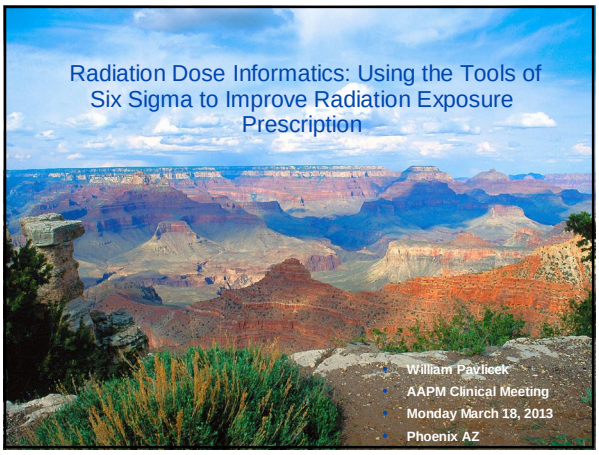
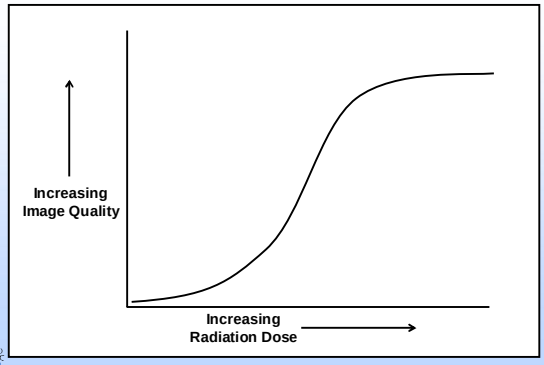


Lots of Commercial Dose Management Software!

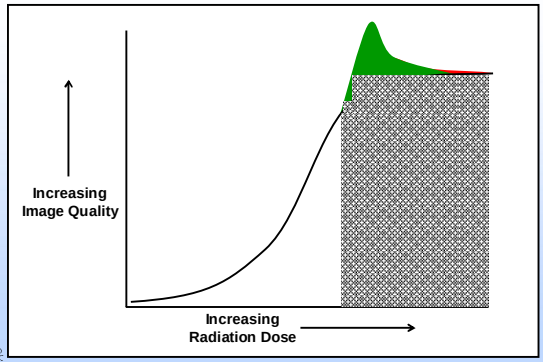
RADTRAC Responsible Imaging

MEDICAL X-RAY DOSE MONITOR

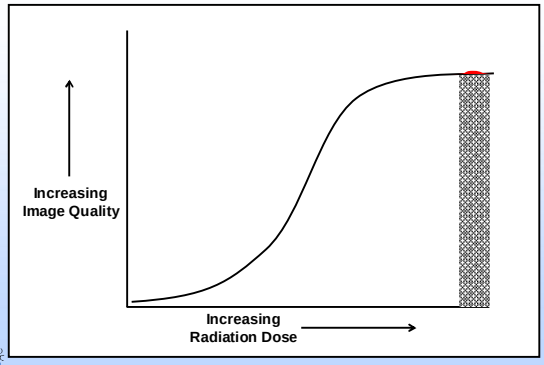
Image Quality and Dose



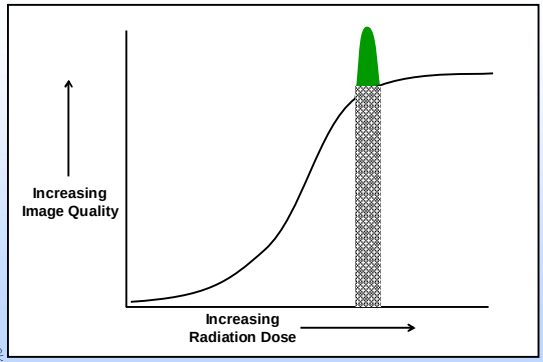
Problem: Good IQ with high (or even too high) dose



Too high dose prescription must be avoided

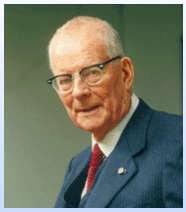


Narrow the range of x-ray prescriptions!



"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

Toyota reduced Variation ..Improved Quality 1960s

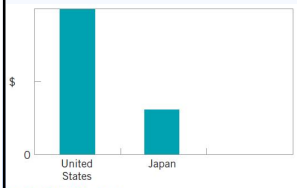


FIGURE 1.1 Warranty costs for transmissions.

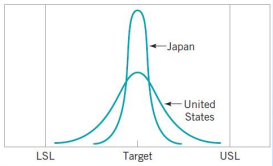
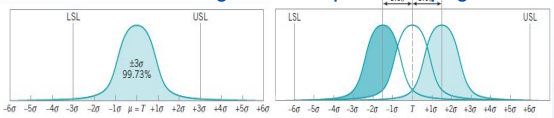


FIGURE 1.2 Distributions of critical dimensions for transmissions.

*** From Montgomery, D. C. (2009), *Introduction to Statistical Quality Control* 6th edition, Wiley, New York**

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

- Motoroloa found process subject to disturbances that could cause it to shift by as much as 1.5 standard deviations off target.
- No process or system is ever truly stable!
- Thus 3.4 parts per million for this system

*** 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!

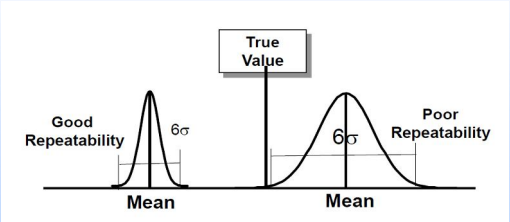
"The mean never happens," — a 4-day delivery time on one order, with an awful 20-day delay on another, and no real consistency! This customers in this chart feel nothing. Their life experience hasn't changed; one bit. The customer only feels the variance that we have not yet removed. ... ***Variation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

***Jack Welch, General Electric Company 1998 Annual Report**

What diagnostic medical physicists measure?

