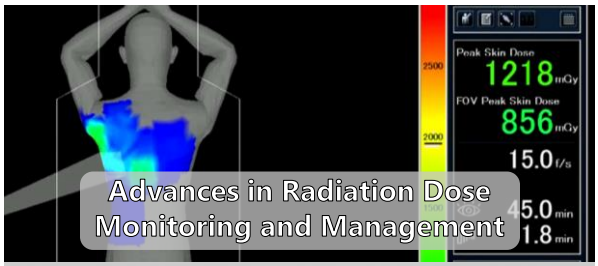

Andrew Kuhls-Gilcrist, PhD, DABR
August 2, 2018

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Learning Objectives

- Review of available dosimetric indications
- Real-time skin dose maps
- Managing radiation dose during a procedure
- Managing radiation dose after a procedure

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The Past | FLUOROSCOPY TIME

Inadequate Estimation of Radiation Exposure

30 Minutes	2x >	15 Minutes
Patient Weight: 70 kg	10x <	Patient Weight: 100 kg
Frame Rate: 7.5 fps	2x <	Frame Rate: 15 fps
Cine Frames: 50	4x <	Cine Frames: 200
Cumulative Air Kerma (mGy): 250	15x <	Cumulative Air Kerma (mGy): 3750

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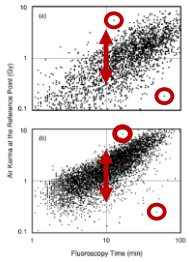
A Look at the Data | NCRP REPORT 168*

(A) 2,100 Non-Cardaic
AK = 0.41 + 0.037 x FT; R^2 = 0.50

(B) 1,700 Coronary-Artery Procedures
AK = 0.53 + 0.12 x FT; R^2 = 0.68

An order of magnitude variability observed across most fluoroscopy times!

"Because fluoroscopy time is such a poor indicator of radiation dose, its use is generally discouraged... in favor of alternative dose measures."



Canon *NCRP Report No. 168 - *Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures (2010)* DoseRite

The Present | AIR KERMA (...AND DAP)

Better Estimation of Radiation Exposure

30 Minutes	Includes 2x >	15 Minutes
Patient Weight: 70 kg	10x <	Patient Weight: 100 kg
Frame Rate: 7.5 fps	2x <	Frame Rate: 15 fps
Cine Frames: 50	4x <	Cine Frames: 200
Cumulative Air Kerma (mGy): 250	15x <	Cumulative Air Kerma (mGy): 3750

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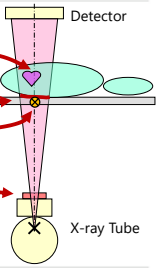
Dose Metrics | AIR KERMA AND DAP

- Detector Exposure – R (Drives AERC)
- Organ Dose / Effective Dose – mSv (Patient Dose)
- Peak Skin Dose (PSD) – mGy (Patient Dose)
- Air Kerma at Reference Point* - mGy (Machine Output)
- Dose Area Product (DAP) – Gy cm^2 (Machine Output)

*"Patient Entrance Reference Point" = 15cm From Isocenter Towards Focus (IEC Standard)

Inverse Square Law:
60 cm vs 65 cm = 20%

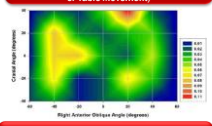


Canon *21CFR1020.32 – Mandatory for Fluoroscopic Equipment after 6/10/2006; **Accuracy Tolerance: ± 35%** DoseRite

What's Missing?

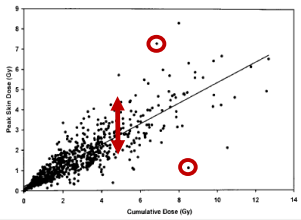
No Source-to-Skin Distance Corrections

No Spatial Information
(All Dose Summed as if it Occurred at a Single Point in Space; No C-Arm Angulation or Table Movement)



Dose to Air, Not Dose to Tissue
(No Patient Support Attenuation/Scatter, Tissue Absorption Factor, Backscatter)

Individual Variability Reduced to a Factor of ~2x



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K.A. Fetterly, "X-ray fluoroscopy imaging in the invasive cardiac laboratory" 2013 AAPM Spring Clinical Meeting
D.L. Miller et al, "Radiation Doses in Interventional Radiology Procedures: The RAD-IR Study Part II: Skin Dose", JVIR 2003

