 cm from isocenter	15 cm from isocenter	15 cm from isocenter
XA image (acq)	server	server	server	server	
Event UID	Y	Y	Y	Y	Y
DAP	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$	$Gy.m^2$
Dose RP	Gy	Gy	Gy	Gy	Gy
X-Ray filters					
Filter type	No/strip	No/strip		No/strip	No/strip
Filter material	Cu	Cu	W	Cu	Cu
Filter thickness min	mm	mm		mm	mm
Filter thickness max	mm	mm		mm	mm
Type of grid			fixed/focused		
Operator			name	name	
Fluoro mode	pulsed	pulsed	pulsed	pulsed	pulsed
Pulse rate	p/s	p/s	p/s	p/s	p/s
Nr of pulses	Y		Y	Y	Y
Name of fluoro or acq protocol			Y	Y	Y
Tube current	mA	mA	mA	mA	mA
kVp	Y	Y	Y	Y	Y
Exposure time			ms	ms	ms
Pulse width	ms	ms	ms	ms	ms
mAs			µAs	µAs	N
Irradiation duration	s	s			s
Frame rate	Y	Y	Y	Y	Y
Nr of frames	Y				Y
Subimages per frame	Y	1			
Focal spot size				Y	mm
Primary angle	deg	deg	deg	deg	deg
Secondary angle	deg	deg	deg	deg	deg
Collimated field area				m^2	m^2
Collimated field height			mm		mm
Collimated field width			mm		mm
Sutter shape					
Bottom shutter	mm	mm			
Left shutter	mm	mm			
Right shutter	mm	mm			
Top shutter	mm	mm			

FOV			cm		
Detector size					
Surface at plane perpendicular to axis of beam at level of IRP ideally needed					
Distance source to isocenter	765 mm	810 mm	720 mm	750 mm	700 mm
Distance source to detector		mm	mm	mm	mm
Distance source to entrance					
Distance source to patient					
Table longitudinal position	94 mm	N		--10 mm	310 mm
Table lateral position	2301,7 mm	N		483 mm	0 mm
Table height position	882 mm	895 mm		192 mm	1030 mm
Table head tilt angle	NA	NA			deg
Table horizontal rotation angle	NA	NA			deg
Table cradle tilt angle	NA	NA			deg
Patient position	Y	headfirst	headfirst		headfirst
Patient orientation	Y	supine	supine		supine
Target region	Y	chest	coronay artery	entire body	entire body
Beam position					
Longitudinal	1456 mm	1939 mm			
Angle	deg	deg			
HT = 0-height of table	882 mm	895 mm			
Threshold				caremonitor 2 Gy	
Source of dose info				dosimeter	
Annex 1					***not in annex***
Procedure reported		projection	projection	projection	projection
		intent	intent	intent	intent
Annex 2					
Scope of accumulation		performed procedure step	performed procedure step		