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

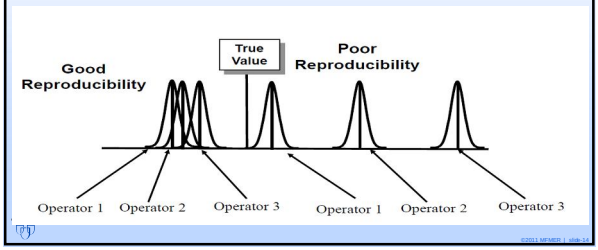
Repeatability of device?
eg. New ACR Daily CT Phantom



These devices were repeatable with accurate output,…..!!!

Reproducibility!!!

Different
Procedures/Protocols, Operator Training, Patients!



Six Sigma
Process Improvement with an Emphasis on Achieving Significant Impact!

- All work is performed in (interconnected) processes
  - Easy to see in some situations (manufacturing)
  - Harder in others
- Any process can be improved
- An organized approach to improvement is necessary

15

Reduce System Variability

DMAIC (duy–may–ick)

DMAIC - Process Improvement Roadmap

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

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Basic Tenets of Quality

- It is the process that creates variability
- Belief that things can be improved
- A blameless environment is needed for team solutions
- People closest to the product are most able to affect quality
- Everyone has responsibility for quality

The Primary Six Sigma Tools

- Process map
- Cause and effect analysis
- Measurement systems analysis*
- Capability study*
- Failure mode and effects analysis
- Observational study (regression)*
- Designed experiments*
- Control charts and out-of-control-action-plans*

* Statistical Tools

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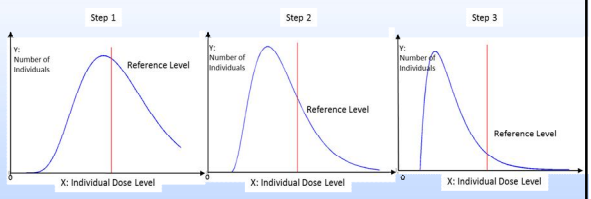
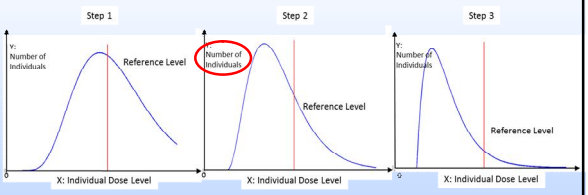
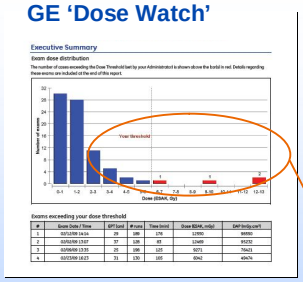
Measure, Analyze and Improve!
Reduce Exam Prescription Variability….



Measure, Analyze and Improve!
Reduce Exam Prescription Variability….



GE 'Dose Watch'



Executive Summary

Exams are grouped by the dose range in 1 Gy increments,

The number of cases exceeding the Dose Threshold (set by the customer) are shown to the right.

Six Sigma/Informatics and Fluoroscopy

Three 'steps' to improve fluoroscopy x-ray prescriptions

1. Adding Copper filtration
2. Lower pulse and frame rates
3. Table-Detector positioning

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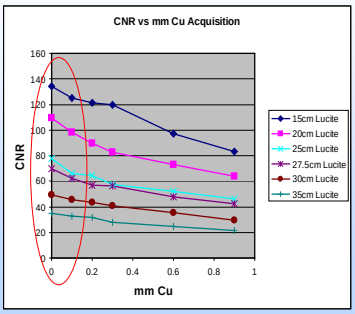
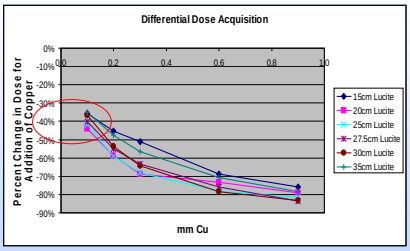
ANALYZE: Lucite 15 cm to 35 cm
20% Iodine solution for CNR measures

Slightly (~8-10%) reduced CNR
0.1 mm copper

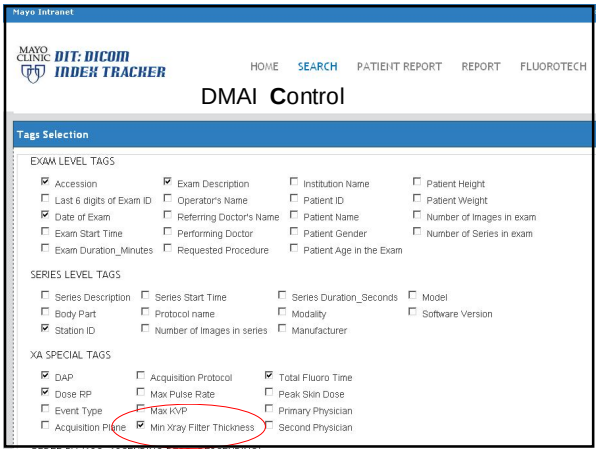


BUT ~**40% Lower Skin Dose** 0.1mm Cu!



Step 1: EASY IMPROVEMENT!

