Patient Dose with Fluoroscopy – Evolving Tools and Technologies
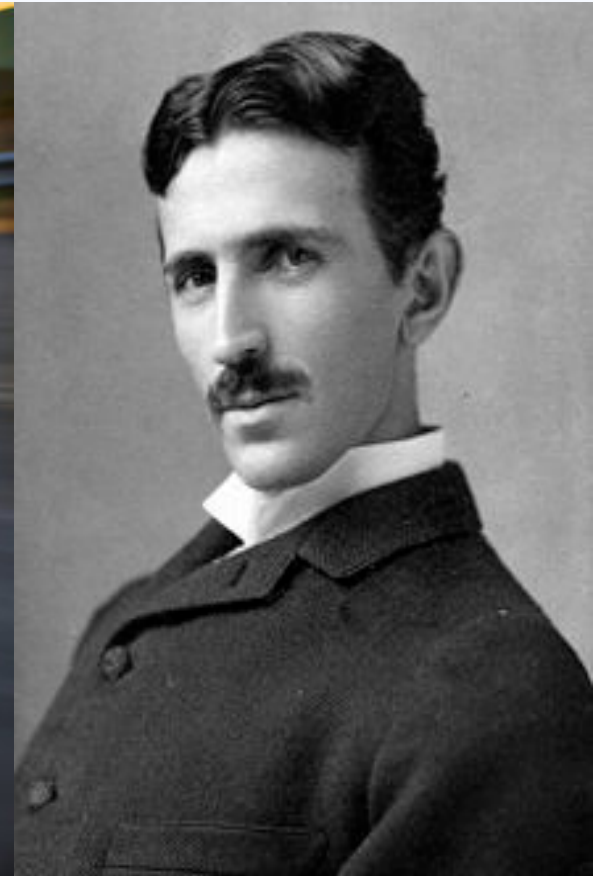
William Pavlicek
July, 2014 Austin Texas

Why Track Patient Dose?

Risk? Its all about **Variability**!

Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer.

Smith-Bindman R, Lipson J, Marcus R, Kim KP, Mahesh M, Gould R, Berrington de González A, Miglioretti DL.
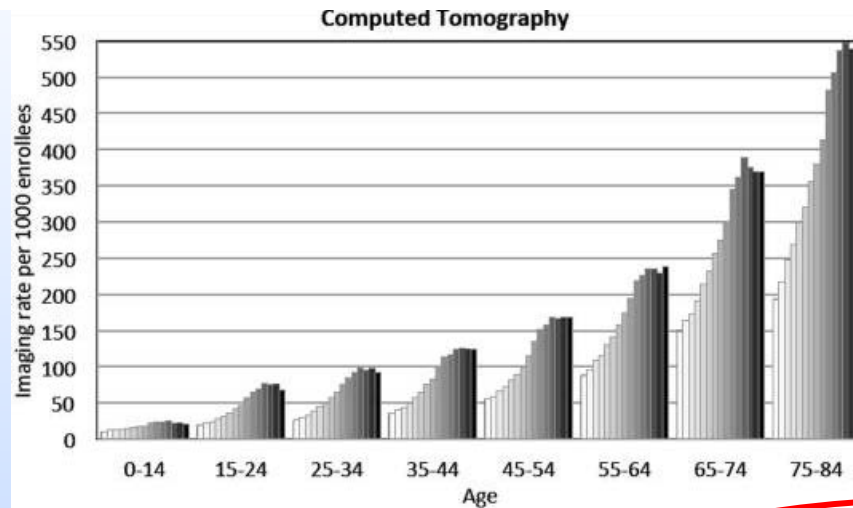
CONCLUSION: Radiation doses from commonly performed diagnostic CT examinations are higher and more variable than generally quoted, highlighting the need for greater standardization across institutions.

Tenets of Quality (Deming)

- Belief that things can be improved

- It is the process that creates variability

- A blameless environment is needed for team solutions

- People closest to the product are most able to affect quality

MAYO
CLINIC

"Inventor" of Six Sigma
W. Edwards Deming

- Physicist PhD (Yale, 28)

- Taught engineering, physics in the 1920s

- Long career in government statistics, USDA, Bureau of the Census

- **Worked with Japan post war.**
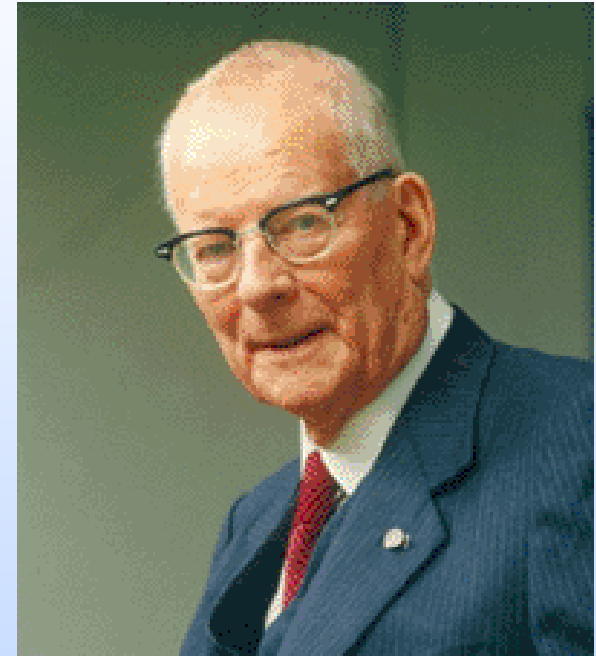
W. Edwards Deming, 1900 – 1993

Individuals closest to 'product' most affect quality

Toyota Assembly Line worker STOPS the Line!

Operating Room – "Procedural Pause"

Min: 78   Avg: 78   Max: 78   HR: 78

Dose Information

Images	CTDIvol mGy (NV)	DLP mGy·cm	Dose Eff. %	Phantom cm
1-481	66.19 (N)	2217.42	94.94	Body 32
482-932	42.03 (N)	1660.14	94.94	Body 32
933-1308	65.80 (N)	2204.19	94.94	Body 32
SmartPrep	67.30 (N)	33.65		

Est. max Z location CTDIvol: 174.02 mGy
Projected series DLP: 6115.41 mGy·cm
Accumulated exam DLP: 0.00 mGy·cm

DOSE ALERT
A dose alert value will be exceeded!

The prescribed scan parameters result in a projected exam dose exceeding the user configured Alert Value. Select Cancel to go back to Viewedit and adjust scan parameters if clinically appropriate to set below the Alert Value. An authorized user name and password must be entered to select Confirm. Selecting Confirm will proceed to scan and log user confirmation of scan parameters exceeding the Alert Value.

