Partners In Health

Implementing Iterative Reconstruction in Your Practice: Barriers to success and strategies for stepwise deployment

Jeffrey B. Mendel, M.D.

What can Iterative Reconstruction do for you?

- Dose reduction
- Use of low kVp technique in a broader group of patients
- Increase the apparent power (kW) of your CT scanner
  - Bariatrics
- Improve image quality
  - Oncology patients
- Decrease artifacts*
  - Streak
  - Blooming
- Metal artifact reduction**

How to successfully implement iterative reconstruction

- Step 1 – buy the equipment
- Step 2 – turn iterative reconstruction on for all scans at a modest level
- Step 3 – decrease your mAs by 30% on all scans
- Step 4 – declare victory

So what's the problem?

The Problem

=

Auckland 2004
Yellow Pages
Auckland 2004
Yellow Pages

Check the traffic before you set off – call AA Roadwatch on 84322
£6.99
AA For the road ahead 2011
GREAT BRITAIN
AND IRELAND
10 GREAT MONEY-SAVING OFFERS* ON AA PRODUCTS AND SERVICES
BRITAIN'S CLEAREST MAPPING
CLEAR 4 MILES TO 1 INCH SCALE

LE MONDE
PIANOS
MAUDITE

Barriers to Success

- Existing QA problems
- Current dose reduction scheme
  - Do you have one?
- 'Paralysis of analysis'
  - Dozens of papers on kVp, dose reduction, contrast administration, iterative reconstruction
- Need for a 'champion'

The enemy of the good is the better

Barriers to Success (2)

- Fracturing of implementation
  - Not all scanners may have IR
  - Not all scanners have the same IR (vendor/age)
  - Not all CT read by the same radiologists
    - Chest vs Body vs MSK vs Neuro
    - New hires vs older radiologists
- Work-life balance Work-paperwork balance
    - Implementation = time & effort
    - Smaller practices
    - Multiple sites / multiple scanners

Stepwise Approach to Implementation: Evaluate Current Protocols (FBP)

1) Review your current QA issues
   - Address persistent quality issues*

     * Do you know your quality issues?
   - Optimize your current protocols

2) Assess your current dose reduction scheme
   - Tailor to patient body size
   - Automatic mA selection
   - Minimizing number of phases
   - Low kVp

Tamm EP et al Radiographics 2011

3) Select representative studies for a benchmark
   - Consider measuring image noise

Leipsic J et al Int J CV Imaging 2012

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Why is this hard?
Remember High School Algebra?

$$2x - 4y + 5z = -33$$
$$4x - y = -5$$
$$-2x + 2y - 3z = 19$$

$$2x - 16x - 20 + 5z = -33$$
$$-2x + 8x + 10 - 3z = 19$$

$$x = -1/2$$
$$y = 3$$
$$z = -4$$

CT Algebra?

2(kVp) – 4(auto-mAs) + 5(iterative reconstruction) +
5(number of phases) – 7(contrast enhancement)
= -33

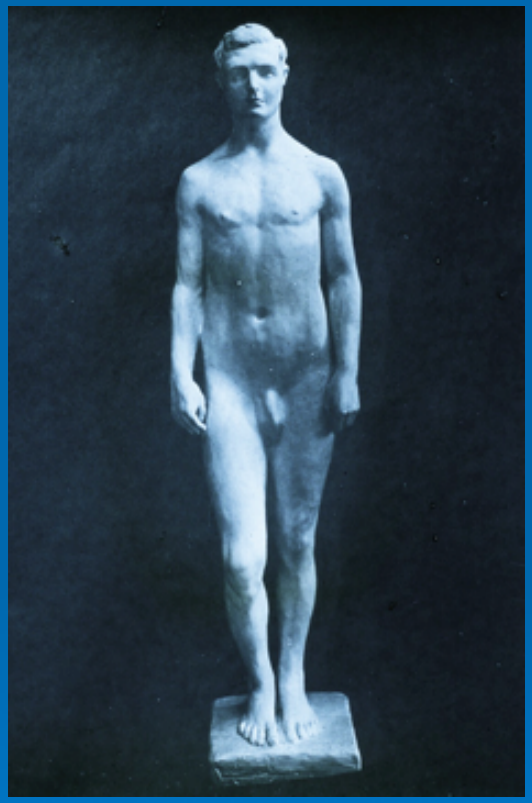
4(mL of contrast) x 2(rate of contrast injection) = -5

-2(patient body weight) + 1/2(BMI) – 3(age) = 19

Know How Your Doses Compare to "Average Doses"

- ACR Dose Index Registry
  http://www.acr.org/Quality-Safety/National-Radiology-Data-Registry/Dose-Index-Registry
  - Join & Implement
    Robinson TJ et al J Digit Imaging 2013
  - Use sample data
    - Core Documents
      - "DIR Sample Report" "DIR Pediatric Sample Report"
- Check typical doses from the literature*
  - Most studies, especially predating the 2011 AAPM TG204 report, do not normalize dose for patient size
  - Check for use of SSDE (size specific dose estimates)

Calculating Patient “Size”



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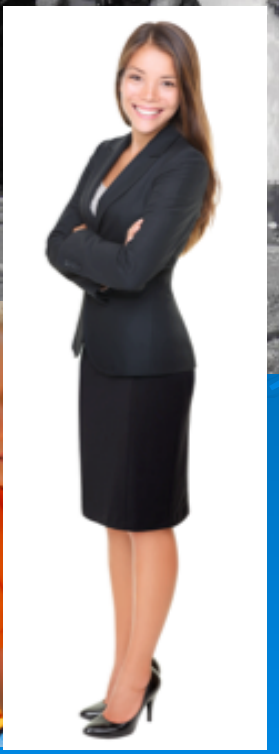