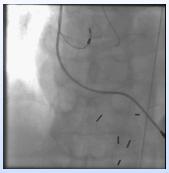
- 0.1mm Copper minimum ADDED TO:
- 100% Stationary Fluoroscopy devices
- 100% protocols
- **100% Patients have 40% reduced exposure!**



Step 2:Operator Frame Rate Behaviors

- Lowering pulse and frame rates
- **Important!**: Can you see what is needed?
- Tool 1: Collect pilot examples
- Tool 2: Share results (data - Shine a light)
- Tool 3: Educate

Low FPS Dose

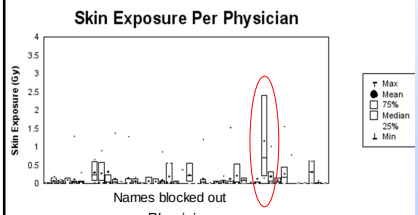


(70-75 bm, II)

Low FPS Dose

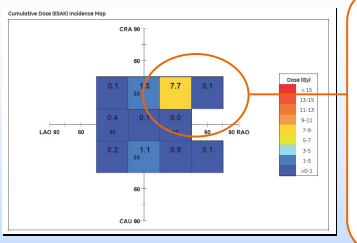
(70-75 bm, flat panel)

Tool 2
Data can Shine a light!



Ufors RaySafe

GE 'Dose Watch'



Cumulative Dose (ESAK) Incidence Map

Shows Cumulative dose (ESAK) with respect to gantry angulations. The horizontal axis indicates gantry positions with respect to LAO/RAO patient positioning, and the vertical axis indicates cranial/caudal gantry positions. The dose (ESAK) is displayed on the incidence map indicating how much of the exam dose was distributed to the patient with respect to the position of the gantry in 30 degree increments.

For purposes of reporting high skin dose events, add up the max total dose in any four contiguous blocks (four blocks with a corner in common). This represents the worst possible overlap of the collimated fields, producing a "hot spot" that is potentially higher dose than any one of the fields

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5/3/2011

DIT: DICOM INDEX TRACKER

HOME SEARCH PATIENT REPORT REPO

REPORTS (Instructions)

10--Highest Average Skin Exposure

Highest Average Skin Exposure

This report summarizes the highest average skin expos procedure equipment.

Please define your scope conditions below then click bu

Start Date:
10/1/2012
The first date to start with.

End Date:
1/12/2013
The last date to include.

Mayo Campus:
PX
Campus abbreviation (PX is Phoenix)

Department:
All
CA or GI or RA or RO or SU or UR

GenerateReport

Highest Average Skin Exposure

MAYO CLINIC

From : 10/1/2012 To 1/12/2013

Campus: Phoenix Dept: All Department

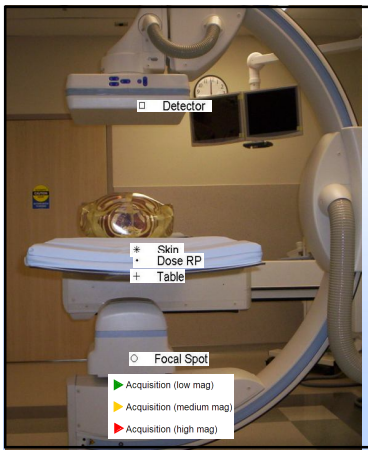
Exams: 541 Procedures: 28

There are 234 exams with skin exposure less than 0.01 Gy.

Procedure Name	Procedure Average (Gy)	Procedures	Max (Gy)	Accession
Vas Aorta	0.9	18	3.8	
Vas Renal	0.7	4	1.1	
Mesenteric	0.6	20	1.1	
Vas Pelvis	0.5	7	0.8	
Vas Mesenteric	0.5	24	3.7	
Vas Pulmonary	0.4	5	0.7	
IR Angio Renal wo+w/Flush	0.4	1	0.4	
IR Angiogram Extremity, Ri	0.3	1	0.3	
CARD	0.3	2	1.0	
IR Angiogram Extremity Bil	0.2	1	0.2	
Vas IVC	0.2	7	0.4	
IVC	0.2	2	0.3	
ERCP	0.2	51	0.9	

NEED TOOL!

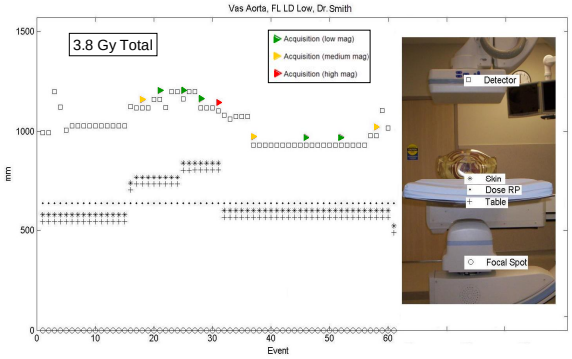
- Was the 3.8 Gy skin exposure optimized?
- **A**nalyze what happened!
- Educate to **I**mprove behaviors



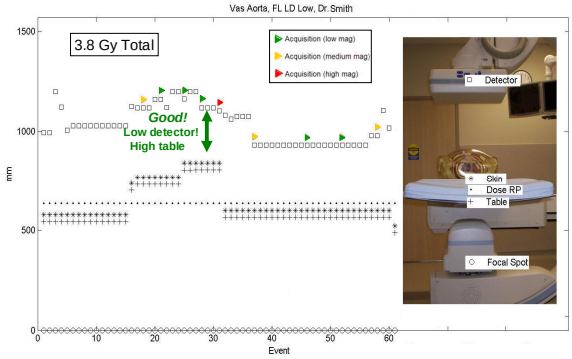
Post Procedure (Informatics)

- Good Geometry?
- When was DSA or Cine used?