	AV	Projected/Accumulated	Start	End
CTDIvol (mGy)	1000	1792.56	12.5	S37.5

Logon Name:

Password:

Diagnostic Reason

[Confirm]   [Cancel]

Prep Group (sec)	ISD (sec)	Breath Hold (sec)	Breathe Time (sec)	Voice Lights Timer	Cine Duration (sec)
SP 7.0	1.3	N	N	2 T	2.0
6.7	1.3	N	N	2 T	2.0
6.7	1.3	N	N	2 T	2.0

Preset List   Preset List

Series D

Add Group

Images

1-481

482-932

933-1308

End Exam

New Patient   Patient Schedule   Protocol Management   Retro Recon   Recon Mgmt   Daily Prep
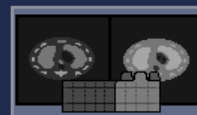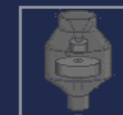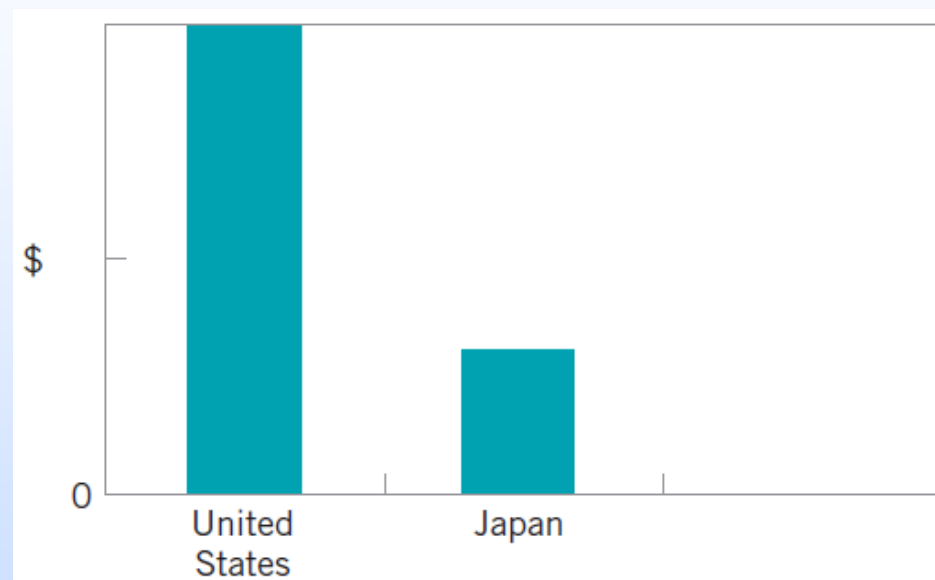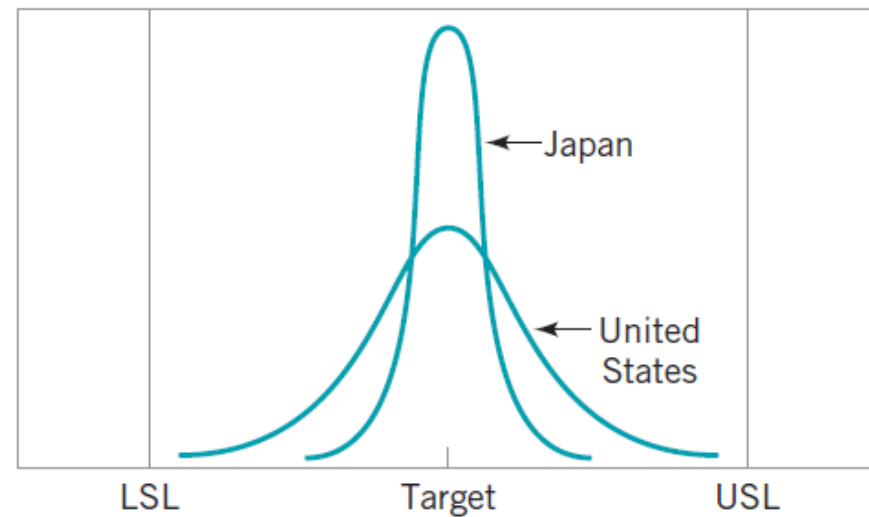
Toyota reduced Variation ..Improved Quality 1960s
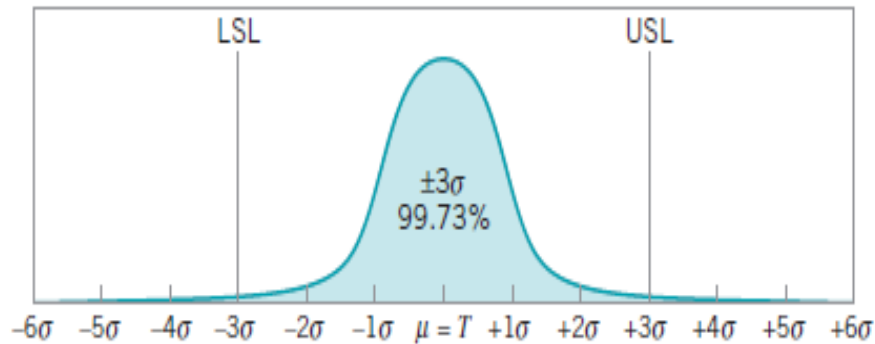

FIGURE 1.1 Warranty costs for transmissions.

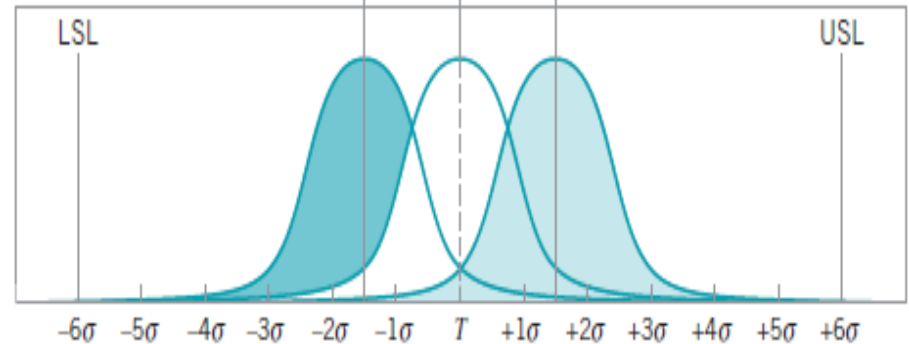**FIGURE 1.2** Distributions of critical dimensions for transmissions.

The Motorola Six-Sigma Concept 1980 - pagers

Spec. Limit	Percent Inside Specs	ppm Defective
±1 Sigma	68.27	317300
±2 Sigma	95.45	45500
±3 Sigma	99.73	2700
±4 Sigma	99.9937	63
±5 Sigma	99.999943	0.57
±6 Sigma	99.9999998	0.002

(a) Normal distribution centered at the target (T)

Spec. Limit	Percent inside specs	ppm Defective
±1 Sigma	30.23	697700
±2 Sigma	69.13	608700
±3 Sigma	93.32	66810
±4 Sigma	99.3790	6210
±5 Sigma	99.97670	233
±6 Sigma	99.999660	3.4

(b) Normal distribution with the mean shifted by ±1.5σ from the target

- Motorola found disturbances cause shifts as much as 1.5 standard deviations off target.

- No process or system is ever truly stable!