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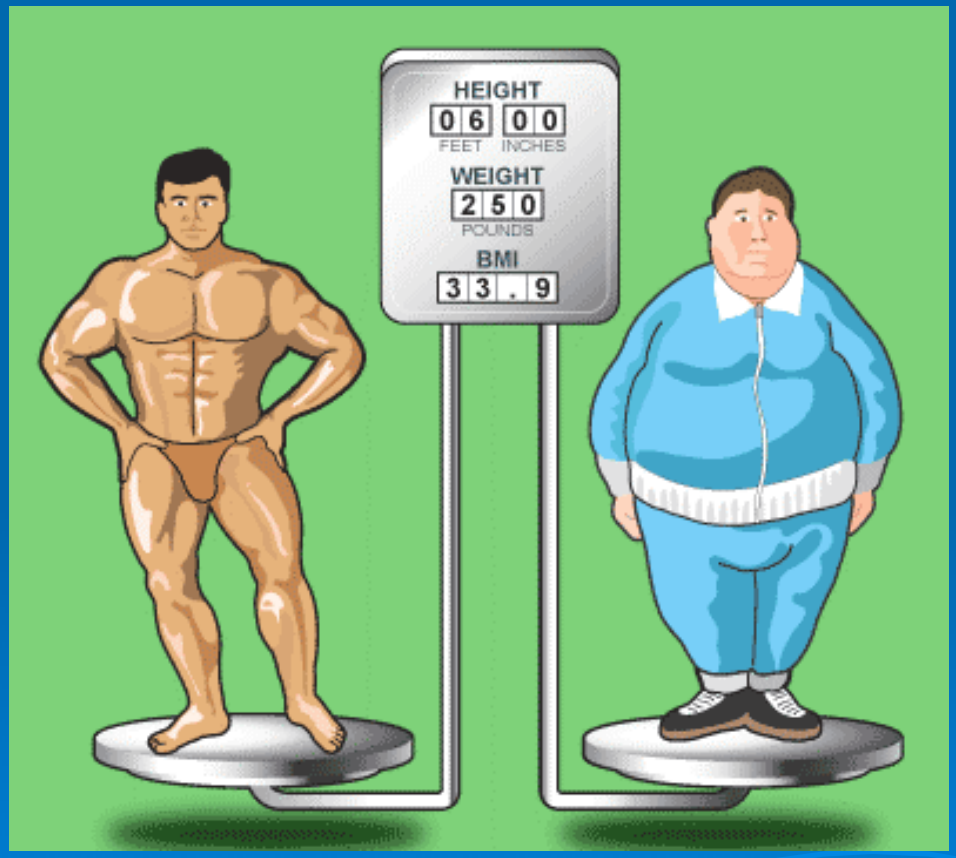
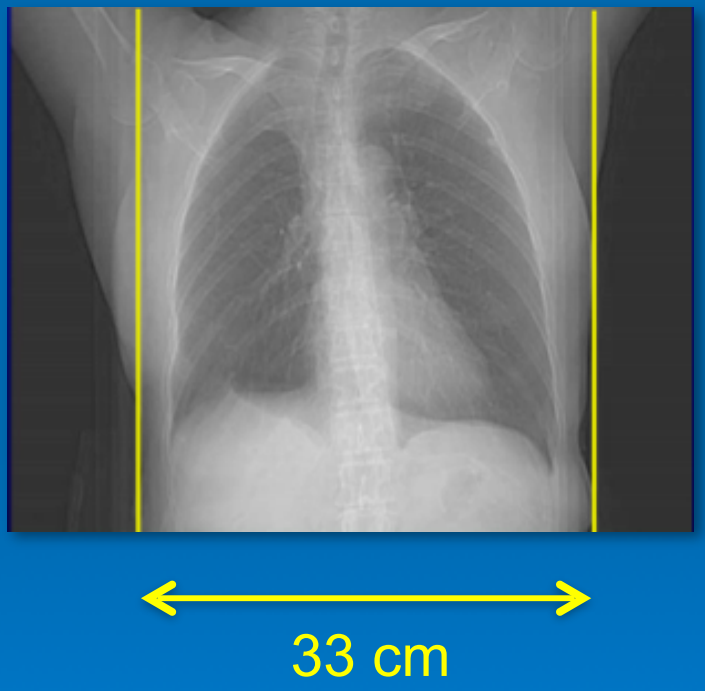


- Exams based on patient’s size provide a basis for the ‘right dose’
- Neither patient weight nor BMI are a good measure of size
- Other approaches should be used as a basis for a dose reduction system

Estimating Patients 'True' Attenuation

- Lateral width (skin to skin) at the level of the liver
- Use AP scout image and then choose FOV as usual
  - Note FOV may differ from the width used to determine mAs
- For patients with very large upper chest or hips
  - Use measurement form the level of the liver
  - If in doubt, may increase one size



Do you know SSDE? (size specific dose estimates)

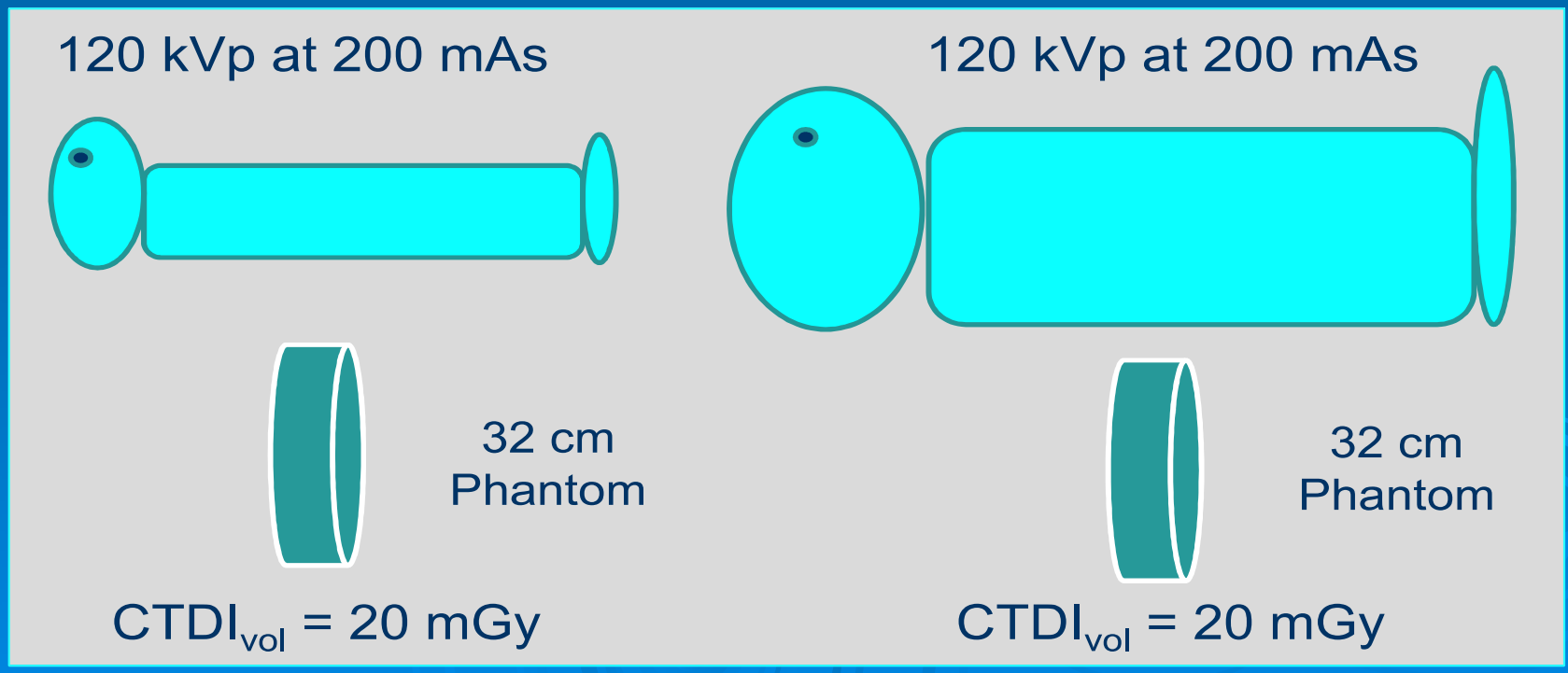
- Developed by AAPM
- Normalizes dose based on body size using AP and lateral body dimensions
- Uses CTDI and a size-dependent factor
- Modern AEC does a reasonably good job in adjusting dose by SSDE

  Christner JA et al Radiology 2012
- Every vendor's AEC functions differently, know your scanner's functionality

  Raman SP et al JACR 2013

Do you know SSDE? (size specific dose estimates)

- Developed by AAPM
- Normalizes dose based on $CTDI_{vol}$ and a size-dependent factor
  - Size calculated using AP & lateral body dimensions