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Dose Metrics | MORE RECENT ADVANCEMENTS

- IEC:2010 recommends a visual warning when RAK exceeds a (configurable) threshold expected to produce a skin injury
- Multiple Implementations of Air Kerma(+) "Maps"

- IEC:2018 recommends a dose map

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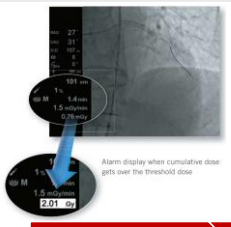
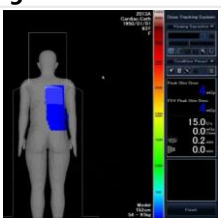
Transition Towards Meaningful Dose Information





Reference Air Kerma
(Dose To Air at Reference Location)

Real-Time Patient Dose Tracking System (DTS)
(Estimated Skin Dose on Patient Graphic)

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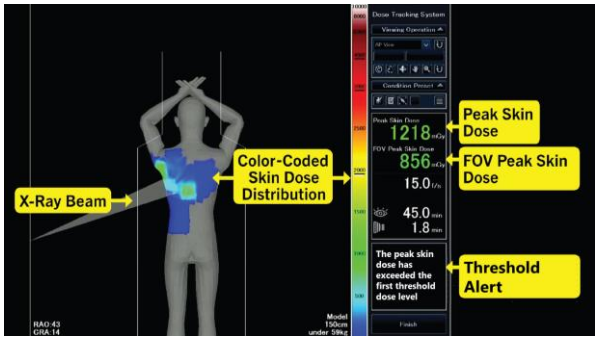

DTS | VALIDATION

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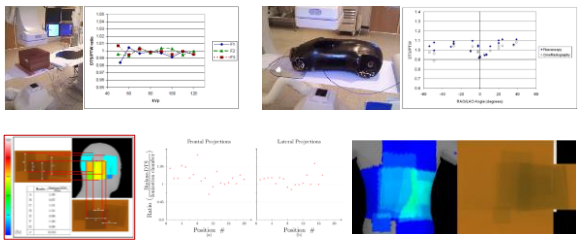
DTS | VALIDATION – EXAMPLE RESULTS*



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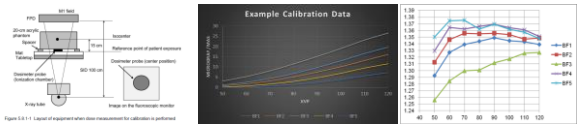
*Yi K. Kona et al, "A tracking system to calculate patient skin dose in real-time during neurointerventional procedures using a biplane x-ray imaging system," Med. Phys. 43(8), 5131-5146 (2016)
*Bednarek et al., "Verification of the performance accuracy of a real-time skin dose tracking system for interventional fluoroscopy procedures" SPIE 7961(7-1 (2011)
*Vano E et al., "Experience with a real-time patient skin dose distribution estimator for interventional radiology," ECR 10.1594/ecr2017/C-0774 (2017)

DTS | ON SITE CALIBRATION



- 5 Beam Filters
- 50 to 120 kV
- Fluoroscopy and Radiographic Modes
- LUTs Used for Rest (FOV, Head v Body, etc.)

*Typical Accuracy ± 20%
With Careful Matching of Patient Graphic with Actual Patient
[Geometry ± 5%]

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DTS | PATIENT MODELS AND POSITIONING

Canon *Skin dose to arms is of secondary value due to smaller body part thickness and variability in position on patient support. DoseRite

DTS | BIPLANE CONFIGURATIONS

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DTS | BODY VERSUS HEAD

Body Ba

Head Backscatter Factor (0.80 – 0.85)

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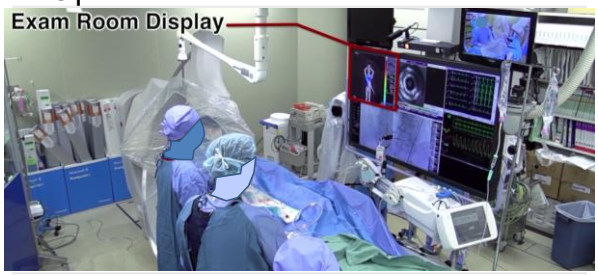
DTS | REAL-TIME