* From Montgomery

X-ray
Tubes
1990s

Customer Dashboard: Customer XYZ
Dashboard Dial: Order to Delivery Time

Order by Order Delivery Times

	Starting Point	After Project
	29 Days	11 Days
	18	24
	7	10
	19	6
	6	12
	8	8
	16	15
	19	10
	33	4
	15	20
Performance Mean	**17 Days**	**12 Days**

Mean — Big Change
17 Days ⟶ 12 Days

Variance — Almost No Change

Customers Feel Variance!
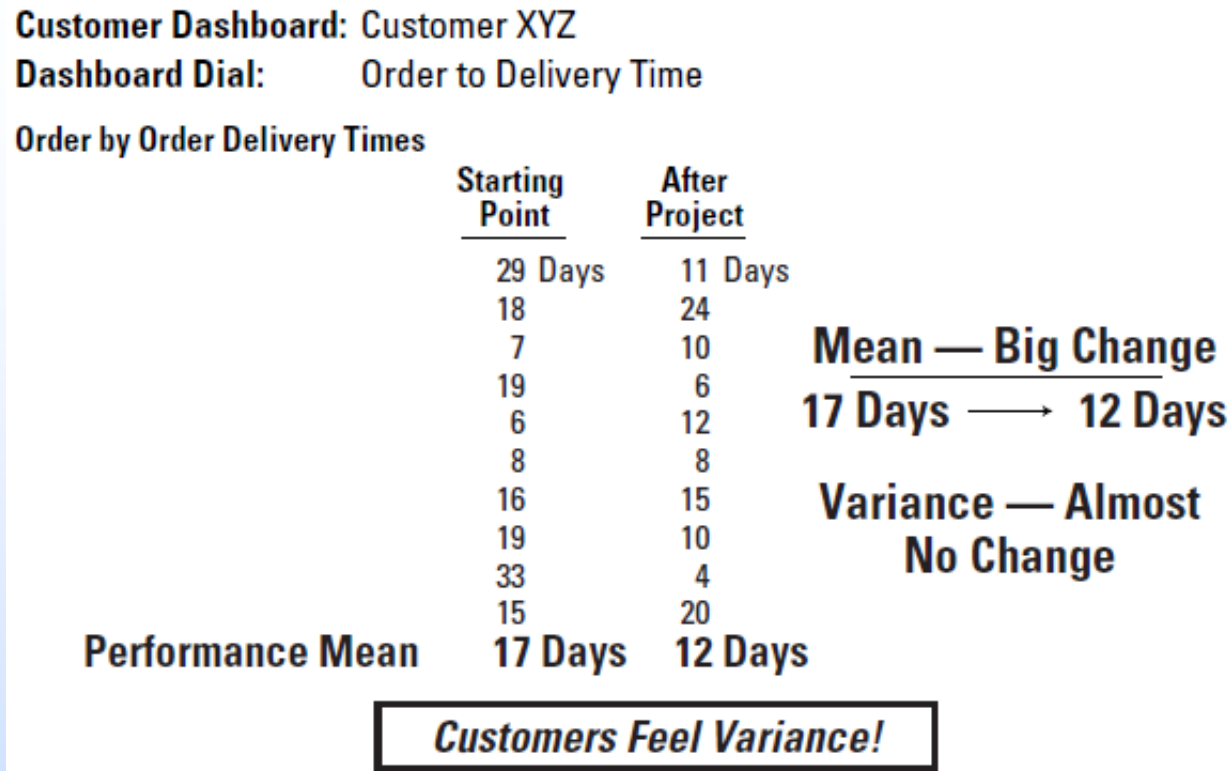
"The mean never happens," — a 4-day delivery time on one order, with an awful 20-day delay on another, and no real consistency! This customers in this chart feel nothing. Their life experience hasn't changed; one bit. The customer only feels the variance that we have not yet removed. ... *Variation is evil in any customer-touching process.* *
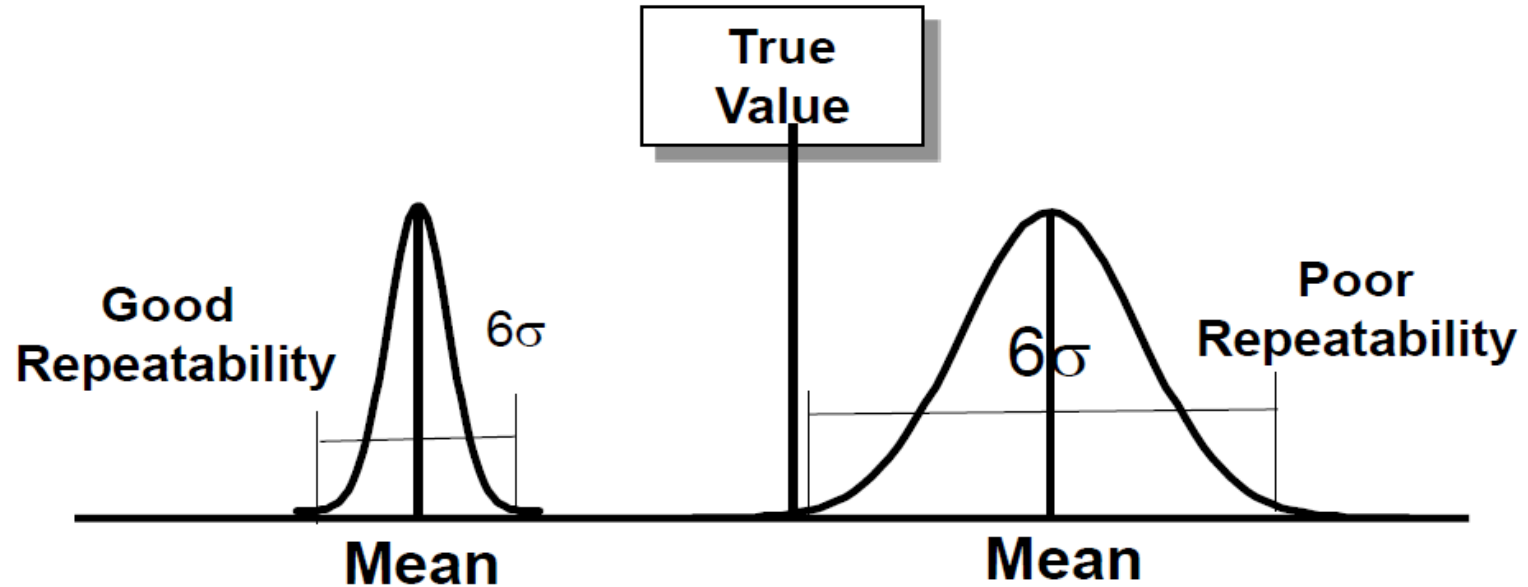
*Jack Welch, General Electric Company 1998 Annual Report

10

What do diagnostic medical physicists (traditionally) measure?

$$\sigma^2_{\text{Measurement}} = \sigma^2_{\text{Repeatability}} + \sigma^2_{\text{Reproducibility}}$$