S. Hale, Jr. PhD

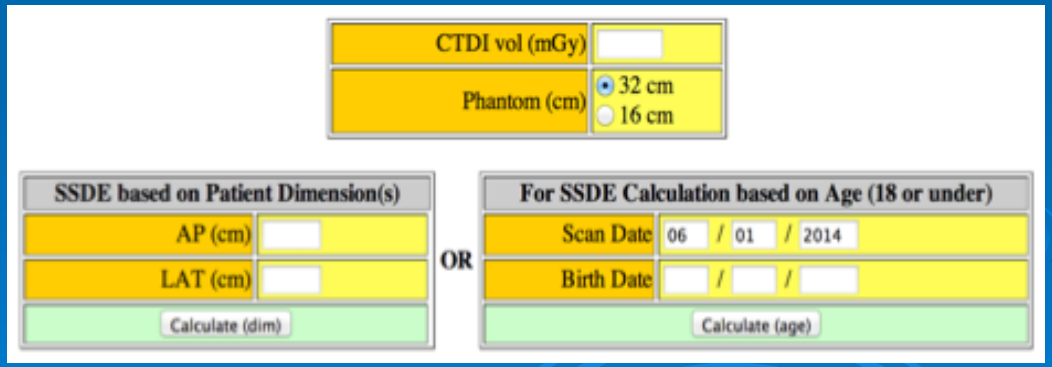
SSDE

- Data
  - Dose Report
    - Phantom (16 vs 32 cm)
  - Scout images
- Calulation
  - Web-based calculator is available
  - http://www.gdavidasp.net/gdavid/DoseCalculators/ssde.asp
  - AAPM tables
    - http://www.aapm.org/pubs/reports/rpt_204.pdf

Exam Description: CT Abdomen/Pelvis wo/w

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	S24.250-I433.250	18.46	929.89	Body 32
200	Axial	I49.750-I49.750	21.26	10.62	Body 32
4	Helical	S28.250-I436.750	21.76	1112.53	Body 32
			Total Exam DLP:	2053.04	



Automatic Exposure Control

- Modern AEC does a reasonably good job in adjusting dose by size

  Christner JA et al Radiology 2012

- Every vendor's AEC functions differently, know your scanner's functionality

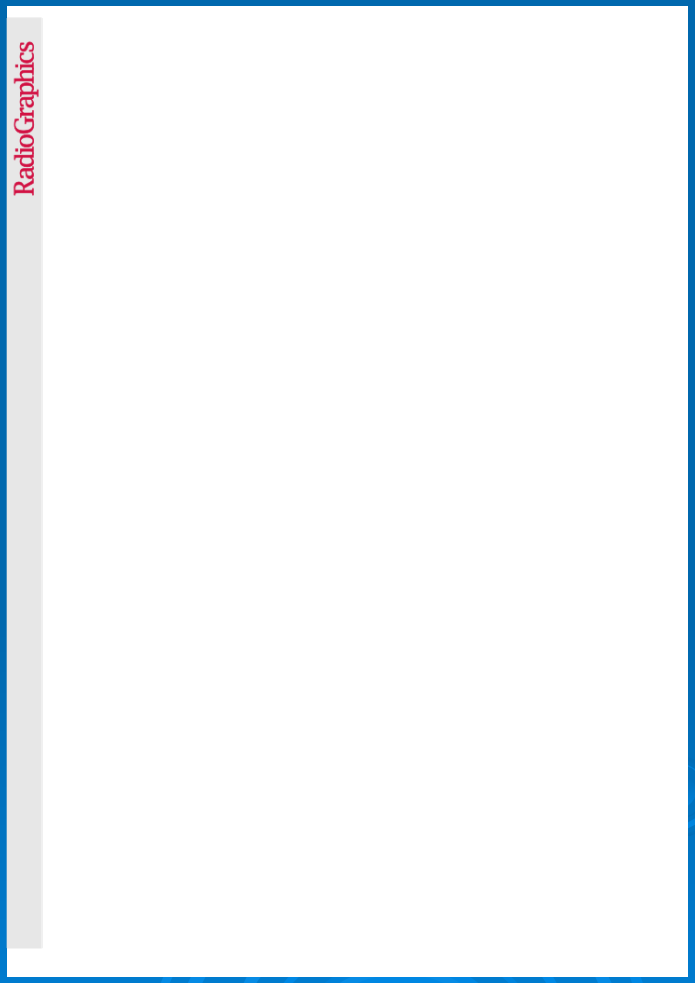
  Raman SP et al JACR 2013

- Know your CT's limitations
  - Most systems need manual adjustments for pediatric and bariatric patients
  - Encourage your technologists to manually adjust based on body type

Divide and Conquer

- Use of AEC / calculate patient size
- Modify protocols (mAs)
- Reduce kVp
- Volume & rate of contrast
- Phases

- Iterative reconstruction



Stepwise Approach to Implementation: Evaluate Current Protocols (FBP)

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Tamm EP et al Radiographics 2011

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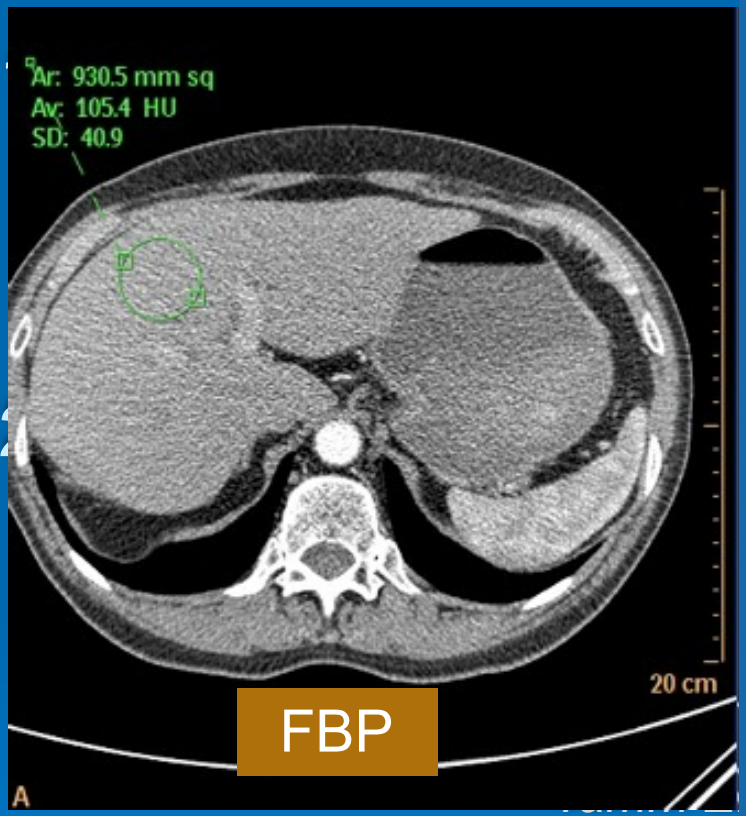
Leipsic J et al Int J CV Imaging 2012

Select Optimum Scans

- Review your current scans and select examples with ‘typical’ image quality
  - Different scans
  - Different patient sizes
- Save those scans (teaching file) as a reference to compare against your future modifications