Table A3.3 : comparison of RDSR and Radimetrics extraction

	Radimetrics excel	RDSR PDF
Exam mode	XA	
Description	Coro	
Date	Date	
Time	time	
Protocol name	Coro/Dilatation	
Institution	HUG	
Equipment	Infinix_Salle15	
Device	DFP-8000D	
Manufacturer	Canon (Toshiba)	
Operator	SA	
Physician	Dr.F R	Not on RDSR
Series	6	Not on RDSR
Images	11	on RDSR = 290
Modality	XA	
kVp	75	Not on RDSR
Mean mAs		on RDSR = 85.6
Code Acquisition Plane (RF)	Plane A	Not on RDSR
Code Event Type	P5-06000	Not on RDSR
Irradiation event	Fluoroscopy	Not on RDSR
Irradiation time	5120770	on RDSR + Exposure time
Acquisition Protocol (RF)	Coro/Dilatation 7.5f/s Low	Not on RDSR
PERP definition (RF)	15cm from Isocenter toward Source	Not on RDSR
Primary angle	0	Not on RDSR
Secondary angle	0	Not on RDSR
Codes_Equipment Filters	C-127F9	Not on RDSR
Min filter thickness	0.3	Not on RDSR
Max filter thickness	0.3	Not on RDSR
Fluoro mpde	Pulsed	Not on RDSR
Pulserate	7.5	Not on RDSR
Pedal activation time		
Number of pulses	385	Not on RDSR
Pulse length	7,69	Not on RDSR
Focal spot size	0,5	Not on RDSR
Source-to-detector distance	1020	Not on RDSR
Source-to-isocenter distance	700	Not on RDSR
Table longitudinal position	300	Not on RDSR
Table lateral position	180	Not on RDSR
Table height	980	Not on RDSR
Table angle of rotation horizontal	3	Not on RDSR
Target (RF)	Entire body	
Collimated field surface	440.364978 en cm^2	RDSR in m^2
Mean mA		
Exposure index (RF)		
DEI	Estimated	
Patient diameter mm		
Dose at PERP mGy	4.581	on RDSR in Gy
Entrance dose mGy		

Beam activation time ms	2960,65	
Fluoro time ms	51333.33333	total duration
Patient BMC kg/m2	24.78425752	Not on RDSR
Number of acquisitions		
PDS Gycm2	0.5798	on RDSR in Gy.m2
PDS fluoro Gycm2	0.5798	
kVp_kV	75	
kVp_(A)_kV		
kVp_(B)_kV		
mAs_mAs		
mAs_(A)_mAs		
mAs_(B)_mAs		
mAs_max_mAs		
mAs_max_(A)_mAs		
mAs_max_(B)_mAs		
Age at examination	57.95470767	

Legend :

In Radimetrics extraction and in RDSR but written in different way

In RDSR but not in Radimetrics extraction

In Radimetrics extraction but not in RDSR

Table A3.4 : comparison of RDSR and Dosewatch extraction

Dosewatch Titles	Dosewatch excel - 1 acquisition event	Dosewatch excel - 1 fluoro event	RDSR PDF
Site	M	M	Not in RDSR
Study date (YYYY-MM-DD)	2018-10-18	2018-10-18	2018-10-18
Study time	08:05	08:05	End time in RDSR (10:51)
Study Instance UID	1.2.250.1.59.915.1.1.1030450 0477886	1.2.250.1.59.915.1.1.1030450 0477886	Not in RDSR
Study ID	RP477886	RP477886	Not in RDSR
Accession number	CA477886	CA477886	Not in RDSR
Local study description	CTO	CTO	CTO
Old local study description			Not in RDSR
Standard study description			Not in RDSR
Institution name	IJC	IJC	Not in RDSR
Referring physician last name			Not in RDSR
Referring physician first name			Not in RDSR
Requesting physician last name			Not in RDSR
Requesting physician first name			Not in RDSR
Performing physician last name	TL	TL	TL
Performing physician first name			Not in RDSR
Operator last name			Not in RDSR
Operator first name			Not in RDSR
Total Effective dose (msv)			Not in RDSR
AE Title	TERRA1	TERRA1	"Device Observer Name"
Device	Salle 1 GE (M)	Salle 1 GE (M)	Not in RDSR
Teams	M	M	Not in RDSR
Manufacturer	General Electric	General Electric	GE MEDICAL SYSTEMS
Model	Innova IGS 520	Innova IGS 520	DL
Performing Device			Not in RDSR
Internal key	14829	14829	Not in RDSR
Patient ID	P142465	P142465	P142465
Patient first name	R	R	R
Patient last name	F	F	F
Patient birthdate (YYYY-MM-DD)	1958-12-15 00:00:00.0	1958-12-15 00:00:00.0	Not in RDSR
Age class	[21+]	[21+]	Not in RDSR
Patient sex	MALE	MALE	Not in RDSR
Patient weight (kg)	93.00	93.00	Not in RDSR