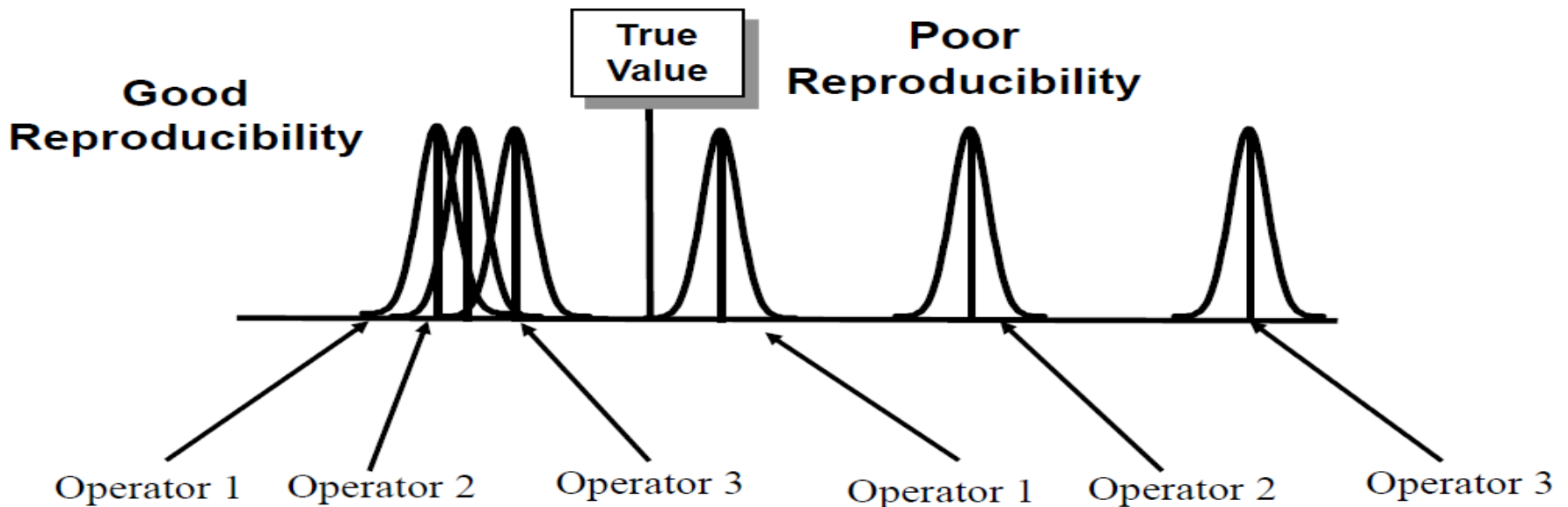# Accuracy of of Air Kerma?
Accuracy of KAP?

These devices had reasonably accurate (and highly repeatable) AK and KAP!

Different
## Procedures/Protocols, Operator Training, Patients!

Variability with Fluoroscopy

- Different pulse and frame rate by physicians

- Different added spectral filters on device protocols

- Different behaviors of Tap and Pause

- Different behaviors of detector/table positioning
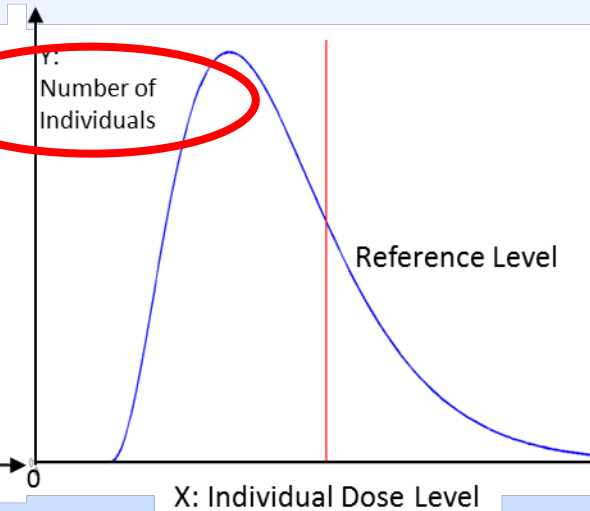
- Different size patients

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Measure, Analyze and Improve!
Reduce Variability….*per Patient!*
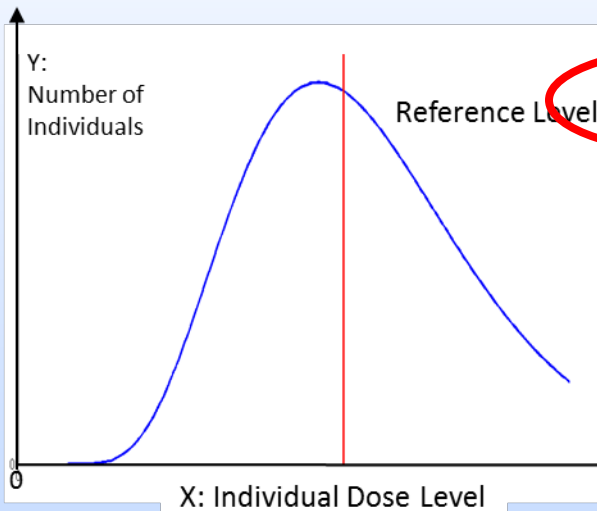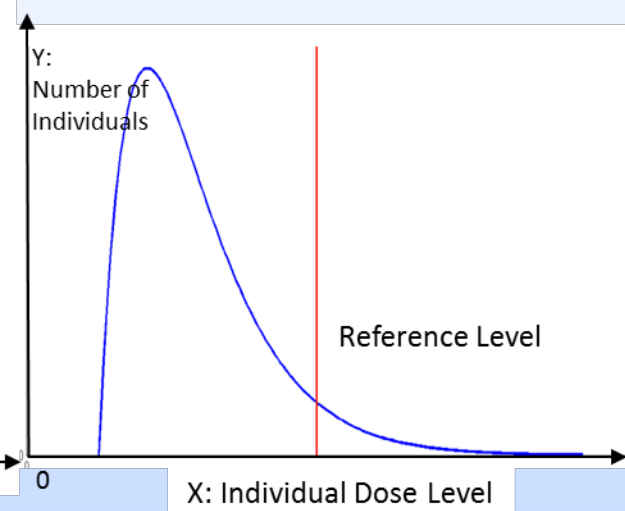
Fluoroscopy Tracking
BEFORE
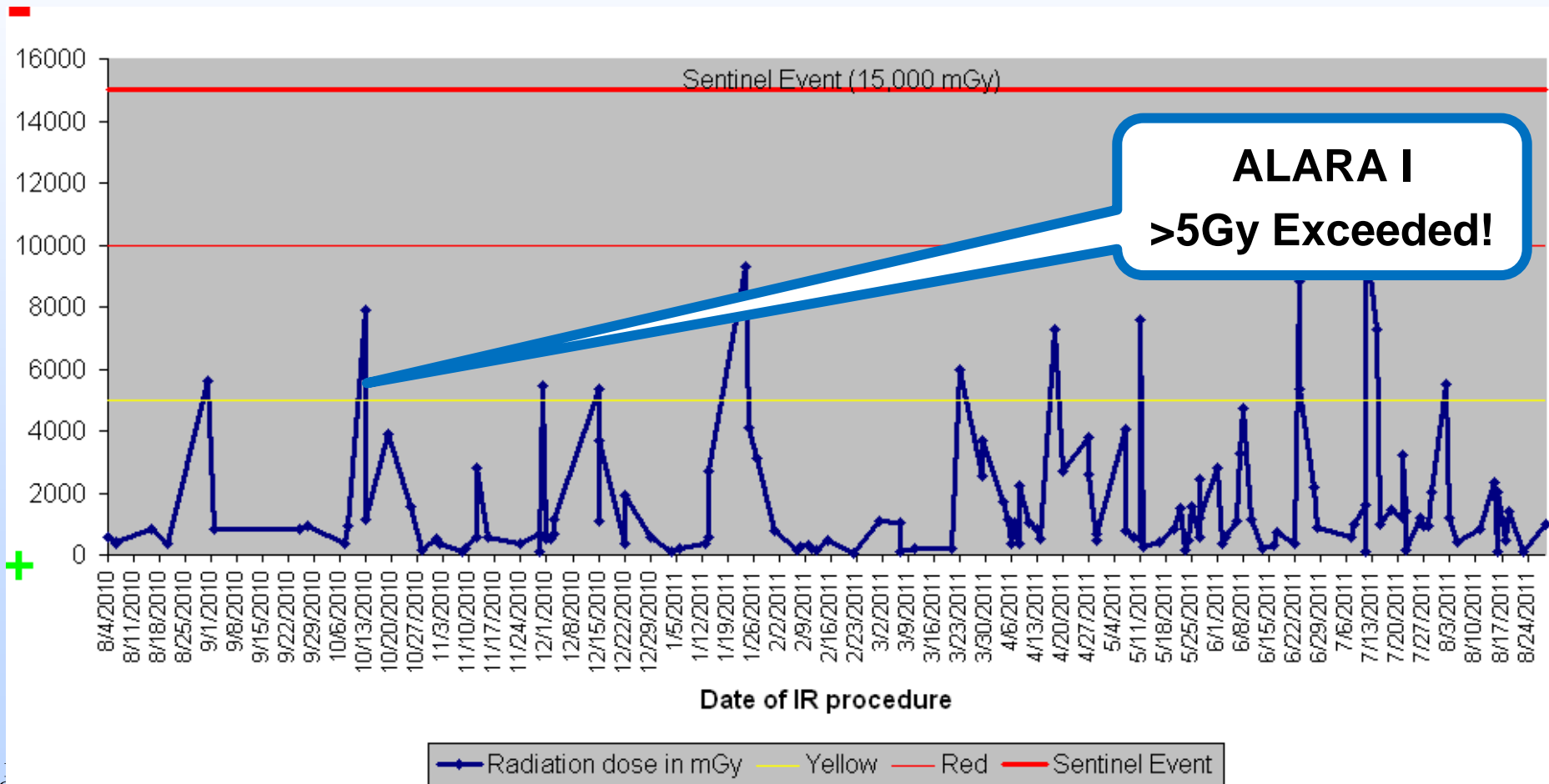
It is About People
There is No Such Thing as Operator Error