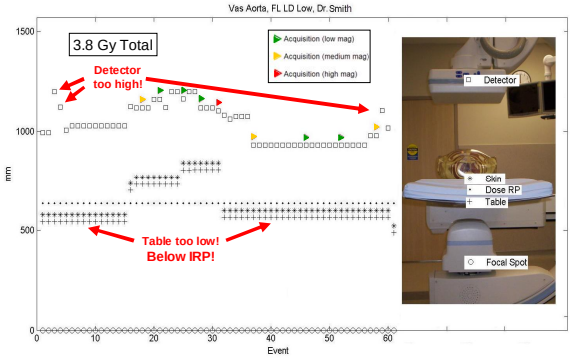
DMAIC-**Improve**: Informatics Tool ALARA Review



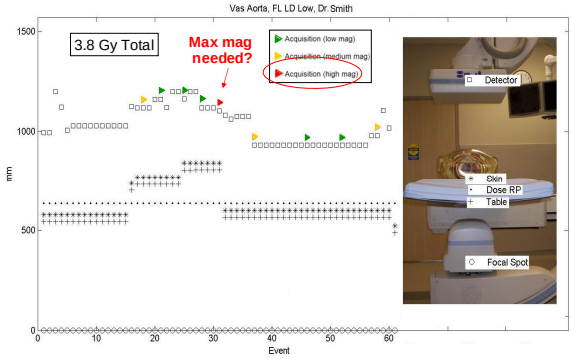
Informatics Tool 3 ALARA Review



DMAIC-**Improve**: Informatics Tool ALARA Review



DMAIC-**Improve**: Informatics Tool ALARA Review



MAYO CLINIC

NOW!

Skin Exposure Report

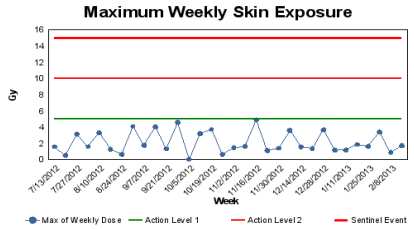
From : 6/1/2012 To 2/16/2013

Campus: All Dept: All Department

Exams : 1,284

Average Dose is 0.2 Gy for 1,284 Patients.

Average Dose over 1.5 Gy is 2.5 Gyfor 32 Patients.



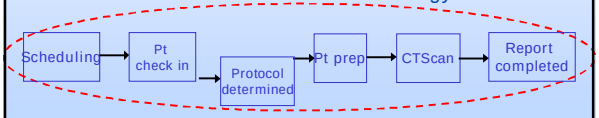
Value displayed is the maximum reported Gy for a given week.

Six Sigma/Informatics and Computed Tomography

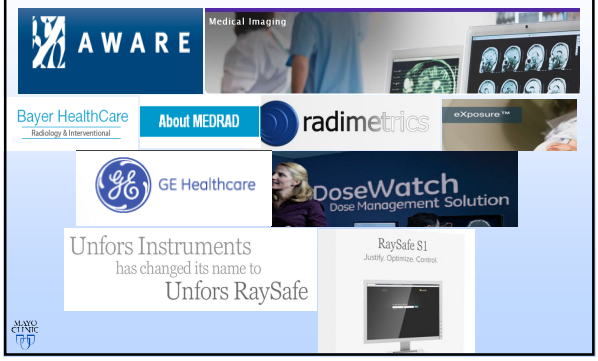
CT Value Stream (Process Map)

- Value is created via efforts of people as product created (knowledge).
- Relentless pursuit of waste elimination as competitive leverages

Value Stream for CT Radiology

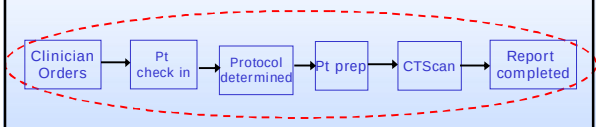


Dose Informatics and Analytics



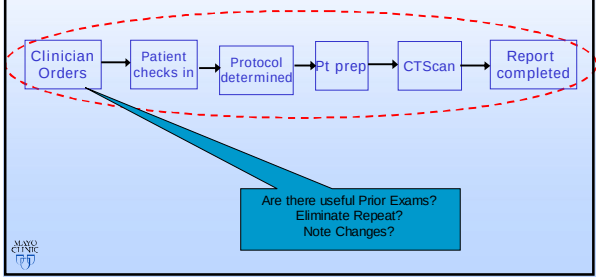
Clinician **needs** a CT

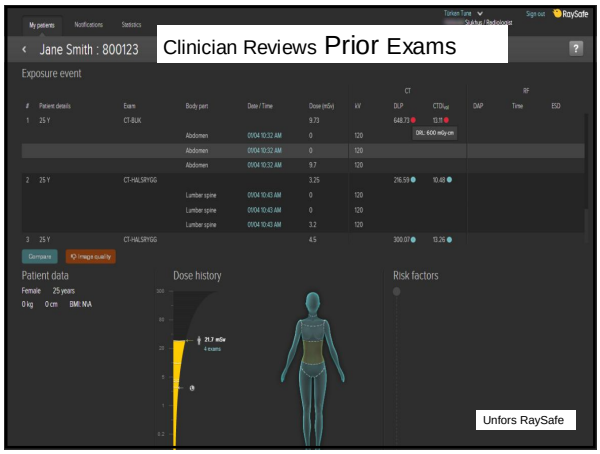
- Value to Patient/Physician customer is knowledge for **optimal next action**