Patient size (cm)	176.00	176.00	Not in RDSR
BMI	30.02	30.02	Not in RDSR
Image and Fluoroscopy Dose Area Product (mGy.cm2)	490060.00	490060.00	"Dose Area Product Total", in Gy.m²
Total Time of Fluoroscopy (s)	5307.00	5307.00	"Total Fluoro Time"
Total number of exposures	262.00	262.00	Not in RDSR
Total Air KERMA (mGy)	6225.76	6225.76	"Dose (RP) Total", en Gy
Raised alerts	Yes	Yes	Not in RDSR
Justification Author			Not in RDSR
Justification Date (YYYY-MM-DD)			Not in RDSR
Justification Code			Not in RDSR
Justification Comment			Not in RDSR
Alerts reviewed	N	N	Not in RDSR
Number of Acquisition Series	26	26	Not in RDSR, but in "Total Number of Radiographic Frames"
Total Acquisition Air KERMA (mGy)	788.45	788.45	"Acquisition Dose (RP) Total", in Gy
Total Acquisition DAP (mGy.cm²)	63240	63240	"Acquisition Dose Area Product Total", in Gy.m²
Total Acquisition Time (s)	123	123	idem
Number of Fluoro Series	236	236	Not in RDSR
Total Fluoro Air KERMA (mGy)	5437.31	5437.31	"Fluoro Dose (RP) Total", in Gy
Total Fluoro DAP (mGy.cm²)	426820	426820	"Fluoro Dose Area Product Total", in Gy.m²
Prior Adverse Event	N/A	N/A	Not in RDSR
Prior Adv. Event Comment			Not in RDSR
Asthma Allergies	N/A	N/A	Not in RDSR
eGFR (ml/min/1.73m2)			Not in RDSR
Creatinine (microMole/L)			Not in RDSR
Diabetes	N/A	N/A	Not in RDSR
Metformin	N/A	N/A	Not in RDSR
Nephrotoxic drugs	N/A	N/A	Not in RDSR
Heart disease	N/A	N/A	Not in RDSR
Heart disease comment			Not in RDSR
Low Hematocrit	N/A	N/A	Not in RDSR
Pre-medicated	N/A	N/A	Not in RDSR
Pre-medicated comment			Not in RDSR
Pregnant	N/A	N/A	Not in RDSR

Pregnant comment			Not in RDSR
Adverse event	N/A	N/A	Not in RDSR
Adverse event comment			Not in RDSR
Creatinine after 3 days (microMole/L)			Not in RDSR
Hypotension	N/A	N/A	Not in RDSR
Total Number of Radiographic Frames	1583.00	1583.00	1583.00
Distance Source to Reference Point (cm)	0.00	0.00	570 mm
Calibration Factor	0.00	0.00	
Calibration Date			
Reference Point Definition	15 cm from Isocenter toward Source	15 cm from Isocenter toward Source	15cm from Isocenter toward Source
Peak Skin Dose (mGy)	0.00	0.00	Pas sur RDSR
Protocol name	2 Cardiac Cust 1 DYNAMIC	2 Cardiac Cust 1 FLUORO	"Acquisition Protocol"
Series Time	09:03	09:46	"DateTime Started"
Irradiation Event Type	STATIONARY_ACQUISITION	FLUOROSCOPY	idem
Proprietary Type		Scopie	Pas sur RDSR
Exposure Time (ms)	159.00	948.00	idem
Irradiation Duration (s)	2.59	13.05	idem
Positioner Primary Angle (deg)	23.20	-19.10	idem
Positioner Secondary Angle (deg)	-14.80	-15.60	idem
Tube Voltage (kV)	81.80	86.20	idem
Distance Source to Isocenter (cm)	72.00	72.00	720 mm
Field of View (cm)	17.20	20.00	"Field Of View Row Dimension", in mm and "Field Of View Column Dimension", in mm
Pulse Width (ms)	5.89	9.99	idem
Table Vertical Position (cm)	16.24	15.01	"Table Height Position", in mm
Distance Source to Detector (cm)	103.40	107.40	in mm
Dose Preference	IQ Standard	IQ +	"Auto Exposure Preference"
Exposure (mAs)	83.35	132.53	in µAs
X-Ray Tube Current (mA)	524.00	139.00	idem
DAP (mGy.cm2)	670.00	1070.00	"Dose Area Product", in Gy.m²
Air KERMA (mGy)	11.18	11.99	"Dose (RP)", in Gy
Frames per Second	10.42	7.28	idem
Number of Frames	27.00	95.00	Number of Pulses