> It is **PROCESSES** – not **PEOPLE** that Fail.

> This maps to one of *Deming's 14 Points for Management*: "**DRIVE OUT FEAR**".

> Focus on Processes implies that people are not accused, but rather, that they are able to investigate processes and be "part of the solution."

http://www.framtidenssjukvard.se/groenbok-vaard-av-idéer.aspx
http://www.1000advices.com/guru/quality_tqm_14points_deming.html
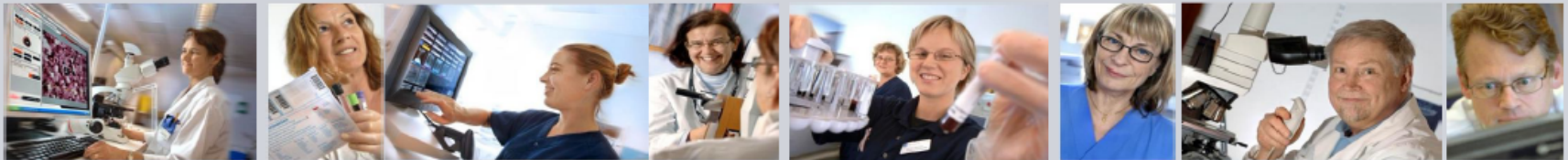
Value with Tracking Dose?

- Patients have a 'right' to feel safe with x-ray exams and procedures.

- It is the process that creates variability – uncertainty of 'being safe'

- People closest to the product/process are most able to affect quality

- *Identify and promote tools that empower operators!*

MAYO
CLINIC

Dose Tracking
56 CT, 35 Fluoro, PET/Nucs, MR, Mammo etc. ~7 years

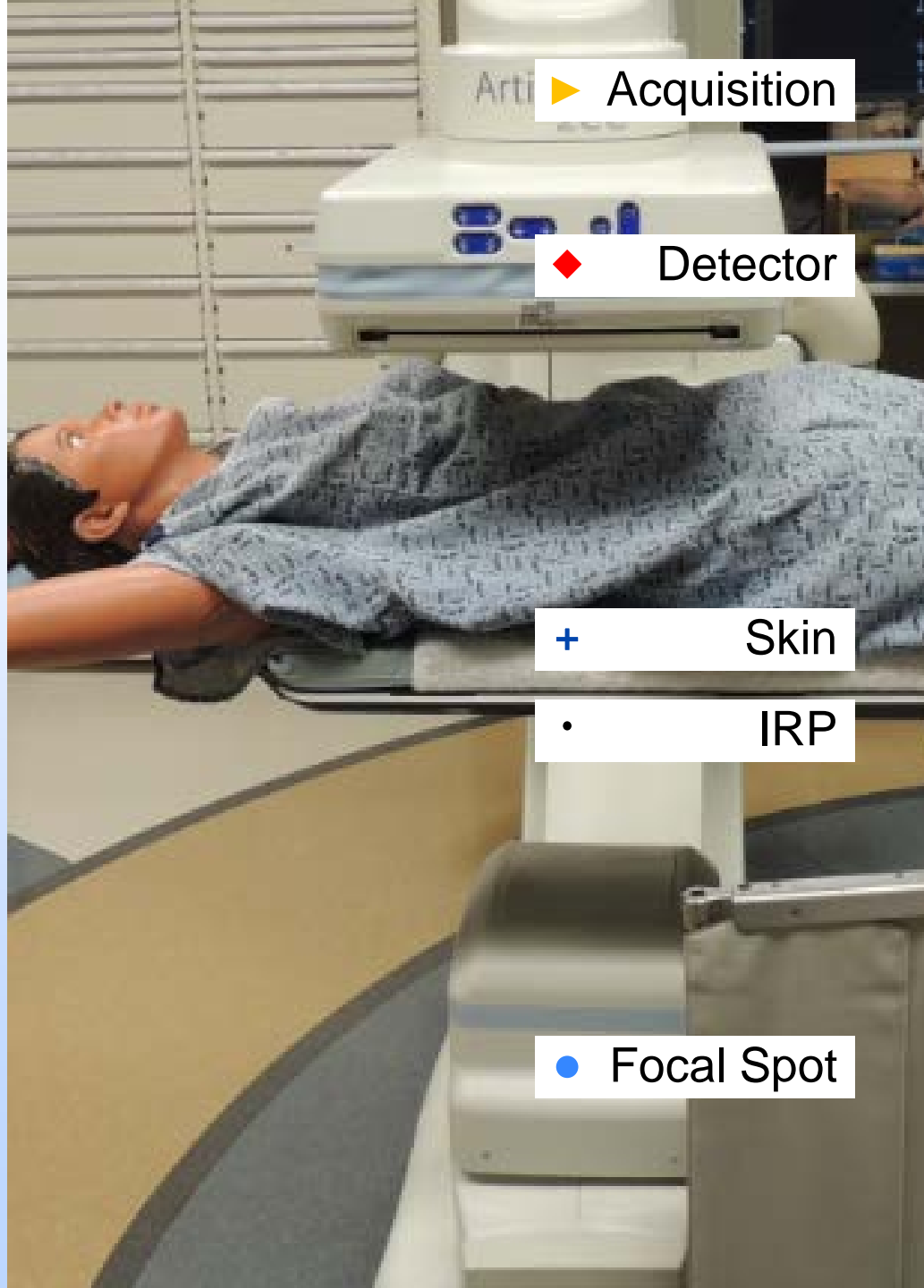**TRACKER:** Dose Tracking System Architecture

Three (new) Tools for Users of Fluoroscopy

- Event Geometry Review

- Table and Detector Positioning

- Tap and Pause Tool

▶ Acquisition

◆ Detector

+ Skin

· IRP

● Focal Spot

Procedure Positioning NEW TOOL!