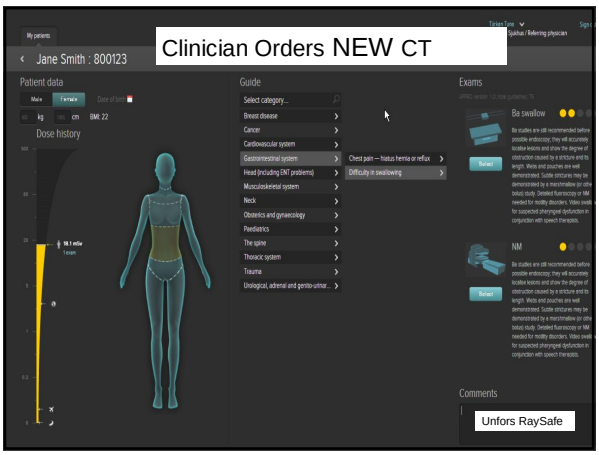


Clinician Orders a CT

- Value to Patient/Physician customer is knowledge for **optimal next action** - 'medical, surgical or interventional'

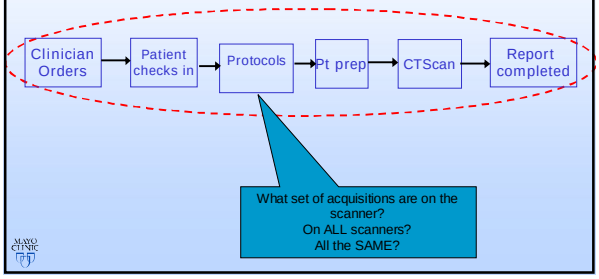


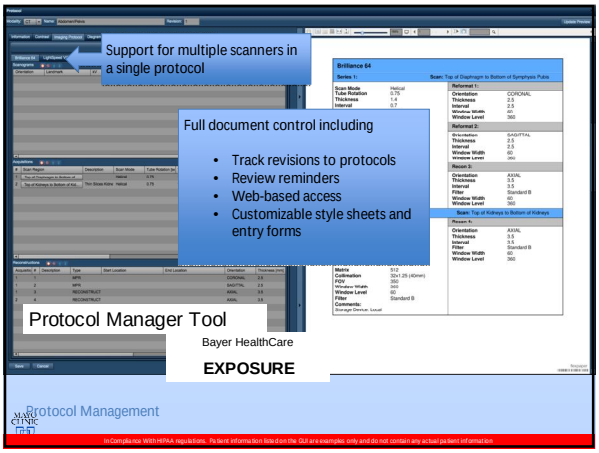


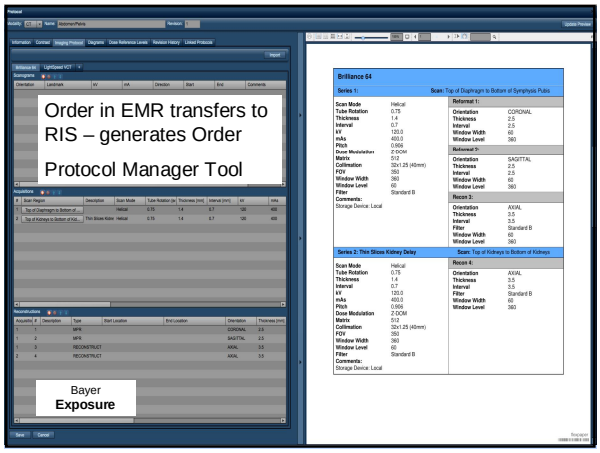


MEANWHILE…. Technologist manages the Protocol Book- the CT Exam 'Scripts'

- Is this efficient?

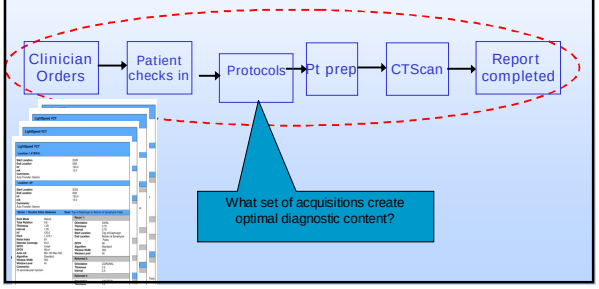






Radiologists selects a CT 'Script'

- Prescribing an **optimal CT exam**



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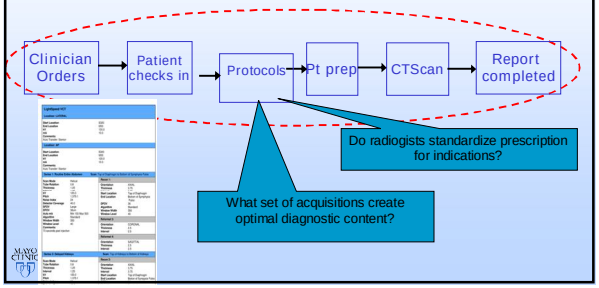
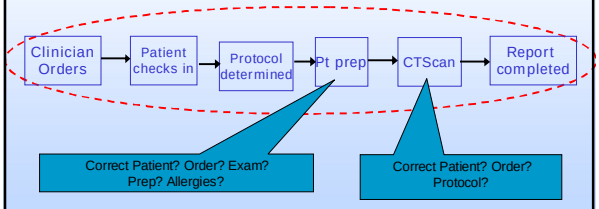
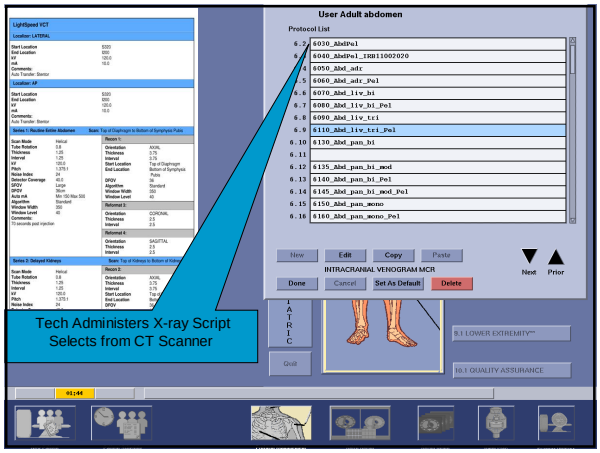


