Performance and accuracy of skin dose mapping software:
Results from the VERIDIC project

EURADOS webinar

15/12/2021

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Interventional cardiology: relative merits

Advantages :

- Substitute to surgery
- One-day vs protracted stay
- Large field of applications

Siemens.com

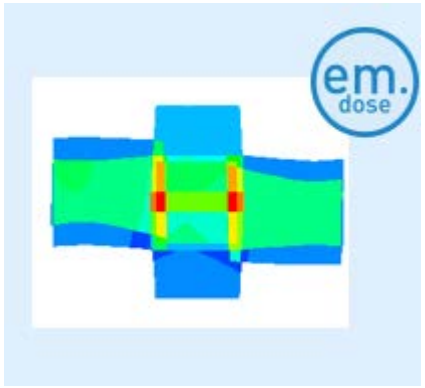
Balter et al, Radiology, 2010

Disadvantages :

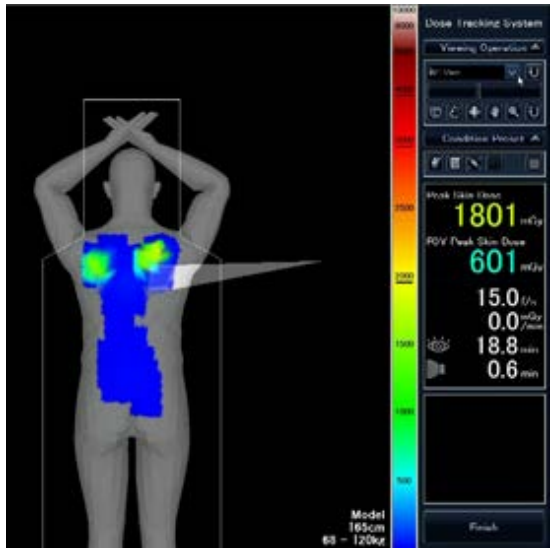
- Risk of high dose to patient skin
- Radio-induced cardiovascular diseases?
- Cumulative dose from multiple procedures
- Highest skin dose challenging to predict

Introduction
Skin dose mapping (SDM) software

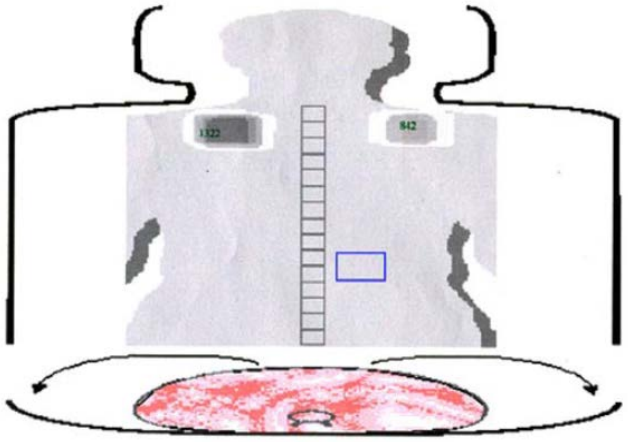
Development of **on- and off-line** software for **MSD (Maximum skin dose) estimate or 2D dose** distribution



em.dose, Esprimed



DTS, Canon



CareGraph System, Siemens

- Limitations remain:
  - **Capabilities/accuracy** of software markedly differ among vendors
  - **Reporting** and accuracy in Radiation Dose Structured Report **(RDSR)** neither systematic nor harmonised
  - No acceptance testing nor quality control **(QC) protocols**

VERIDIC

Validation and Estimation of Radiation skIn Dose in Interventional Cardiology

EUROPEAN JOINT PROGRAMME FOR THE INTEGRATION OF RADIATION PROTECTION RESEARCH

CONCERT

Objectives

- Reviewing existing SDM software products
- Identification of harmonization needs in RDSRs for MSD calculations and reporting
- Comparing SDM software capabilities and accuracy
- Investigating feasibility of commissioning and quality control protocols
- Investigating skin dose determinants for dose optimisation

Outline

- **(Non-exhaustive) Overview of SDM products**
- Current limitations
- Testing of 10 SDM products
- Conclusions
- Perspectives

Many software products available
Non-exhaustive (!) review of contemporary products:

Software Name	Company name
Dose Map	GE healthcare
Dosewatch	GE healthcare
DTS	CANON Medical Systems
em.dose	ESPRIMED
Radimetrics	BAYER
RDM	MEDSQUARE
DOSE	QAELUM
UF-RIPSA	Non-commercial
MCAR	Non-commercial
FDEIR	Non-commercial
MCGPU	Non-commercial

Software Name	Company name
TeamPlay	SIEMENS Healthineers
Dosewise	PHILIPS
Dosetrack	SECTRA
Nexodose	BRACCO
Dose monitor	PACSHEALTH
Dosem	INFINITT
OpenSkin	Open Source
PySkinDose	Open Source
SkinCare	Open Source
CAATSDOSE	CAATS
DIDO	Hospital San Carlos Madrid Madrid