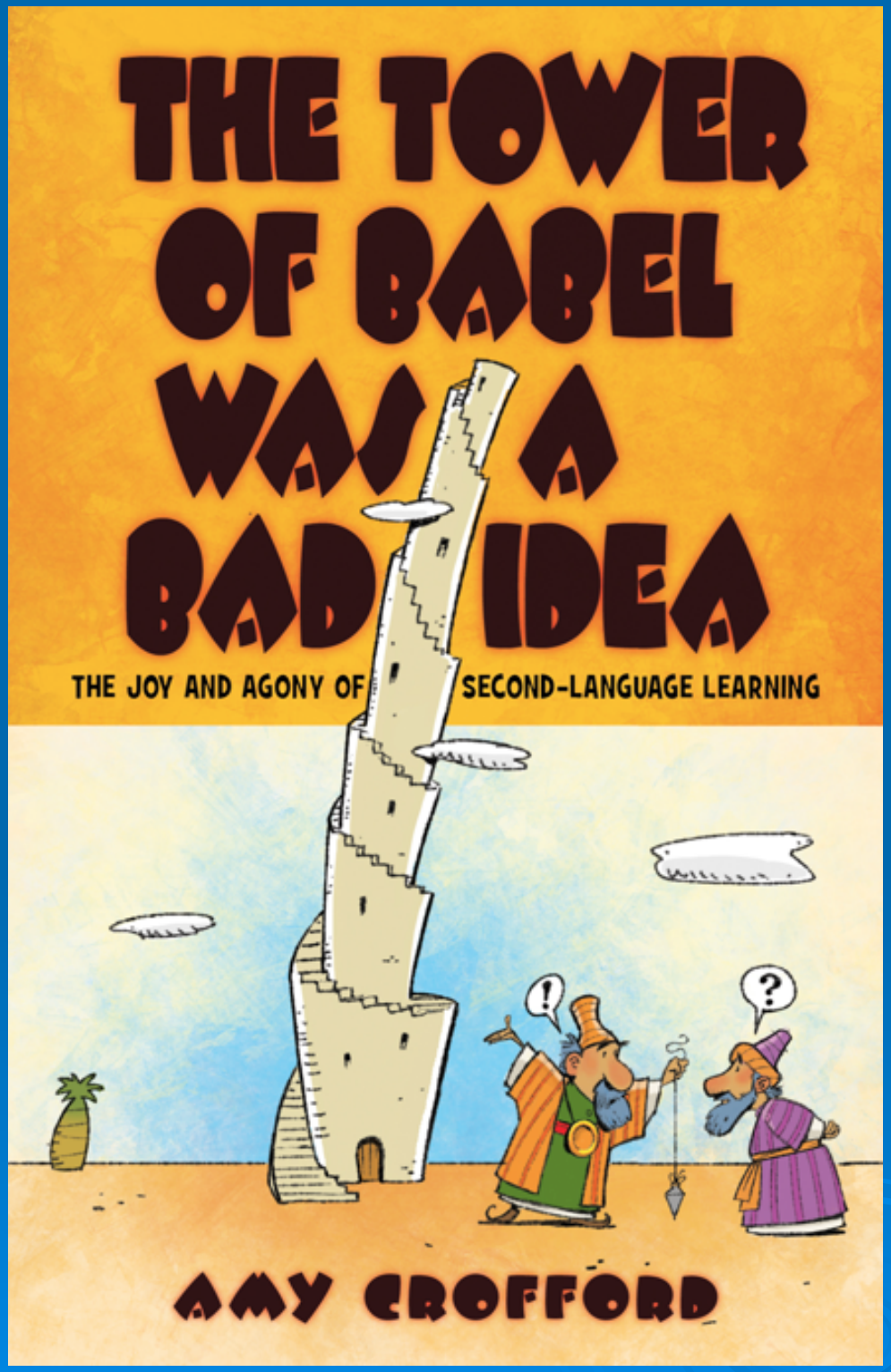
Stepwise Approach to Implementation: Evaluate Current Protocols (FBP)



Be prepared to measure ‘quality creep’

As low as reasonably achievable

No one complains about an overexposed CT image



Or why all these different acronyms?

- Is this just more pain like MRI?
  - *FIESTA, True FISP, TrueSSFP*
- Yes and No
- All iterative methods share common general properties
- Each iterative method has specific strengths and limitations
- As a user, knowing your IM's strengths and limitations is important to maximize utility

What can Iterative Reconstruction do for you?

- Dose reduction
- Allow for reduced kVp technique in a broader group of patients
- Increase the apparent kW of your CT scanner
  - Bariatrics
- Improve image quality
  - Oncology patients
- Decrease artifacts*
  - Streak
  - Blooming
- Metal artifact reduction**

Noise vs. Spatial Resolution

- High spatial frequency algorithms (sharper filters) improve spatial resolution
- Sharper filters increase image noise so their use is generally restricted to high signal to noise tasks (e.g. pulmonary parenchyma, bones)
- If noise gain is unacceptable, the traditional approach is to increase dose but the gain is not linear

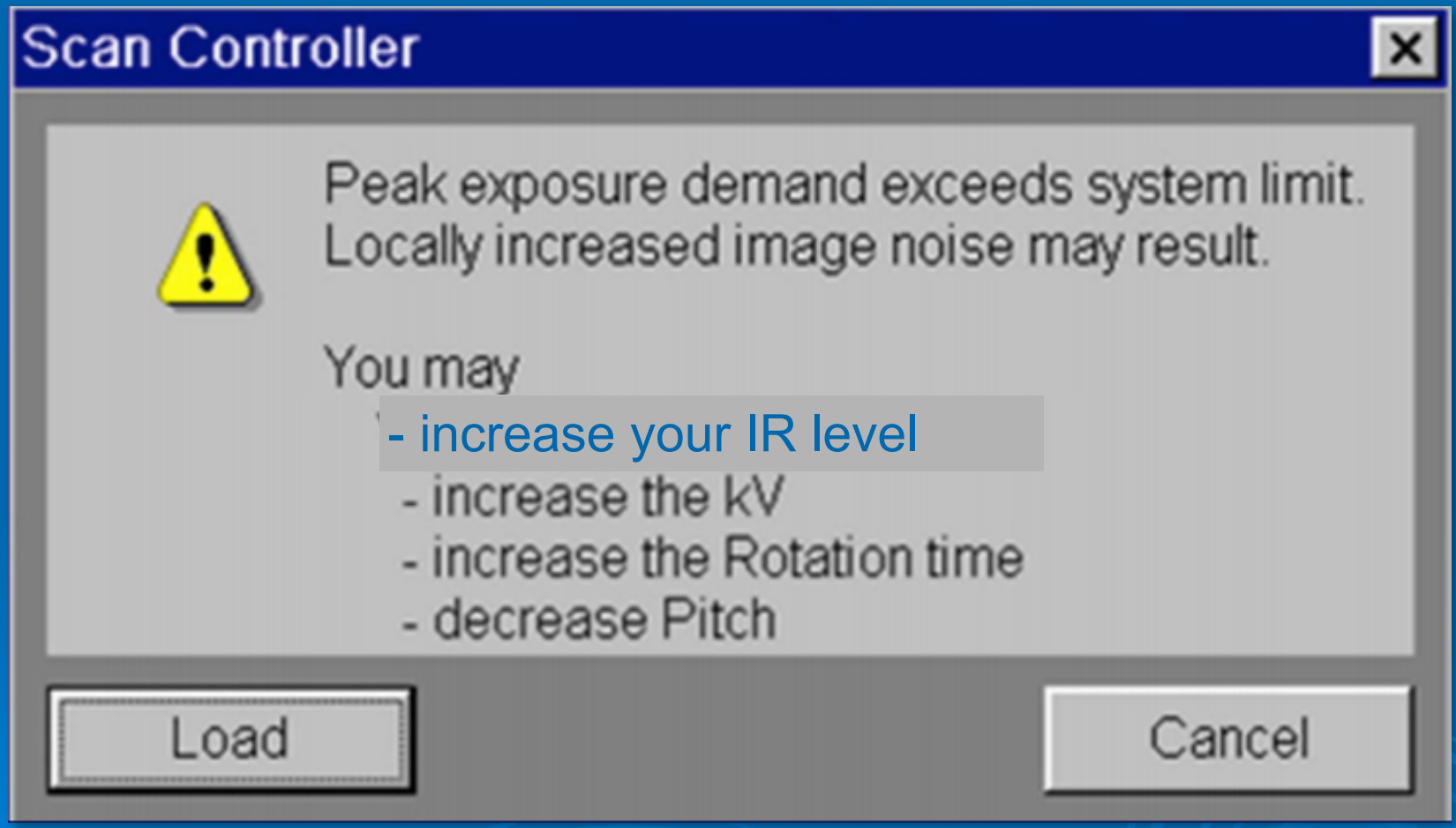
- Image noise $= 1 / \sqrt{\text{mAs}}$
- Doubling the mAs decreases noise by only 29 %

Improving Image Appearance

Percentage of Dose Reduction (relative to FBP)	Approx. Quantum Noise Reduction (relative to FBP)
20 %	11 %
30 %	16 %
40 %	23 %
50 %	29 %
60 %	37 %
70 %	45 %
80 %	55 %

Noise Reduction ≠ Dose Reduction

What to do when you reach your (mA) limit?