Do you get asked about positioning?

NEW Event Geometry Tool
(Post-Procedure Review)

Available from RDSR!
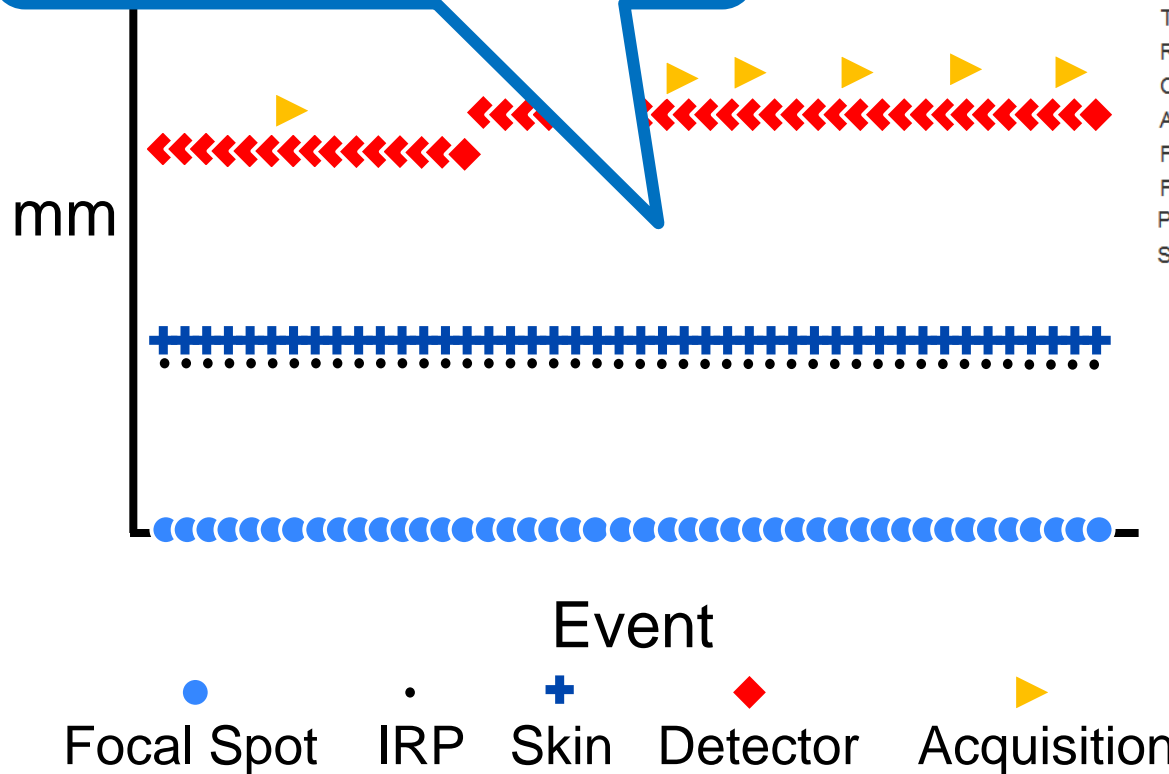
mm

Event

Focal Spot   IRP   Skin   Detector   Acquisition

PATIENT INFO

NAME: ID: SEX: ACCESSION: DATE OF EXAM:

Number of Events: 84   Number of Acquisitions: 7

Table Position: 100%

Req Procedure: IR Angio Visceral wo+w/Flush

Cumulative Skin Dose: 711 mGy

Acq Dose: 324 mGy

Fluoro Dose: 387 mGy

Fluoro Time: 18.8 Min

Peak Skin Dose including Fluoro: 440 mGy

Skin area with more than 95% of the peak skin dose: 28 cm^2

Ant   Pos

Event Geometry Tool

Good Detector Positioning.

Excellent Table Height.
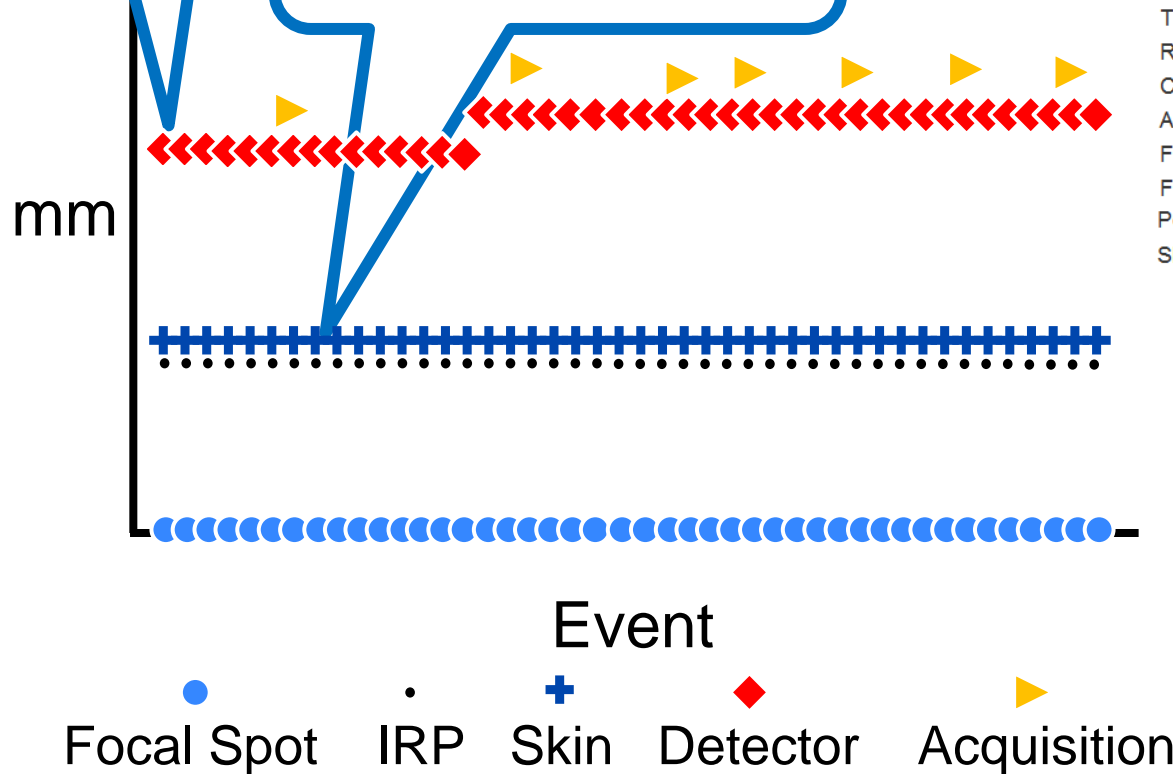
mm

Event

Focal Spot   IRP   Skin   Detector   Acquisition

PATIENT INFO

NAME: ID: SEX: ACCESSION: DATE OF EXAM:

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Cumulative Skin Dose: 711 mGy

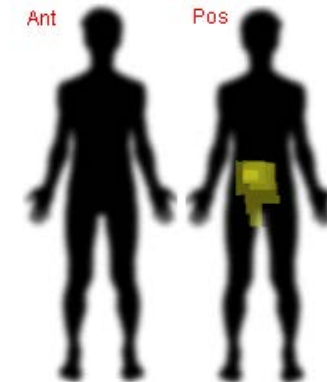Acq Dose: 324 mGy

Fluoro Dose: 387 mGy

Fluoro Time: 18.8 Min

Peak Skin Dose including Fluoro: 440 mGy

Skin area with more than 95% of the peak skin dose: 28 cm^2

Ant   Pos

Possible Poor Positioning

(operators need real time!)