Malchair et al, Phys Med, 2020

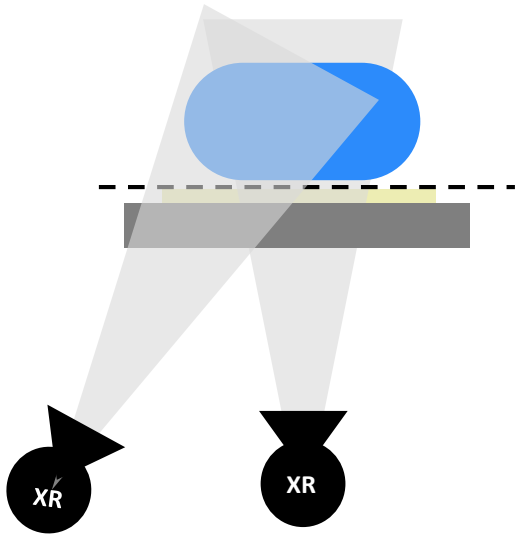
→ Review based on : calculation algorithm, factors accounted for in calculations, patient representation, 2D or 3D-dose distribution, validation studies, limitations

Main calculation algorithm:
Sum of Skin dose from all irradiation events

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

Jones and Pasciak, Med Phys, 2011

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



Software products differ in factor selection…

Wide range of possible/used values

BSF **~ 1,20 to 1,70**	**Table and mattress transmission** **~60% to 90%***	**$K_{a,r}$ calibration factor (CF)** **0% to 35%**	**F_{skin}** **~1,02 to 1,05**
- Single default value - Possibly set by user - Multiple values from literature *→f(kV, filtration, patient thickness & material)*	- Single default value - Possibly set by user - Multiple values from measurements *→f(kV, filtration, table thickness & material)*	- None - Single value - Possibly set by user *→f(kV, filtration)*	- None - From literature *→f(kV, filtration)*

*in PA

Malchair et al, Phys Med, 2020; Krajinovic et al, Phys Med, 2021; DeLorenzo et al, Med Phys, 2018; Benmakhlouf el al, Phys Med Biol, 2011

...and in patient representation

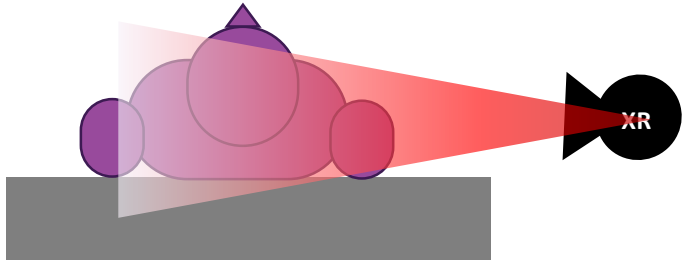
BSF	Table and mattress transmission	$K_{a,r}$ calibration factor (CF)	Fskin	**Patient model**
- Single default value - Possibly set by user - Multiple values from literature	- Single default value - Possibly set by user - Multiple values from measurements	- None - Single value - Possibly set by user	- None - From literature	- Cylindrical - Elliptical - ICRP phantom - Phantom library (UF, Caeser) - Voxelised CT phantoms

Outline

- (Non-exhaustive) Overview of SDM products
- **Current limitations**
- Testing of 10 SDM products
- Conclusions
- Perspectives

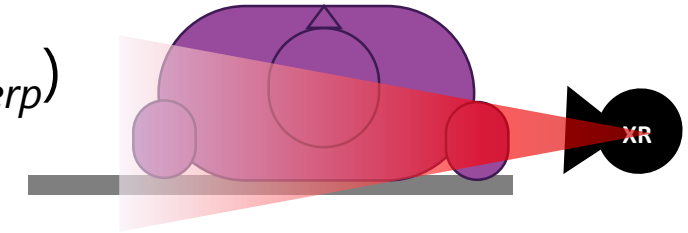
Some – major - limitations to be addressed

- Missing data / fields in the RDSRs
  - $K_{a,r}$ calibration factor(s)/curve(s)
  - *Trans* table/(mattrass?) transmission
  - Field shape/wedge filter