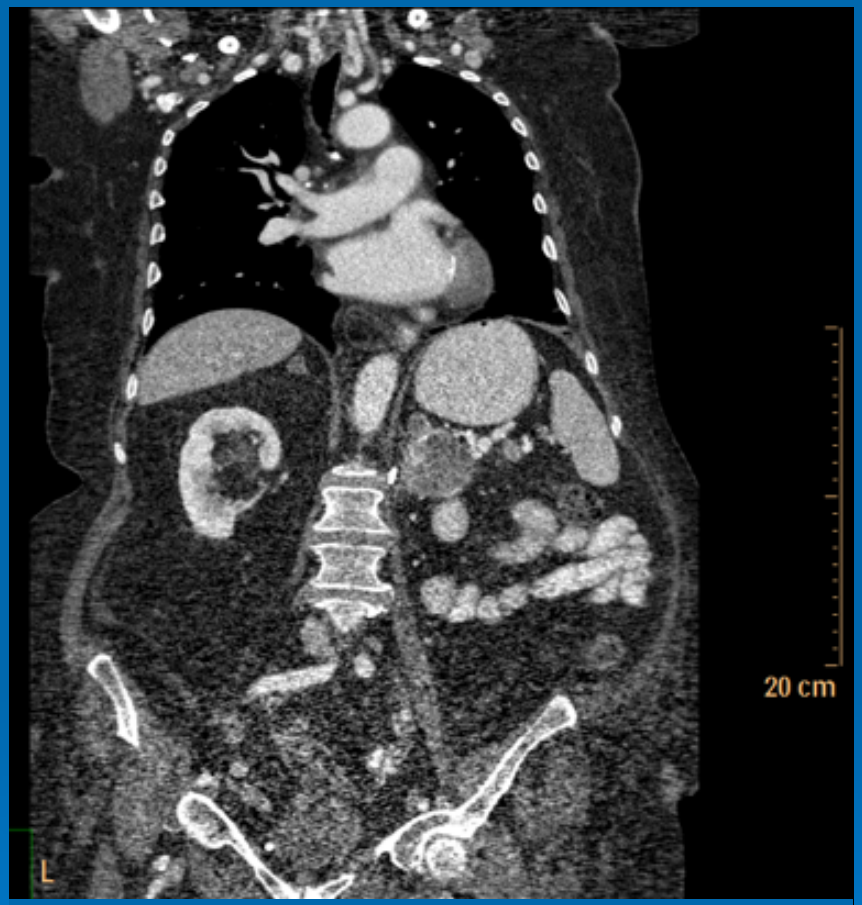


Improving Image Quality

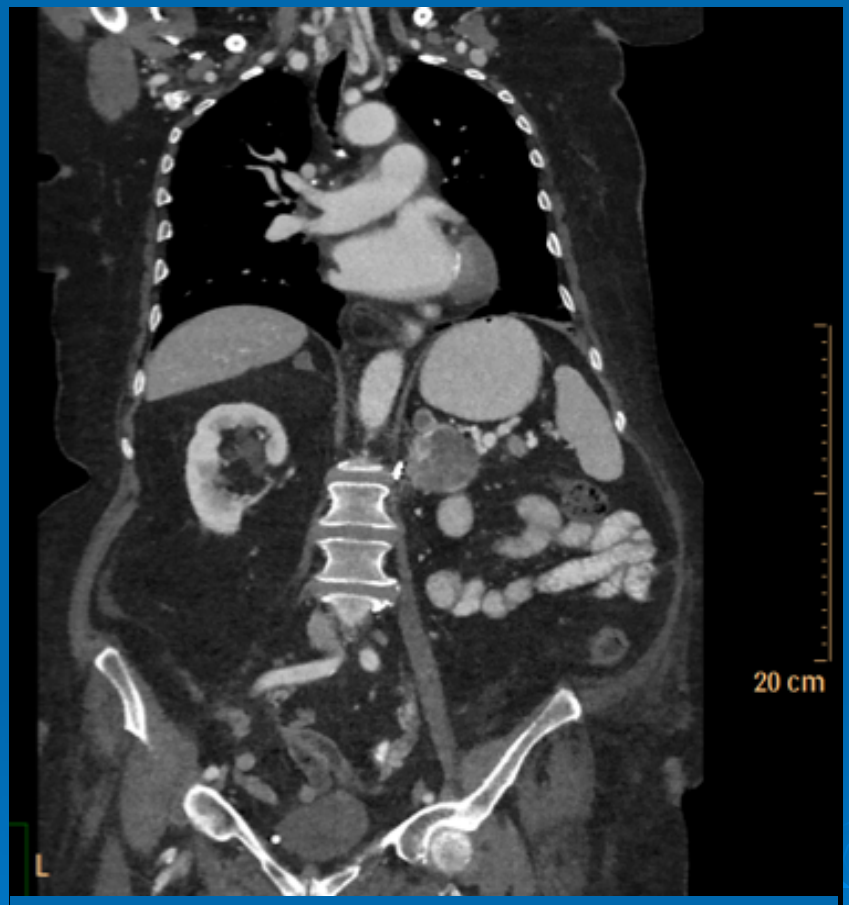
Dose Reduction	Noise Reduction	mAs Equivalent	Effective Tube Limit based on 60 kW CT
20 %	11 %	1.2 x	72 kW
30 %	16 %	1.4 x	84 kW
40 %	23 %	1.6 x	96 kW
50 %	29 %	2.0 x	120 kW
60 %	37 %	2.5 x	150 kW
70 %	45 %	3.3 x	198 kW
80 %	55 %	4.9 x	294 kW