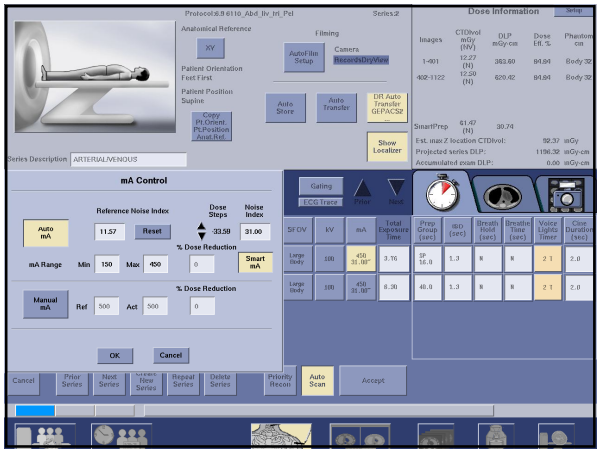
CT tech and Nurse: Closest to Prescription can highly affect quality!

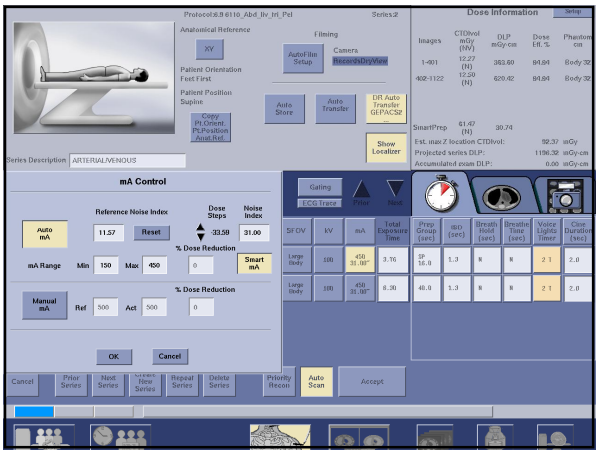




Protocol ✗ Scanner

- Scanners are NOT a node on the network!
- Scanner settings differ from Protocol Book!
- Differ *between* scanners
- Established console settings – **good!**
- On the fly changes – *variability* in exams
- Console settings complicated – need virtual scanner

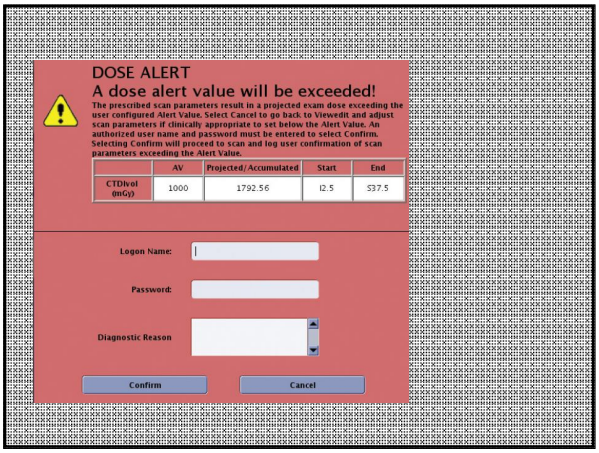




Individuals closest to 'product' **most** able to affect quality

- Toyota Assembly Line worker STOPS the Line!
- Procedural Pause – Operating Room

Dose Check!



GE: Establish **Dose Check** Values by Protocol

Detail Tables

Threshold Values by Study Description

Study Description	Threshold (mGy.cm)	Number of Studies
	1,396.08	75
CT ABD & LIVER DONOR W	2,020.03	34
CT ABDO & CHOLANGIO W	1,507.27	25
CT ABDOMEN PEL W/CONTR	1,002.94	1848
CT ABDOMEN PEL W/O CON	964.94	619
CT ABDOMEN PEL W/W/O C	1,637.52	543
CT ABDOMEN W	894.56	388
CT ABDOMEN WO	809.80	136
CT ABDOMEN WOW	1,427.72	301
CT BRAIN LAB NAV ENHAN	1,978.62	23
CT BRAIN LAB NAV UNENH	1,652.75	20
CT BRAIN W	1,836.14	70
CT BRAIN WO	1,428.37	2069
CT BRAIN WOW	2,339.58	100
CT C OR T SPINE N BLK	117.30	49
CT C SPINE WO	610.28	225
CT Chest Atrial Fibril	873.40	33
CT Chest Pulmonary Emb	851.55	452
CT CHEST THIN SECTION	260.84	208
CT CHEST W	648.96	615
CT CHEST WO	356.03	1296
CT CHEST WOW	654.42	75

Centering the Patient in the Gantry
Process Variability

1. Magnification Errors
2. FOV Cut-off AP
3. FOV Cut-off Z_{axis}

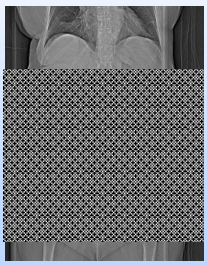
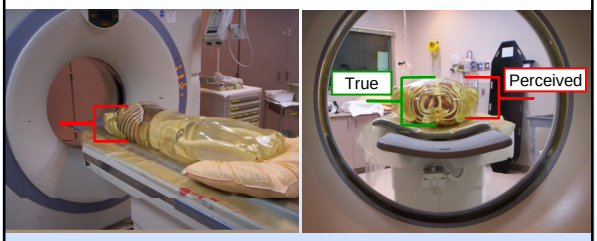
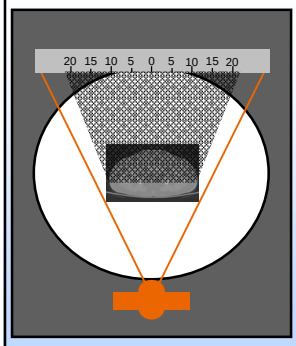