- Lack of harmonisation among manufacturers
  - Definition of table height

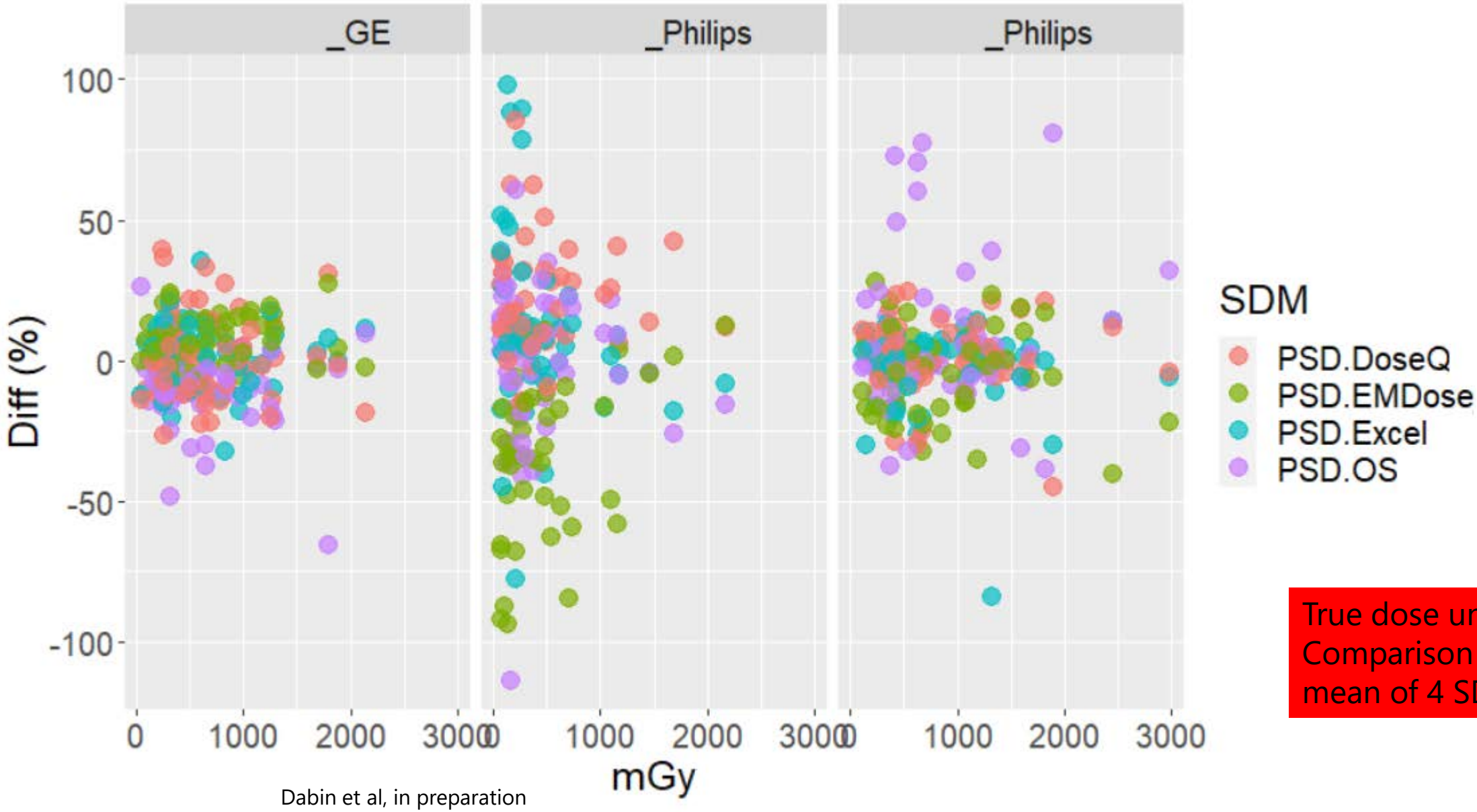
- Need for determining patient's contour and position (→d_{perp})
  - Where is the patient? How thick/thin?



- Other factors not accounted for:
  - Wedge filters, heel effect, backscatter from adjacent fields, …

Dabin et al, Med Phys, 2021; Greffier et al, Med Phys 2021; Colombo et al, Phys Med 2021

Effect of SDM difference and limitations?
Comparison of MSD from different SDM; 3 hospitals, 4 SDM, 160 proc



True dose unknown!
Comparison with mean of 4 SDM soft!