$$\text{Increase in Power} \cong \frac{1}{\%\ \text{Dose Reduction}}$$

Bariatric Imaging: Improving image quality without dose reduction



FBP

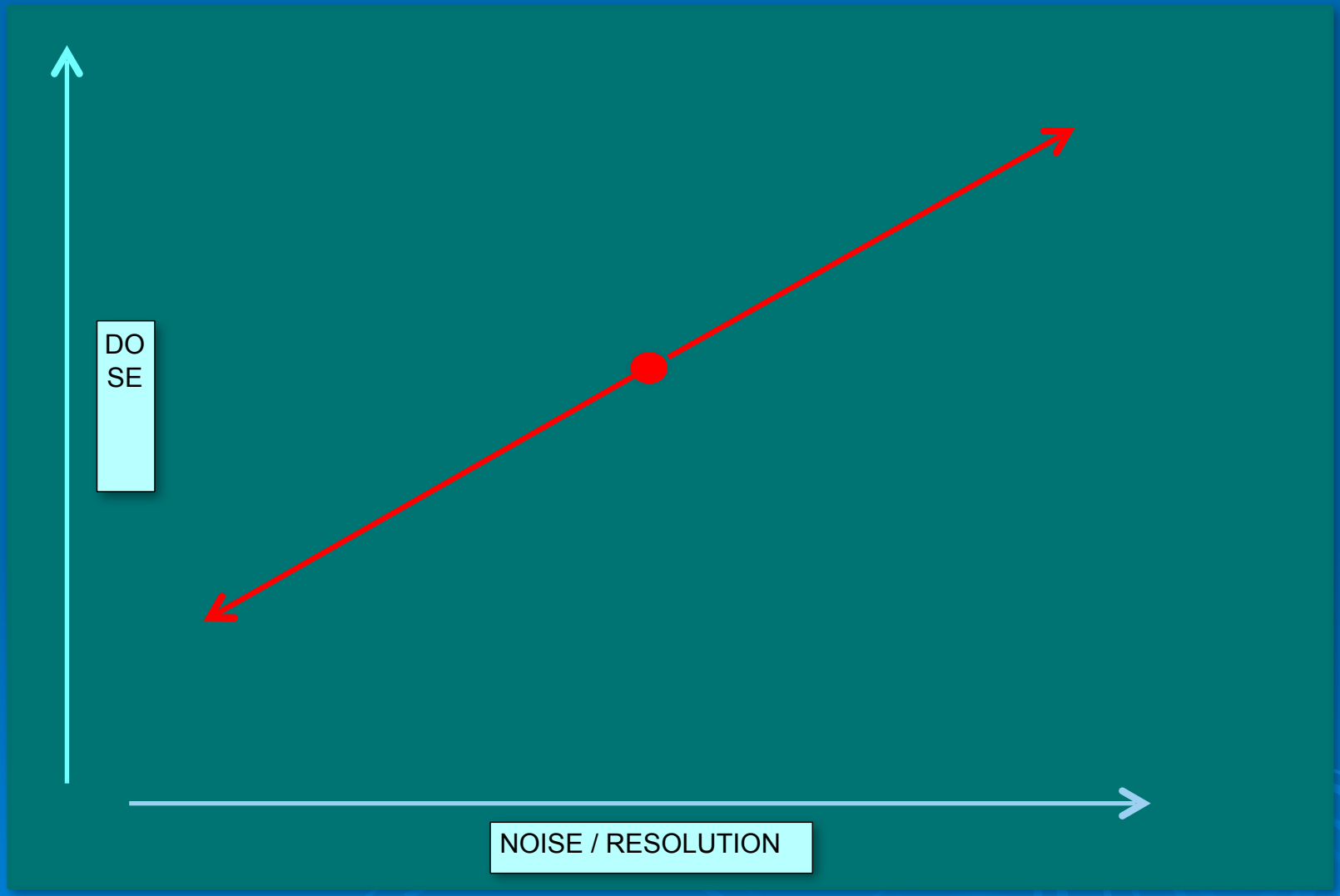


IR

Depending on the size of the patient and the level of IR, you may achieve both noise and dose reduction