Table Too Low?

mm

Event

Focal Spot   IRP   Skin   Detector   Acquisition

PATIENT INFO
Number of Events: 214
Number of Acquisitions: 17
Table Position: 0%
Req Procedure: V&IRAD
Cumulative Skin Dose: 8025 mGy
Acq Dose: 1664 mGy
Fluoro Dose: 6362 mGy
Fluoro Time: 74.8 Min
Peak Skin Dose: 10730 mGy
Skin area with more than 95%
of the peak skin dose: 22 cm^2

Ant   Pos
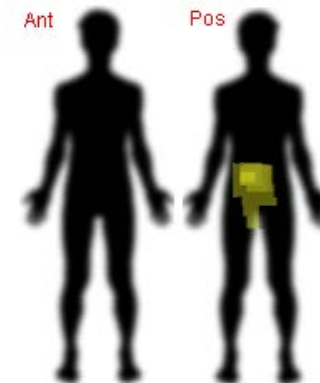
Possible Poor Positioning

(operators need real time!)

PATIENT INFO
Number of Events: 214
Number of Acquisitions: 17
Table Position: 0%
Req Procedure: V&IRAD
Cumulative Skin Dose: 8025 mGy
Acq Dose: 1664 mGy
Fluoro Dose: 6362 mGy
Fluoro Time: 74.8 Min
Peak Skin Dose: 10730 mGy
Skin area with more than 95% of the peak skin dose: 22 cm^2

mm

Detector Too High?

Event

● Focal Spot   · IRP   + Skin   ◆ Detector   ▶ Acquisition

Ant   Pos
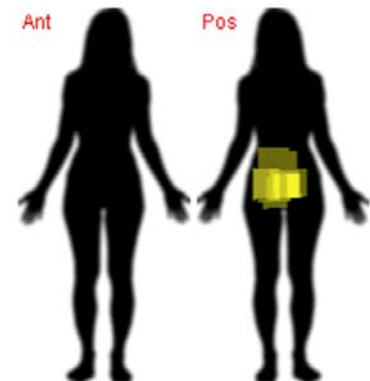
New Tools for Users of Fluoroscopy

- Event Geometry Review

- Table and Detector Positioning

Real time!

77.1kV   DSA
496.6mA   2f/s

A

Aorta
FL LD LOW
705mGy/min
3347Gym^2

Σ 003.3min

22cm FOV

Positioning:
Table
Detector

New Tools for Users of Fluoroscopy

- Event Geometry Review

- Table and Detector Positioning

- Tap and Pause

FLUOROSCOPY

Tracking Found Variability:

1. Pulse and frame rates
2. Use of Cu Filter
3. C-arm Position
4. Tap and Pause Behavior

Review of High Exposures

Highest Skin Exposures

From: 6/2012 to 6/2013

Average Dose: 0.5Gy for 1,768 patients

Exam Description	Skin Dose (Gy)	DS* #	FLU Time (min)	X-Ray Event w/ Longest Time (s)		Min FOV (cm)		Filter Min	Max FLU pps	Max ACQ fps
				FLU	ACQ	FLU	ACQ			
Vascular	7.45	0	66.9	312.5	11.25	16.0	16.0	0.0	15.00	4
Angiogram	6.26	0	58.3	150.8	8.67	16.0	16.0	0.1	7.50	30
Aorta	5.68	0	52.7	140.8	8.67	20.0	20.0	0.0	7.50	15
AAA	5.22	0	25.2	238.3	10.07	20.0	20.0	0.1	7.50	15
Aorta	4.75	0	43.2	92.4	13.93	20.0	20.0	0.1	7.50	15
Angiogram	4.70	0	32.9	177.8	3	16.0	16	0.0	15.00	0
Vascular	4.22	1	80.1	240.1	9.2	20.0	20.0	0.1	10.0	15

**ALARA I
>5Gy Exceeded!**

Review High Exposures

Highest Skin Exposures

From: 6/2012 to 6/2013

Average Dose : 0.5Gy for 1,768 patients

Exam Description	Skin Dose (Gy)	DS* #	FLU Time (min)	X-Ray Event w/ Longest Time (s)		Min FOV (cm)		Fil Min	Max FLU pps	Max ACQ fps
				FLU	ACQ	FLU	ACQ			
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Angiogram	6.26	0	58.3	150.8	8.67	16.0	16.0	0.1	7.50	30
Aorta	5.68	0	52.7	140.8	8.67	20.0	20.0	0.0	7.50	15
AAA	5.22	0	135.2	238.3	10.07	20.0	20.0	0.1	7.50	15
Aorta	4.75	0	43.2	102.4	13.93	20.0	20.0	0.1	7.50	15
Angiogram	4.70	0	32.9	177.8	3	16.0	16	0.0	15.00	0
Vascular	4.22	1	80.1	240.1	9.20	20.0	20.0	0.1	10.0	15

Review High Exposures

Highest Skin Exposures										
From:	6/2012 to 6/2013									
Average Dose :	0.5Gy for 1,768 patients									
Exam Description	**Skin Dose (Gy)**	**DS* #**	**FLU Time (min)**	**X-Ray Event w/ Longest Time (s)**		**Min FOV (cm)**		**Filter Min**	**Max FLU pps**	**Max ACQ fps**
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Angiogram	6.26	0	58.3	150.8	8.67	16.0	16.0	0.1	7.50	30
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AAA	5.22	0	135.2	238.3	10.07	20.0	20.0	0.1	7.50	15
Aorta	4.75	0	43.2	102.4	13.93	20.0	20.0	0.1	7.50	15
Angiogram	4.70	0	32.9	177.8	3	16.0	16	0.0	15.00	0
Vascular	4.22	1	80.1	240.1	9.20	20.0	20.0		10.0	15

**Add 0.1mm Cu
All procedures.**

~**40% Lower Skin Dose** with 0.1mm Cu!

Review High Exposures

Highest Skin Exposures										
From:	**6/1/12 to 6/1/13**									
Average Dose :	**0.5Gy for 1,768 patients**									

Exam Description	Skin Dose (Gy)	DS* #	FLU Time (min)	X-Ray Event w/ Longest Time (s) FLU	ACQ	Min FOV (cm) FLU	ACQ	Filter Min mm	Max FLU pps	Max ACQ fps
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Angiogram	6.26	0	58.3	150.8	8.67	16.0	16.0	0.1	7.50	30
Aorta	5.68	0	52.7	140.8	8.67	20.0	20.0	0.0	7.50	15
AAA	5.22	0	135.2	238.3	.07	20.0	20.0	0.1	7.50	15
Aorta	4.75	0	43.2	102.4		20.0	20.0	0.1	7.50	15
Angiogram	4.70	0	32.9	177.8		16.0	16	0.0	15.00	0
Vascular	4.22	1	80.1	240.1					10.0	15

Too LONG!
Use 'Tap and Pause'!