Dabin et al, in preparation

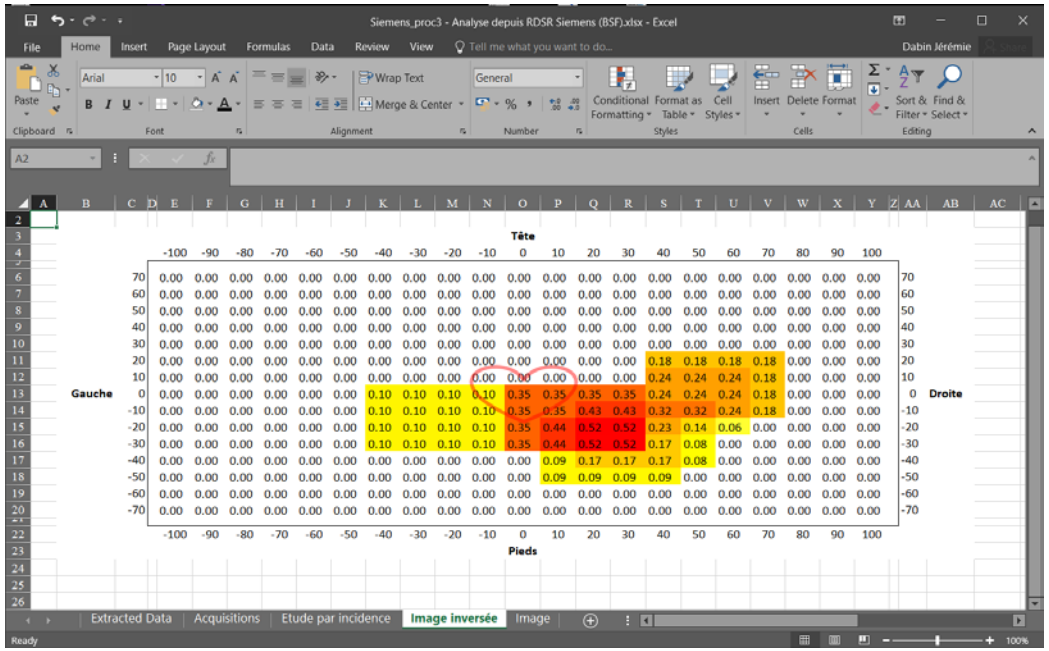
Outline

- (Non-exhaustive) Overview of SDM products
- Current limitations
- **Testing of 10 SDM products**
- Conclusions
- Perspectives

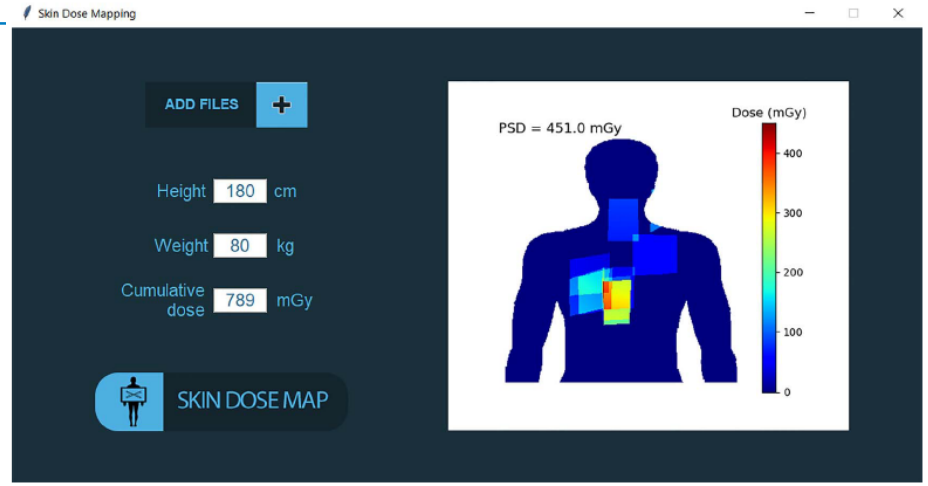
Material and Methods
Software and angio units

4 Angiographic units:

- Canon, Infinix CF-i biplane
- GE, Innova IGS 540
- Philips, Allura Xper
- Siemens, Artis Zee biplane



CAATSDOSE, CAATS



SkinCare, Krajinovic et al 2020, RPD

Combined with up to 10 SDM software:

- **Dose Map,** GE
- **DoseWatch Skin Dose Map**, GE
- **Dose Tracking System,** Canon
- **em.dose,** Eprimed
- **RDM,** Medsquare
- **DOSE by Qaelum,** Qaelum
- **CareMonitor,** Siemens
- **OpenSkin,** opensource
- **SkinCare**, MSc thesis
- **CAATSDOSE**, CAATS, Excel sheet