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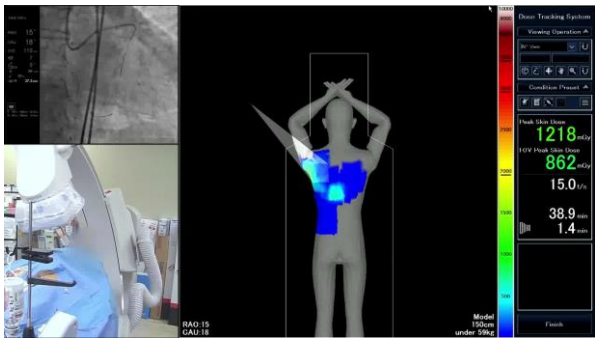
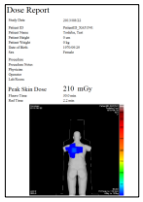
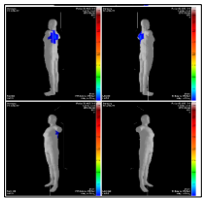


DTS | REPORTING

- Local Storage of 2D and 3D Maps
- Export to: USB; Windows Networked Drive; External Server via FTP





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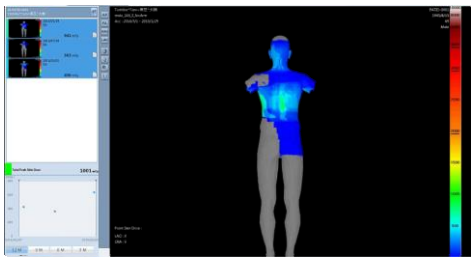
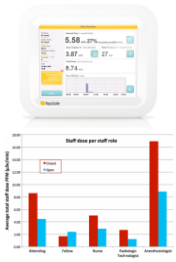
DTS | MULTIPLE PROCEDURES



Canon *Conceptual Illustration. Not available as a product. DoseRite

Real-Time Dose Monitoring | STAFF

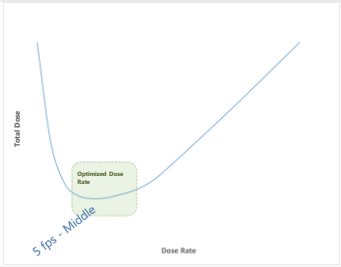


Canon *Baumann F et al., "The Effect of Realtime Monitoring on Dose Exposure to Staff Within and Interventional Radiology Setting." Cardiovasc Intervent Radiol 38(5), 1105-1111 (2015)

21

*Kiliam-Meneghin J et al., "Evaluation of Methods of Displaying the Real-Time Scattered Radiation Distribution during Fluoroscopically-Guided Interventions for Staff Dose Reduction," SPIE 2018

Clinical Dose Optimization



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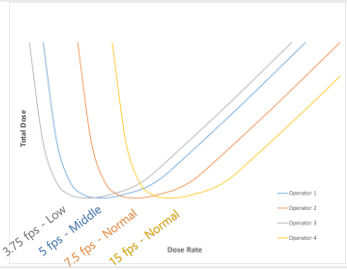
Clinical Dose Optimization



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A CASE REPORT

- 46 Year Old Male
- FGI: Cerebral angio with transvenous coil and glue embolization
- Procedure Time: 150 minutes
- Exposure Time: 67 minutes
- Peak Skin Dose: 2.9 Gy
- Two weeks: nonscarring alopecia
- Four months: complete hair regrowth

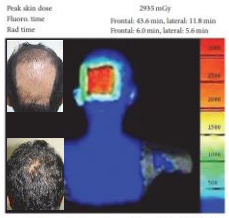

FIGURE 2: The rectangular shape of the radiation field in fluoroscopy-guided endovascular embolization is consistent with alopecic area in our patient.