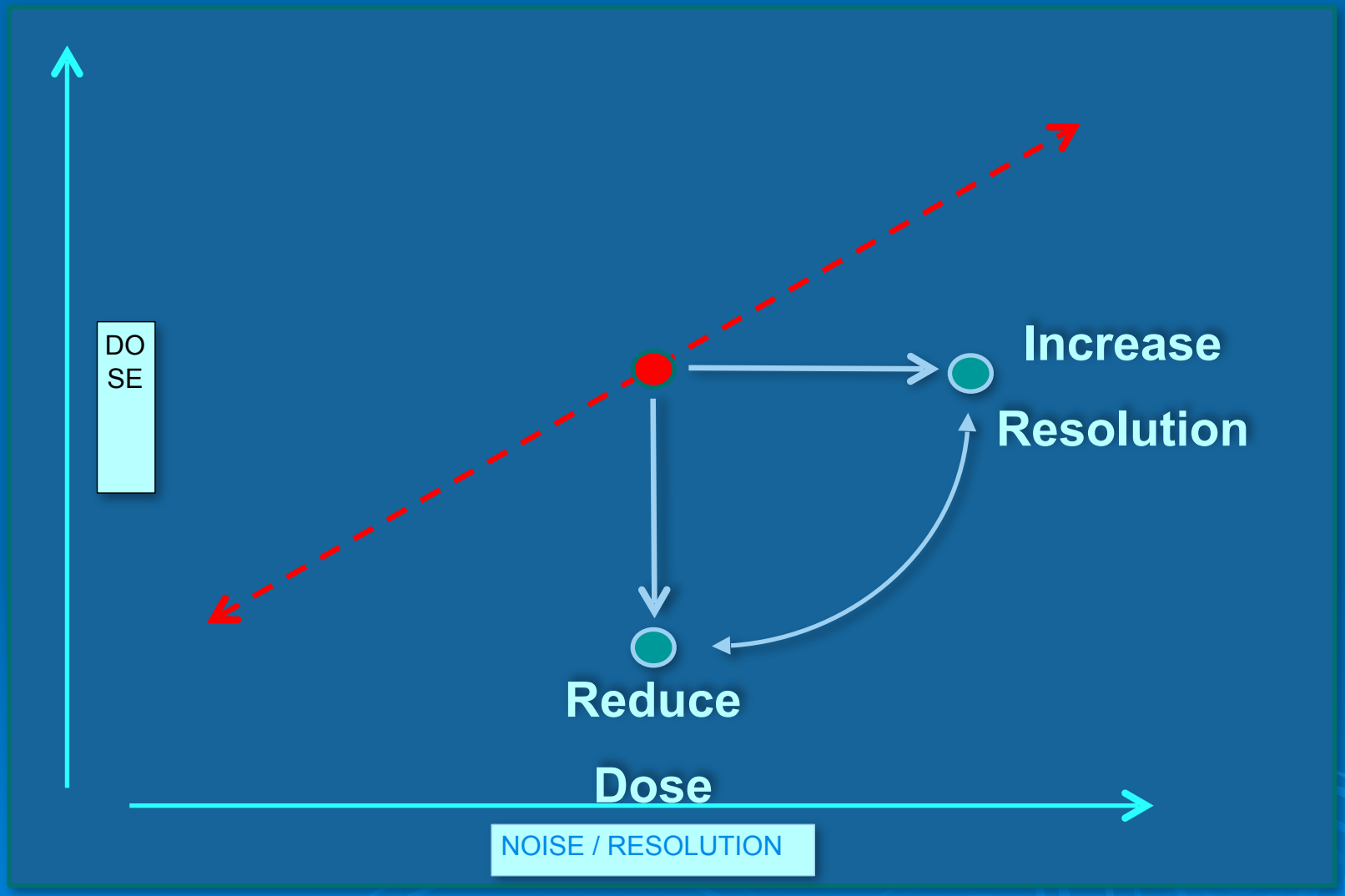
120kVp, 275 mAs

FBP: Dose vs Image Quality



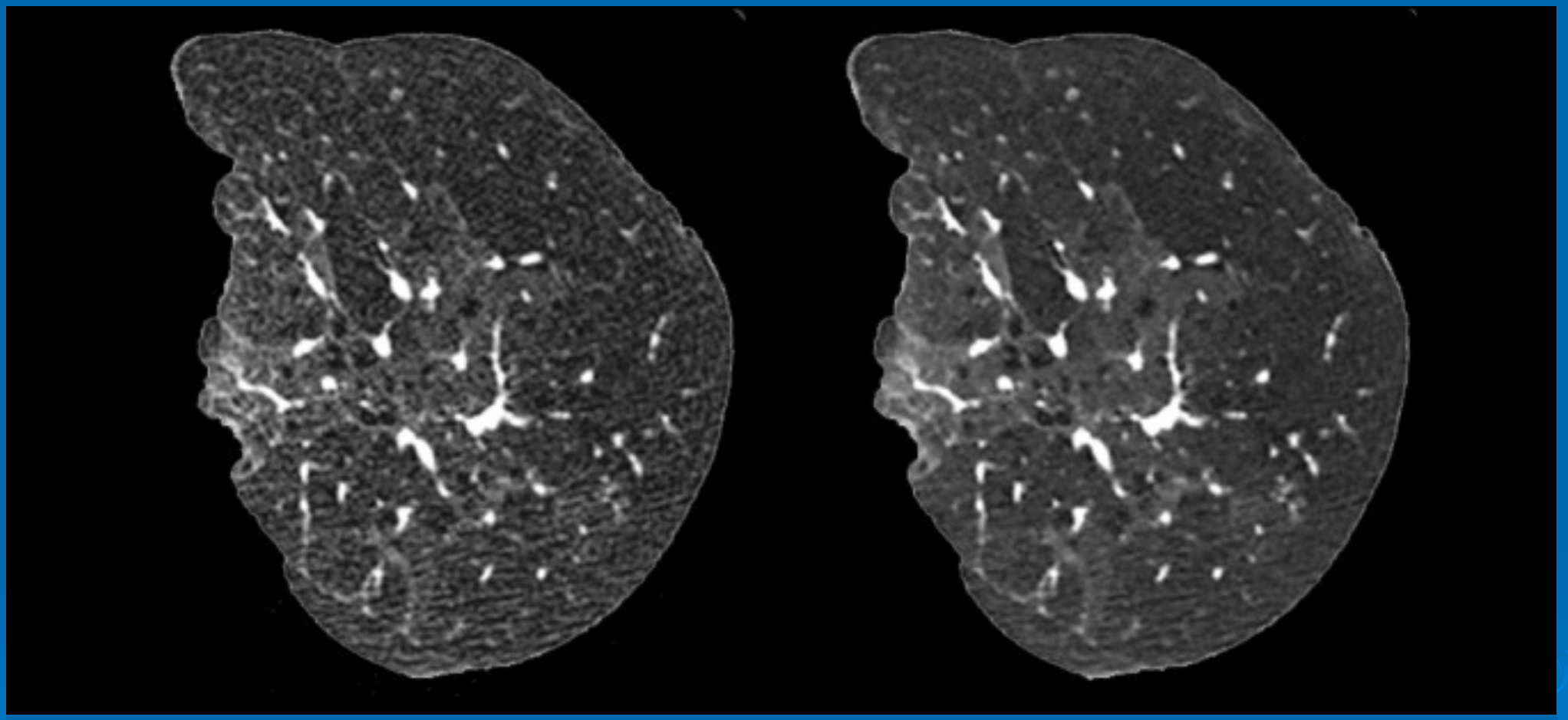
- You can improve resolution by increasing dose
- You can lessen dose but increase noise level

IRT: Dose vs Image Quality



- You can improve resolution & maintain dose
- You can lessen dose & maintain noise level

Noise vs. Spatial Resolution



FBP iDose^4

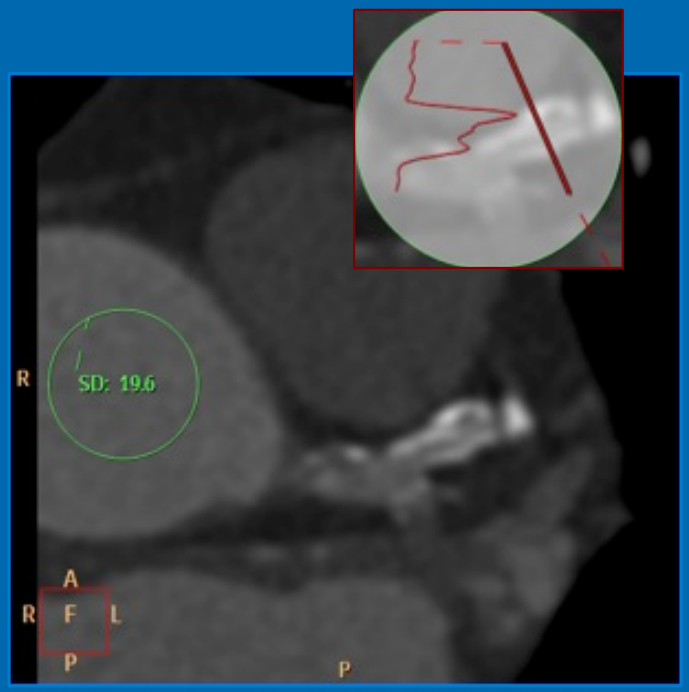
68% improvement in spatial resolution at equal dose

55% noise reduction (80% level - level 7)

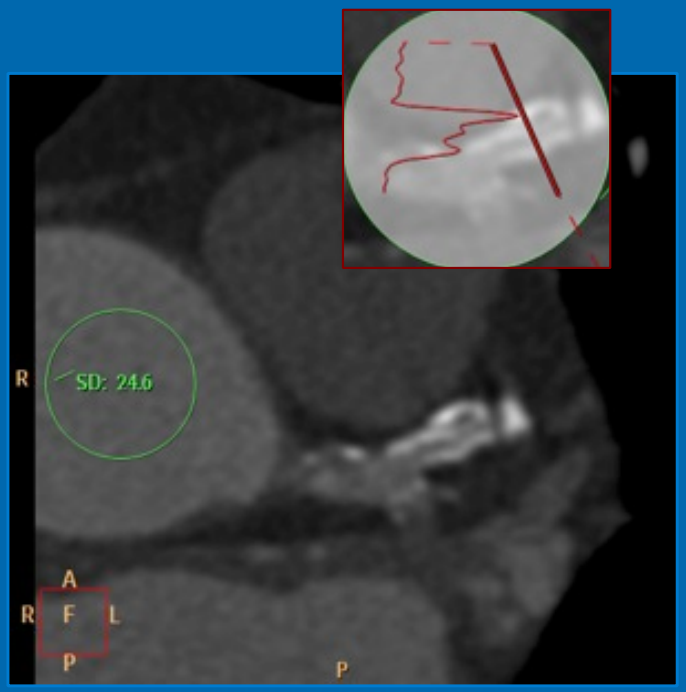
Equivalent to 1500 mAs scan with FBP

Saitama Hospital, Japan

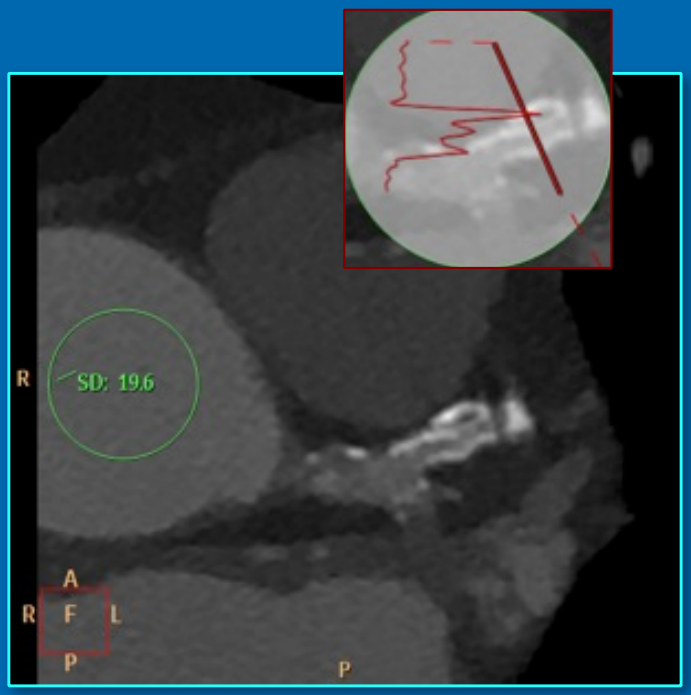
How is Blooming Artifact Reduced?



