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Strategies for Reject Analysis

Expectations and Experience

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The Need for Quality Review in Digital Radiography

What Digital Radiography offers

Ease of Image Distribution: uncoupling acquisition and read locations	**Communication Difficulties: hard to provide timely and directed image quality feedback**
Flexibility of Image Processing	**Variability of Image Quality**
Wide Detector Latitude	**Variability of Exposure (dose creep)**
Ease of Acquisition	**Ease of Repeat (reject creep?)**
System Flexibility	**System Complexity**

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From the ASRT

"It is a best practice in digital radiography to implement a comprehensive quality assurance program that involves aspects of quality control and continuous quality improvement, including repeat analyses* that are specific to the digital imaging system"

ASRT, Best Practices in Digital Radiography, ASRT White Paper, (2012). Available at: http://www.asrt.org/docs/whitepapers/asrt12_bstpracdigradwhp_final.pdf

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Benefits of Repeat Analysis*
from the ASRT

A repeat analysis allows for assessment of:

- **overall image quality**
- **modification of examination protocols**
- **the need for in-service education**
- **tracking of patient radiation exposures**

Analysis of the department's repeat rate provides valuable information for process improvement

*Repeat analysis directly relates to wasted exposure and inefficiency, but is harder to get accurate repeat data.
Rejected images and image data lend themselves for analysis more easily

ASRT, Best Practices in Digital Radiography, ASRT White Paper, (2012). Available at: http://www.asrt.org/docs/whitepapers/asrt12_bstpracdigradwhp_final.pdf

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The problem with focusing on Self-Reported Data and Rate Targets

Didn't make the target ?
Recount!

- Acknowledged poor accuracy*
- Effort is spent on program compliance
- Little impact on quality improvement

*Comparing self-report to system-integrated and required reporting:

For the same month

	Room A	RoomB
Self-Report	1.6%	3.3%
System Integrated and Required	8.8%	14.3%

Image source http://www.awesomeinventions.com/designed-useless-items-prank-gifts/

Image Reject % - Expected Dependencies

Rate Dependencies	Examples
Anatomical view	AP knee is easier to position than lateral
Exam purpose	Length and alignment of spine vs. finding a hairline fracture
Patient population	Trauma, pediatric, sports medicine: different positioning challenges and exam purposes
System robustness	Image processing failures that look like acquisition problems
Detector size, technologists positioning aides	Inability to get all of anatomy on one image; Difficult to position well or know where cells are
Practice Standards	Tolerance for sub-ideal quality

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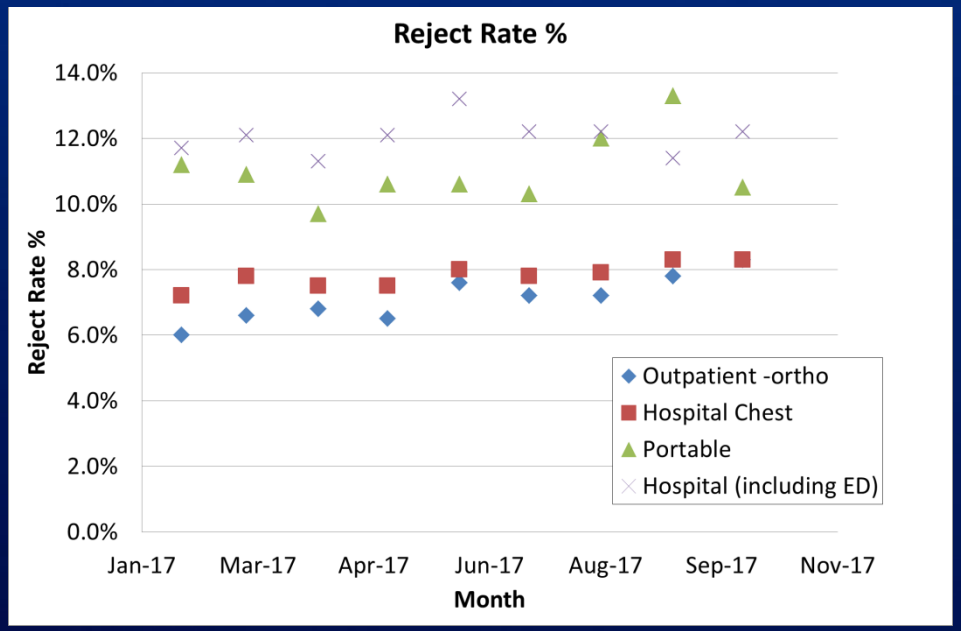
Rate variability