Canon Ounsakul V et al, "Radiation-Induced Alopecia after Endovascular Embolization under Fluoroscopy," Case Reports in Dermatological Medicine, Article ID 8202469 (2016)

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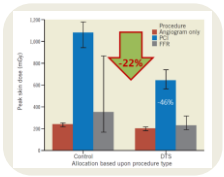
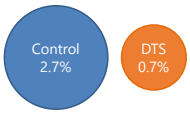
Dose Management | DURING A PROCEDURE

- 6 months pre / post DTS display in exam room
- 16 operators free to choose all imaging parameters
- 1,077 consecutive procedures



Procedures exceeding 3 Gy



*Miller DL et al, "Patient radiation doses in interventional cardiology in the U.S.: Advisory data sets and possible initial values for U.S. reference levels," Med Phys. 39(10), 6276–6286 (2012)

Canon Wilson SM et al, "Real-time colour pictorial radiation monitoring during coronary angiography: effect on patient peak skin dose and total dose during coronary angiography," EuroIntervention, 12, e939–e947 (2016)

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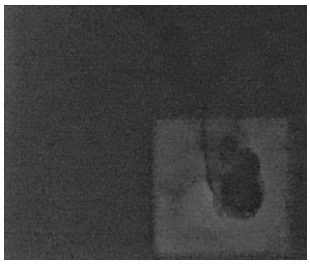
Next Generation Dose Reduction Technologies



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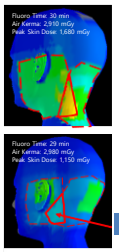
Dose Management | DURING A PROCEDURE



Area of overlap avoided

Frequency with which Interventional Radiology Procedures Resulted in Peak Skin Dose Greater Than 1 Gy, 2 Gy, or 3 Gy

Data Source	Procedure Description	Total Cases	> 1 Gy		> 2 Gy		> 3 Gy	
			n	%	n	%	n	%
RAD-IR	Neuroembolization-head (all)	356	286	80%	136	48%	60	17%
	Neuroembolization-spine (all)	18	17	94%	16	89%	10	56%
	Stroke therapy	5	3	60%	0	0%	0	0%
	Carotid Stent	17	3	18%	1	6%	0	0%
RAD-IR	All Related Procedures	396	309	78%	153	39%	70	18%
GVI	All Related Procedures	348	45	13%	9	2.6%	2	0.6%

Table 4. Comparison of PSD with RAD-IR study.

State of Practice: 1 in 5 Exceed Threshold Dose
Study Population: <1 in 100 Exceed Threshold Dose

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*VL WF. "*Infinix-i Dose Tracking System: Patient Skin Dose Estimates in Real Time.*" (2017)

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Dose Management | POST PROCEDURE

- Compare to state-of-practice data.
- DICOM RDSR is most effective for monitoring and managing clinical radiation dose levels post procedure.
- Monitor to understand actual results with clinical use.

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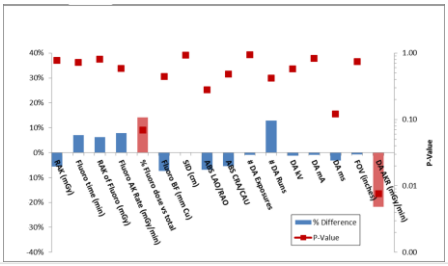
Dose Management | POST PROCEDURE



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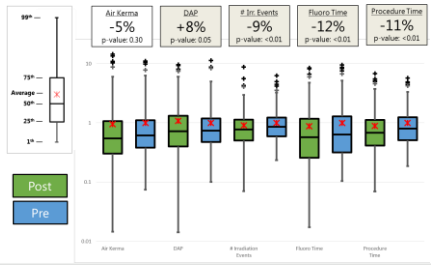
Dose Management | POST PROCEDURE



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Summary | KEY LEARNING POINTS

- Fluoro Time < Air Kerma < Peak Skin Dose
- Skin dose estimates need to include backscatter, patient support attenuation/scatter, field size, beam angulation, etc.
- Real-time skin dose maps empower the operator to better manage patient dose
- DICOM RDSR is an effective tool for monitoring and managing clinical radiation dose levels

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For over 100 years, the Canon Medical Systems 'Made for Life' philosophy prevails as our ongoing commitment to humanity. Generations of inherited passion creates a legacy of medical innovation and service that continues to evolve as we do. By engaging the brilliant minds of many, we continue to set the benchmark because we believe quality of life should be a given, not the exception.

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