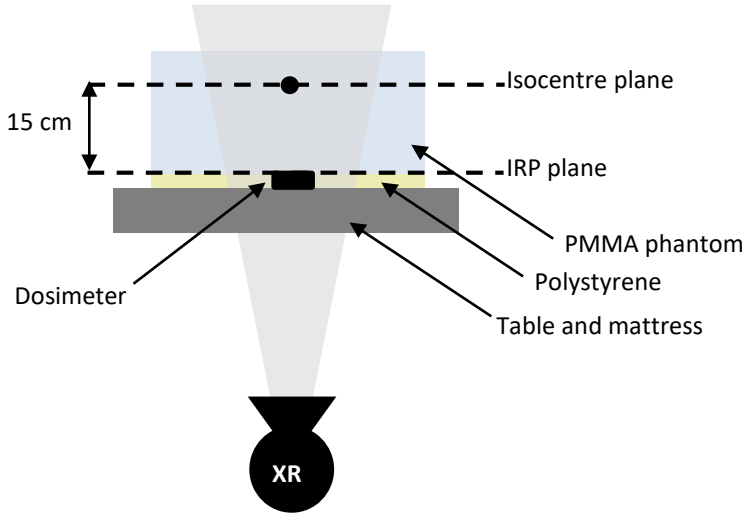
Material and Methods

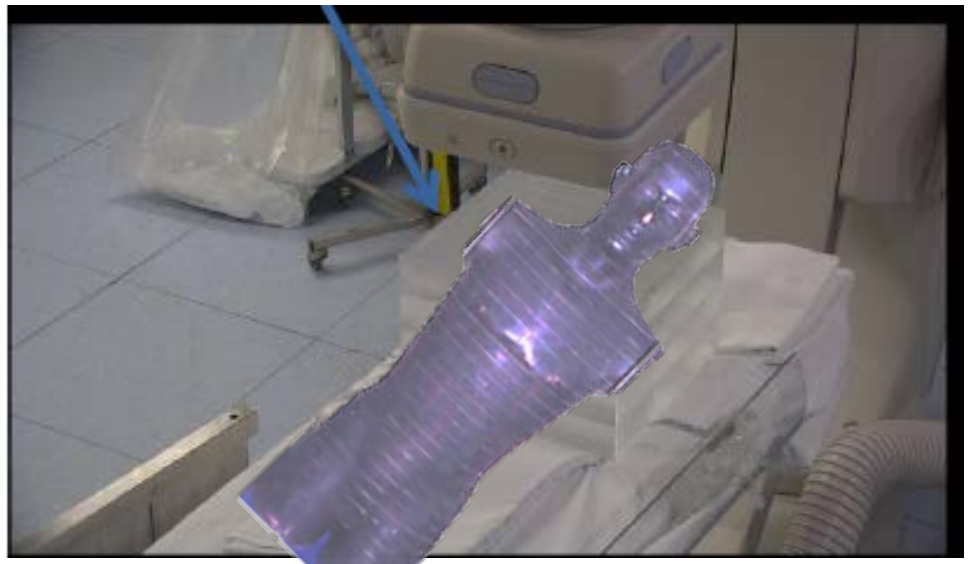
Measurement protocol

- Dosimeters:
  - Gafchromic films
  - TLDs
  - QC multimeter
- Phantoms
  - PMMA slab
  - Rando Alderson
- Configurations
  - 13 simple configurations
  - 3 short “clinical” procedures
- Correction factors:
  - Table attenuation (1)
  - Ka,r calibration (1)