Table Height in gantry

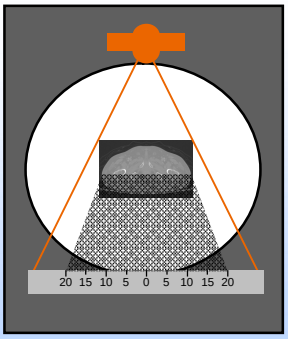


- Lateral Laser Lights – Table Height
- Table Height – affects mA modulation
- Table more LIKELY to be too LOW

Configure x-ray tube at top!



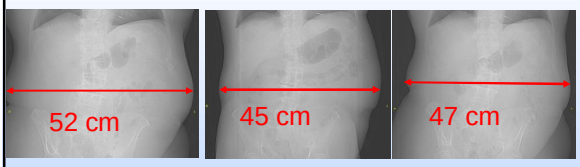
PA Scout



AP Scout

1. Mag Error - mA modulation

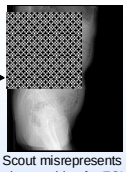
PA Scout Table Low	AP Scout Table Center	AP Scout Table High



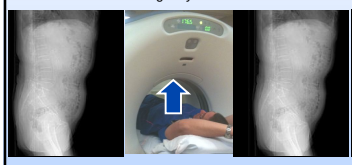
Tube: below	above	above

2. FOV Cut-off AP

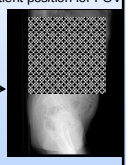
Patient low on lateral scout. | Raise table in gantry. | Acquire AP scout.



Scout misrepresents patient position for FOV

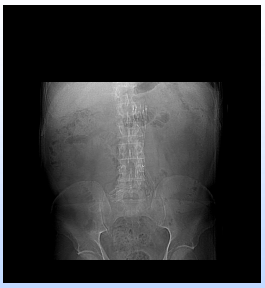


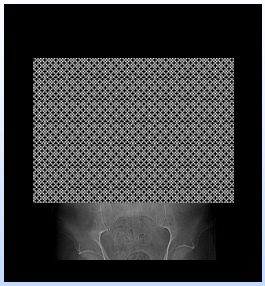
Patient low on lateral scout. | Raise table in gantry. | Re-acquire lateral scout. | Acquire AP scout.

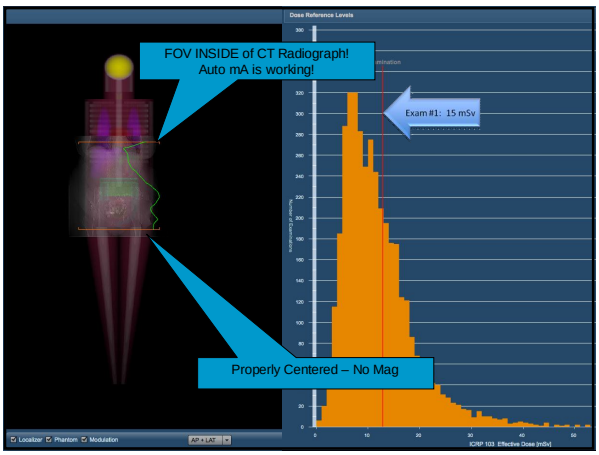


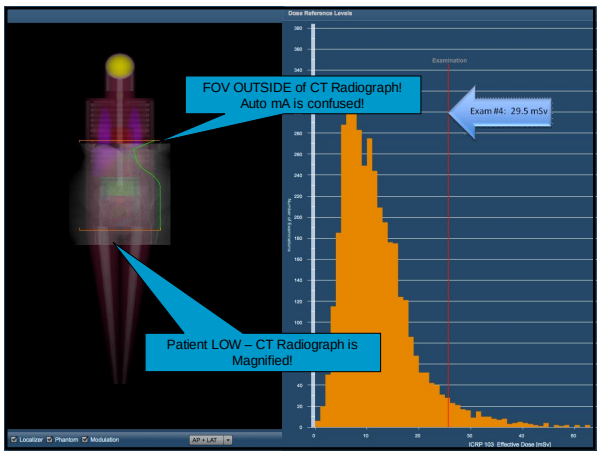
Scout represents patient position for FOV

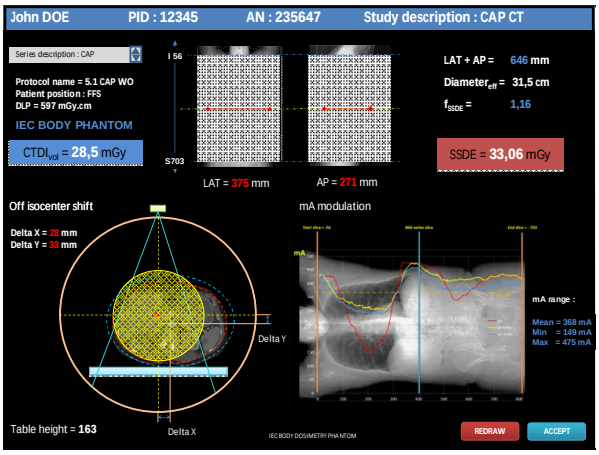
3. FOV Cut-off Zaxis







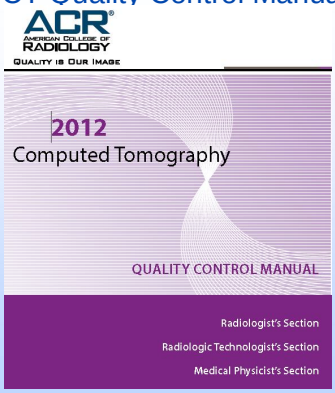




Quality Review of CT Dose

- ACR National Radiation Dose Registry
- ACR CT Accreditation - Medical Physics Review
- Joint Commission SE #47
- California SB 1237