FBP - Soft Kernel



FBP - Standard Kernel



iDose⁴ - Sharp Kernel

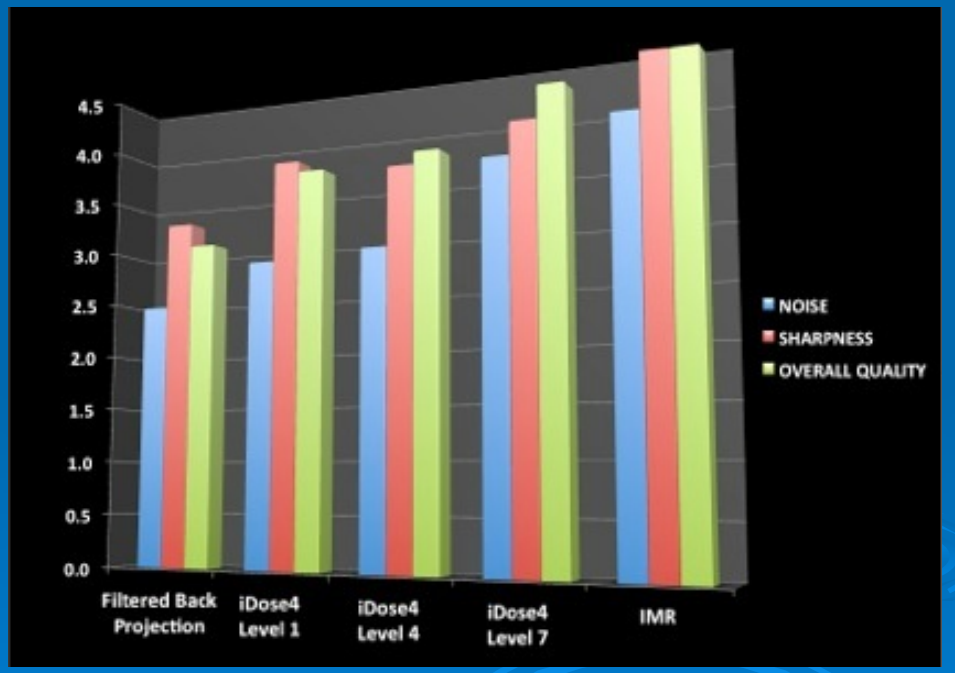
- FBP and a standard spatial frequency FBP kernel increases noise (SD) compared to the soft kernel
- iDose⁴ & high spatial frequency kernel maintains noise equivalent to the soft FBP kernel while reducing blooming (narrowed peak)

Sakurabashi Watanabe Hospital, Japan

"In times of rapid change, experience could be your worst enemy"

J. Paul Getty

- Residents do not show any threshold effect in judging IR images
- Anticipate divergent opinions on 'image quality' based on experience and specialty



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Tamm EP et al Radiographics 2011

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Leipsic J et al Int J CV Imaging 2012

Stepwise Approach to Implementation: Part 2

4) Options for Implementation: Hardware
   - Are all my scanners IR-compatible?
   - Can I afford to upgrade them all?
   - Are all scanners from the same vendor?
     - How do I implement multiple types of iterative reconstruction?

5) How is CT organized (how are CT's read)?
   - Section (body part) – Need buy-in from all sections on IR*

   * You need acceptance of IR, not agreement on section-specific protocols

6) Rationing: who goes on the IR-compatible scanner?
   - Pediatrics, young women, bariatrics, radiologists' family members….
   - What are the barriers to patient-specific adoption?

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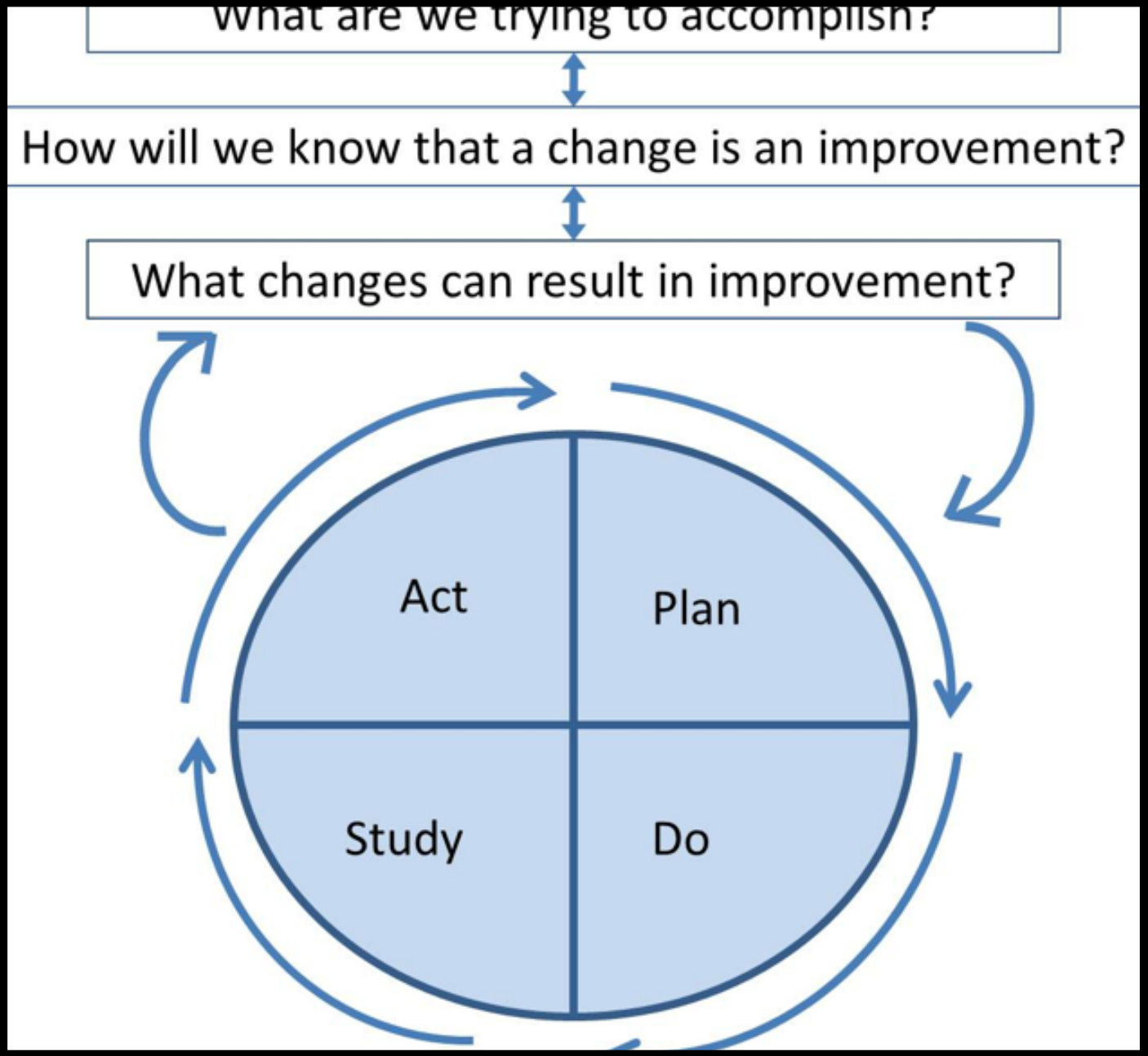

Do / Study / Act

- DO
  - Trial initial IR level
    - Typically 20-50 cases / body part
- STUDY
  - Compare image quality with ‘benchmark’ studies
  - If satisfied with the initial IR level, select initial set of ‘IR benchmark’ studies
- ACT
  - Act 1a – implement current IR levels throughout department
  - Act 1b – increase IR levels and re-trial

Know Your Own Strength

FBP

IM (iDose^4 level 1)

Remember to Keep Pushing the Envelope

SCHOOL OF VISUAL ARTS "PUSH THE ENVELOPE" IMAGES OF ENVELOPES WITH CUSTOM-ENGRAVED STEEL PUSH-PLATES WERE INSTALLED ON THE SCHOOL'S DOORS.

Conclusions

- D
- Lea