Run number	168.00	36.00	Not in RDSR
Series number	0.00	0.00	Not in RDSR
Series type	RECORD	FLUORO	Not in RDSR, but in "Irradiation Event Type"
Irradiation Event UID	1.2.840.113619.2.429.651406 53521075042061.1539605797 .1113.3239	1.2.840.113619.2.429.651406 53521075042061.1539605797 .1113.3387	idem
Target Region	Heart	Heart	idem
Acquisition Plane	Plane A	Plane A	Not in RDSR
Fluoro Mode		Pulsed	idem
Focal Spot Size (mm)	1	0.6	idem
Patient Equivalent Thickness (cm)	26.61	25.86	idem, but in mm and in cm
Number of Pulses	27.00	95.00	idem
Table Longitudinal Position (cm)	58.55	57.85	idem, but in mm
Table Lateral Position (cm)	6.05	-0.32	idem. but in mm
Reference Point Definition	15cm from Isocenter toward Source	15cm from Isocenter toward Source	idem
Patient Table Relationship	headfirst	headfirst	idem
Patient Orientation	recumbent	recumbent	idem
Patient Orientation Modifier	supine	supine	Not in RDSR
Table Head Tilt Angle (deg)	0.00	0.00	0.00
Table Cradle Tilt Angle (deg)	0.00	0.00	0.00
Acquired Image			
Positioner Primary End Angle (deg)	0.00	0.00	Not in RDSR
Positioner Secondary End Angle (deg)	0.00	0.00	Not in RDSR
Collimated Field Area (m^2)	0.02	0.03	idem
Collimated Field Height (mm)	0.00	0.00	idem
Collimated Field Width (mm)	0.00	0.00	idem
Distance Source to Reference Point (cm)	57.00	57.00	idem, but in mm
Table Horizontal Rotation Angle (deg)	-1.80	-1.80	idem
Table Longitudinal End Position (cm)	0.00	0.00	Not in RDSR
Table Lateral End Position (cm)	0.00	0.00	Not in RDSR
Table Height End Position (cm)	0.00	0.00	Not in RDSR
Anode target material	Tungsten or Tungsten compound	Tungsten or Tungsten compound	idem
X-Ray Grid	Fixed grid	Fixed grid	idem
X-Ray Filter Type		flat filter	idem

X-Ray Filter Material		Copper or Copper Compound	idem
X-Ray Filter Thickness Minimum (mm)	0.00	0.10	idem
X-Ray Filter Thickness Maximum (mm)	0.00	0.10	idem
Second X-Ray Filter Type			Not in RDSR
Second X-Ray Filter Material			Not in RDSR
Second X-Ray Filter Thickness Minimum (mm)	0.00	0.00	Not in RDSR
Second X-Ray Filter Thickness Maximum (mm)	0.00	0.00	Not in RDSR
Third X-Ray Filter Type			Not in RDSR
Third X-Ray Filter Material			Not in RDSR
Third X-Ray Filter Thickness Minimum (mm)	0.00	0.00	Not in RDSR
Third X-Ray Filter Thickness Maximum (mm)	0.00	0.00	Not in RDSR

Legend :

In Dosewatch extraction and in RDSR but written in different way

In RDSR but not in Dosewatch extraction

In Dosewatch extraction but not in RDSR