→ Measurements compared with SDM soft Calculations

→ ± 40% used as reference range for comparison purpose

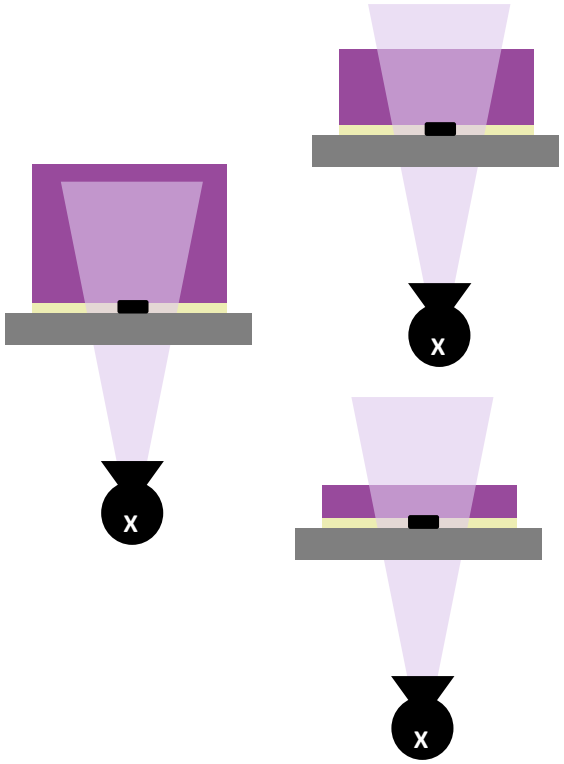




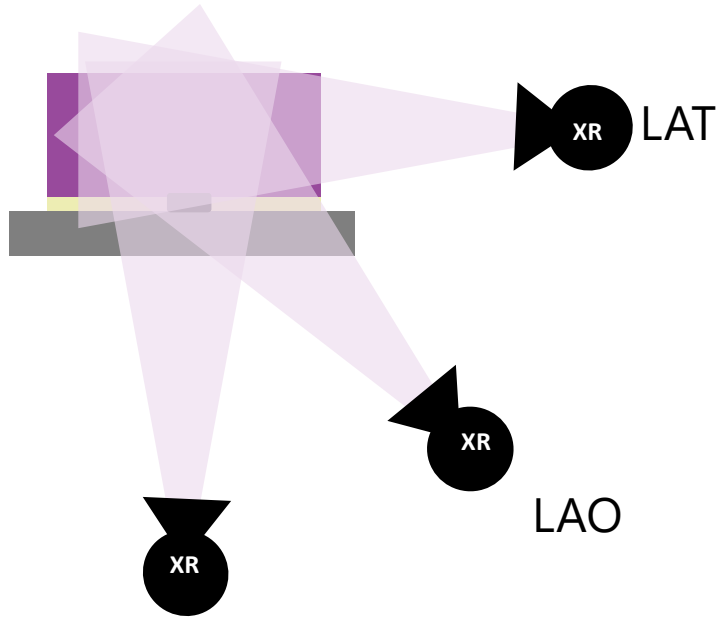
Deleu, 2018, master thesis

Material and Methods
Configurations

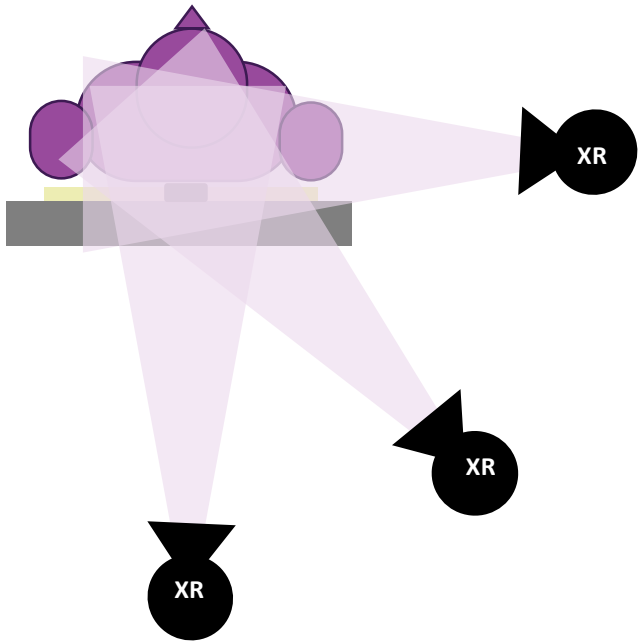
Thicknesses



Angulations

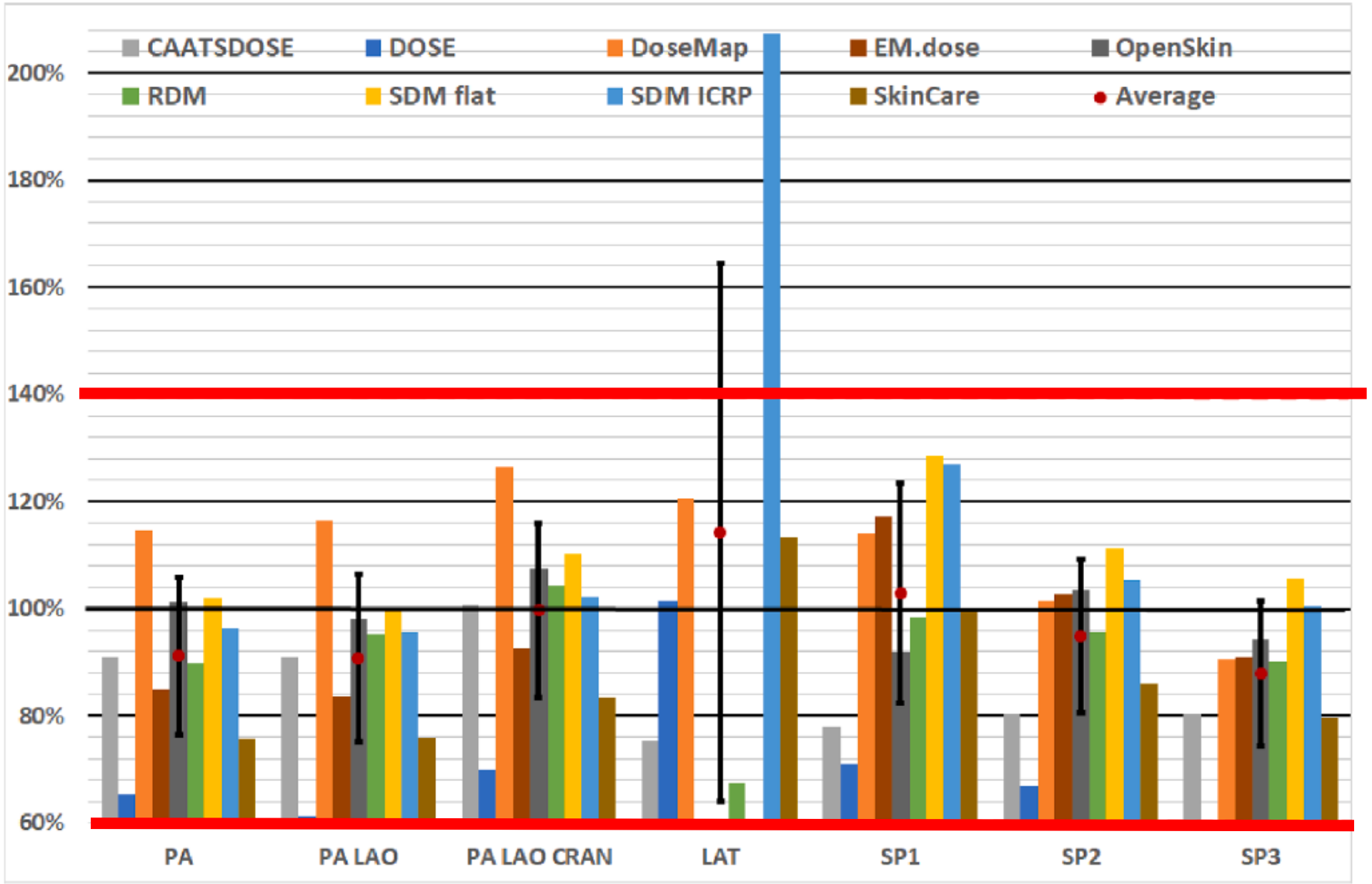


Anthropomorphic phantom



Results: GE unit
Simple projections and short procedures on RA phantom

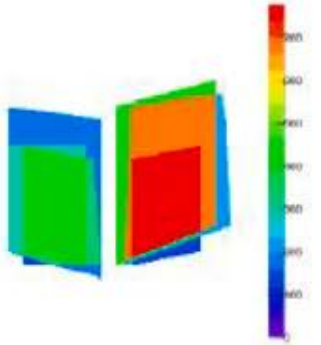
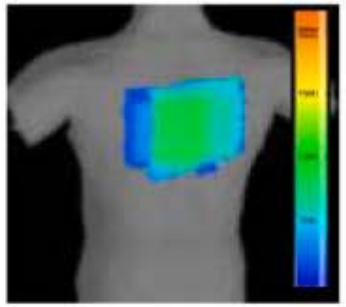
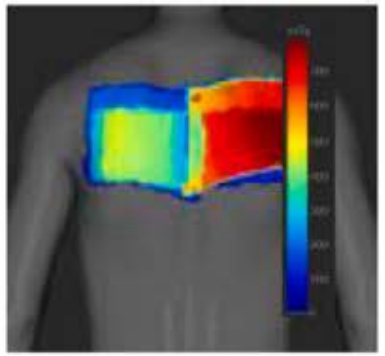
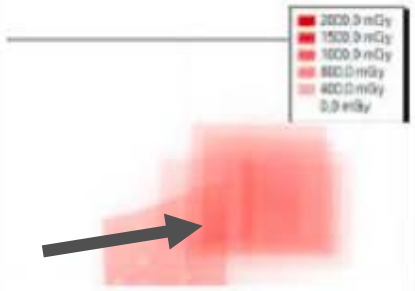
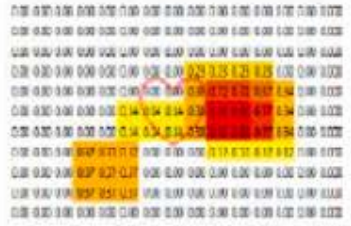
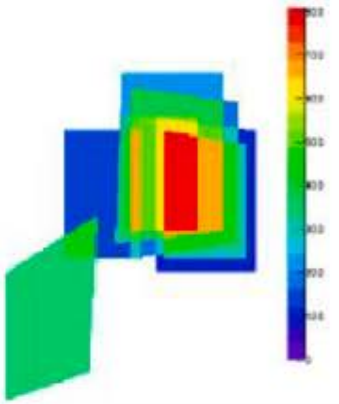
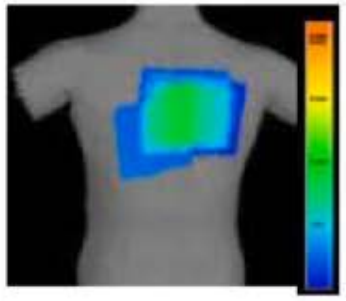
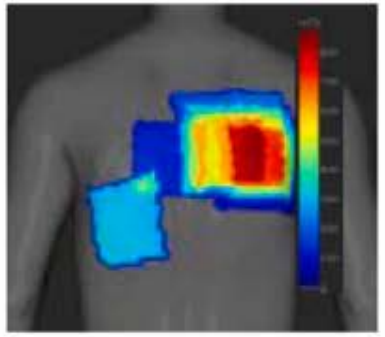
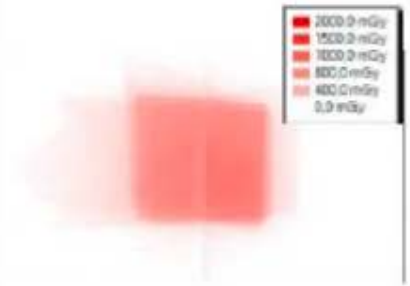
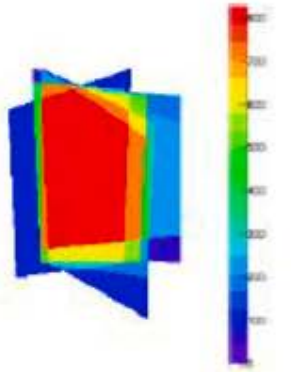
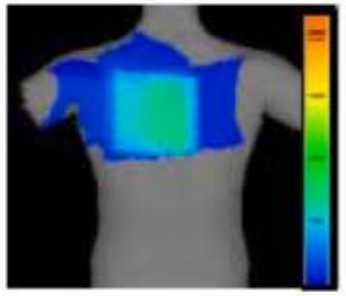
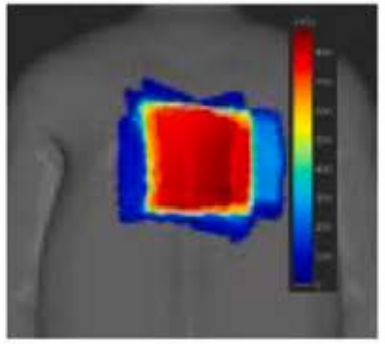
MSD_{calc}/MSD_{meas}



Dabin et al, 2021,
Phys Med

Spot the differences

Canon unit

CP	Film	CAATSDOSE	EM.dose	Modality (DTS)	OpenSkin	SkinCare
1						
2						
3						

Results
Summary

MSD estimates generally within ±40% of measurements but can be severely off

Only 3 SDM products within 40% for all RA phantom irradiations on the compatible units

Some SDM products within ± 20% for all the irradiation configurations (but the strictly lateral projection) on a specific system

strictly lateral projection remains challenging:
- **some SDM products provided no MSD estimates**
- **quite variable accuracy and possibly >> underestimation (up to 66%).**

Outline

- (Non-exhaustive) Overview of SDM products
- Current limitations
- Testing of 10 SDM products
- **Conclusions**
- Perspectives

Conclusions

SDM software are promising MSD,
MSD estimates generally within ±40% of measurements but can be severely off too!