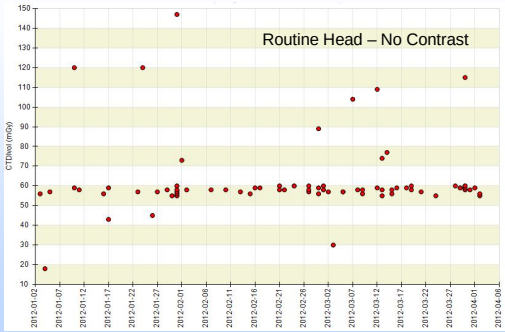
ACR CT Quality Control Manual



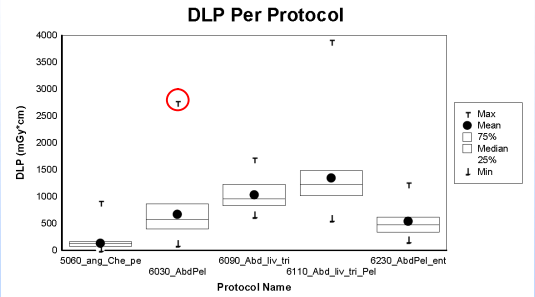
New Requirements for CT ACR Accreditation

2. Institute a regular review process of all protocols to be sure that no unintended changes have been applied that may degrade image quality or unreasonably increase dose. Review at least 6 clinical protocols (more if required by state or local regulatory body), including:
   a. Pediatric head (1 year old)
   b. Pediatric abdomen (5 years old; 40-50 lb or approx. 20 kg)
   c. Adult head
   d. Adult abdomen (70 kg)
   e. High-Resolution chest
   f. Brain perfusion (if performed at the facility)

NRDR – ACR Informatics for CT

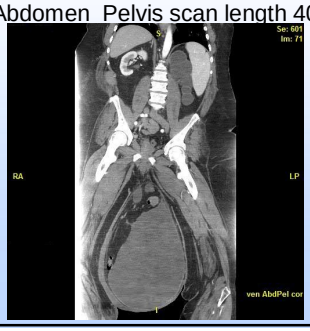


*JC: Institute a process for the review of **all** dosing protocols…*



JC: Investigate Doses outside the range

- 6030_Abdomen_Pelvis scan length 40-60 cm



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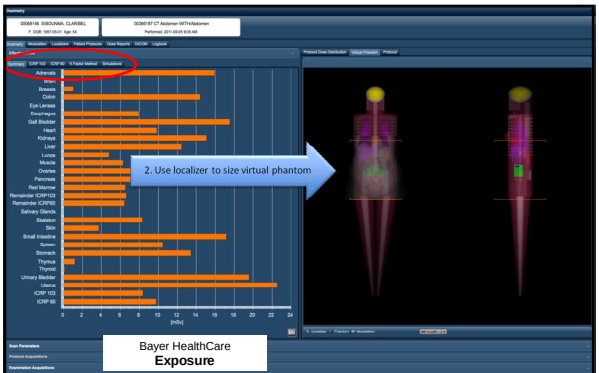
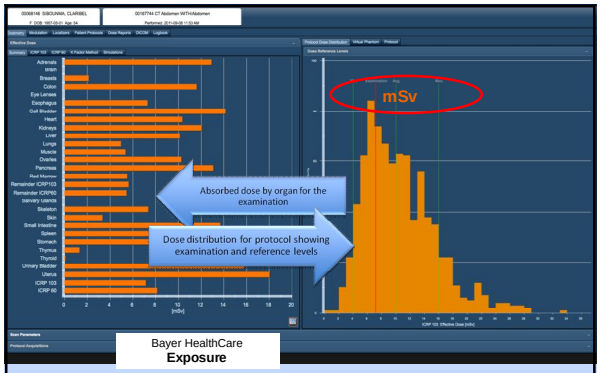


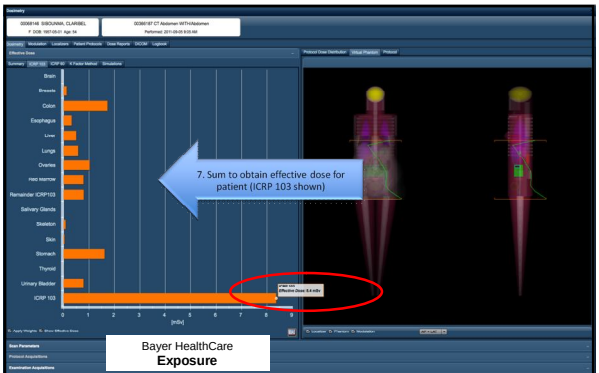
Integrated Dosimetry

In Compliance With HIPAA regulations. Patient information listed on the GUI are examples only and do not contain any actual patient information



Examination Analysis

In Compliance With HIPAA regulations. Patient information listed on the GUI are examples only and do not contain any actual patient information



Integrated Dosimetry

In Compliance With HIPAA regulations. Patient information listed on the GUI are examples only and do not contain any actual patient information

Informatics - Powerful tools for your toolbox!

Thank you!