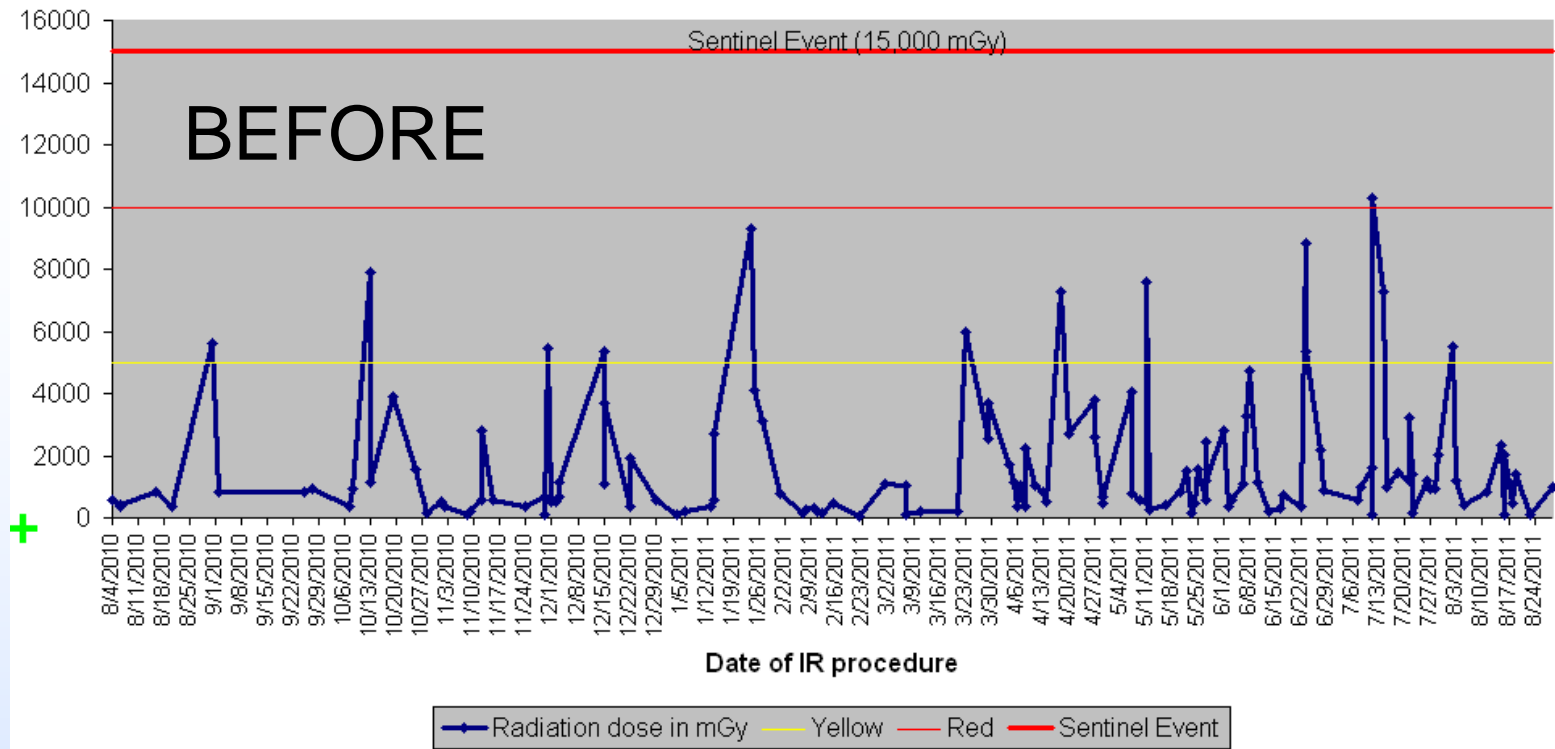MAYO CLINIC

Review High Exposures
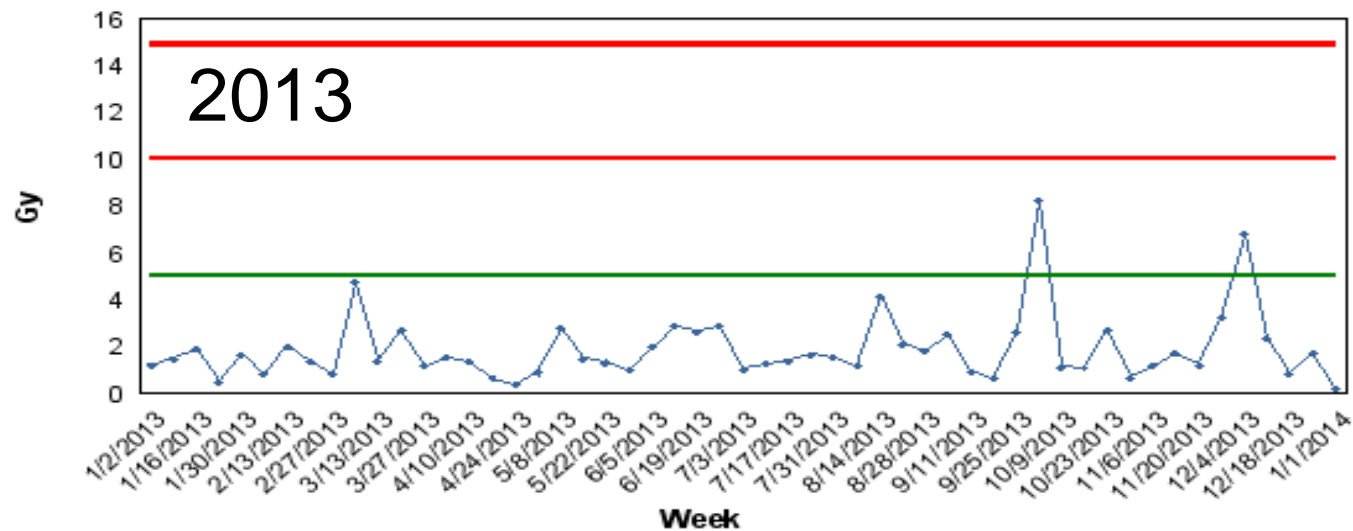
Highest Skin Exposures

From: 6/1/12 to 6/1/13

Average Dose : 0.5Gy for 1,768 patients

Exam Description	Skin Dose (Gy)	DS* #	FLU Time (min)	X-Ray Event w/ Longest Time (s) FLU	ACQ	Min FOV (cm) FLU	ACQ	Filter Min mm	Max FLU pps	Max ACQ fps
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Aorta	4.75						20.0	0.1	7.50	15
Angiogram	4.70						16	0.0	15.00	0
Vascular	4.22						20.0	0.1	10.0	15

WHAT IF?
+'Tap and Pause'
+ 0.1mm Cu
+7.5 pps

Sentinel Event (15,000 mGy)

BEFORE

Date of IR procedure

Radiation dose in mGy — Yellow — Red — Sentinel Event

Maximum Weekly Skin Exposure

2013

Gy

Week

New Tools Can Assist
(just Blind Spot warning)

Tools Do Assist!