Some major limitations to be addressed:

- Missing data / fields in the RDSRs
- Lack of harmonisation among manufacturers
- Need for determining patient's contour and position

Outline

- (Non-exhaustive) Overview of SDM products
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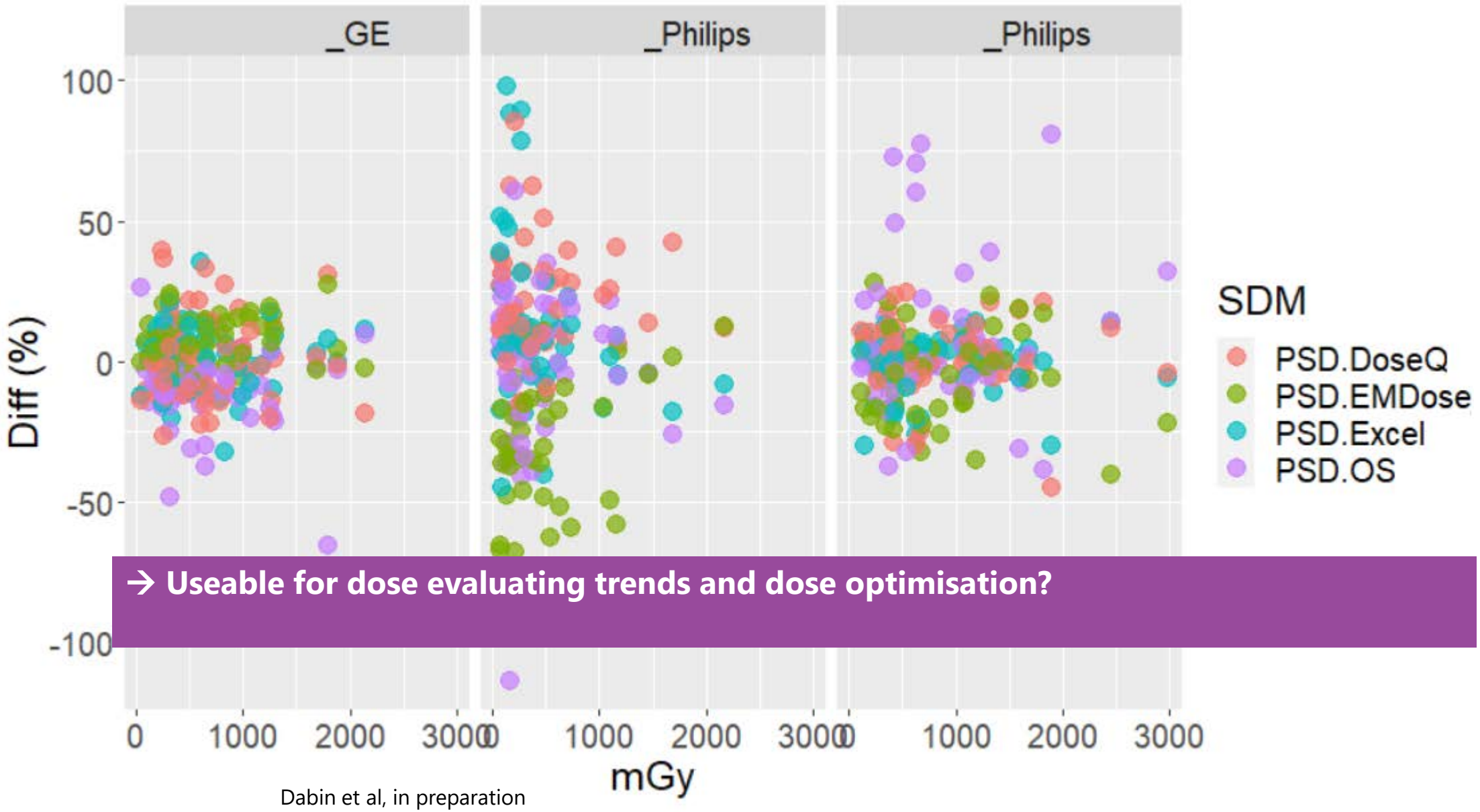
Perspectives

How to use the SDM software?

→Need for Quality control! Know your model, your patients and your physicians ☺!

→ Not advisable for replacing dosimeter for individual patient monitoring
→ What about replacing Ka,r? Or using them together? Useable for evaluating dose trends and optimizing dose?

Perspectives



→ **Useable for dose evaluating trends and dose optimisation?**

Dabin et al, in preparation

VERIDIC partners

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