By Practice



	Outpatient - ortho	Hospital Chest	Portable	Hospital (including ED)
Average Rate	7.1%	7.8%	11.0%	12.0%
Std Dev	0.7%	0.4%	1.1%	0.6%

By Part

Anatomy	Contribution to overall rejects	reject %	Number of Images
Knee	14.6%	19.7%	1012
Shoulder	12.5%	21.5%	790
Chest	10.9%	8.7%	1721
Lumbar spine	8.9%	27.8%	435
Ankle joint	6.9%	9.9%	953
Cervical spine	6.3%	18.1%	476
Femur	5.1%	11.3%	609
Pelvis	4.2%	15.0%	380
Elbow	4.0%	14.4%	376
Hip joint	4.0%	12.6%	430
Foot	3.4%	11.7%	393
Thoracic spine	3.3%	23.7%	190
Hand	2.8%	9.2%	413
Abdomen	2.1%	9.7%	298
Humerus	2.0%	16.9%	160
Wrist	1.5%	6.1%	343
Forearm bone	1.1%	6.3%	239
Patella	1.1%	39.5%	38
Leg	1.0%	5.3%	244
Clavicle	0.8%	10.9%	101
Rib	0.7%	10.6%	94
Facial bones	0.7%	23.1%	39
Skull	0.6%	21.6%	37

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Reject Reasons

Repeat analysis software typically allows users to identify the reason for a reject.

This detail can help identify a target area for intervention

Repeat Reason	Knee	Shoulder	Chest	Overall
Patient Positioning	88.9%	82.4%	77.9%	78.0%
Image Artifacts	3.5%	3.5%	4.7%	4.3%
Patient Jewelry or Clothing	0.5%	4.7%	3.4%	4.2%
Noisy Image(s)	1.5%	5.9%	0.0%	3.5%
Incorrect Technique Selected	2.0%	2.9%	2.0%	3.2%
Patient Motion	0.5%	0.6%	8.1%	2.9%
Incorrect Collimation	0.5%	0.0%	1.3%	2.4%
Missing or Incorrect View Markers	1.5%	0.0%	0.7%	0.6%
Incomplete Acquisition	0.5%	0.0%	0.0%	0.2%
Incorrect Anatomy Selected	0.0%	0.0%	0.7%	0.2%

As for reject rate, self-reported data may be inaccurate:

- Sampled bimonthly review of images showed ~25% had been given inaccurate reject reasons (lateral hip)

Reject reason inaccuracy may relate to:

- Poorly designed user interface may discourage taking time for accuracy
- Multiple similar categories may dilute the appearance of an issue.
- It may be difficult for the tech to assess cause of poor quality with the complexity of DR

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Value of Reject Rates

- A control measure or counter-measure for intentional practice change
- A signal of a previously unknown or unintended practice change
- A tool for prioritizing further in-depth analysis

Unless a change in rate is solely tied to a change in distribution of acquired exams more information is needed for quality assurance and quality improvement

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Incorporating Reject Analysis into Comprehensive Radiography QA

Diverse Team Perspectives and Skills

Physics staff, technologists and radiologists review data and images to set standards and identify quality gaps.

Sufficient and Accurate Data

System Integrated and Required Reject Reporting , DICOM header database, Rejected Images, original images, technologist interviews, Radiologist and Technologist Issue Reports

Meaningful Analysis Granularity and Scope Constraint

One anatomical view at a time. Targets, processing, charts, positioning…. all linked with anatomical view

Structured Analysis

DMAIC framework, standard work and reporting

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Program Structure

1. Define or determine standard acquisition and standard quality
2. Review accepted images and data*, establish baselines
3. Review rejected images and data*, establish baseline rates
4. Describe the quality gaps, construct stories of root causes
5. Design interventions to address gaps
6. Follow-up analyses to test effectiveness of intervention on closing gaps or improvement in rates

* May be a sampling

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1. Define Expected Performance

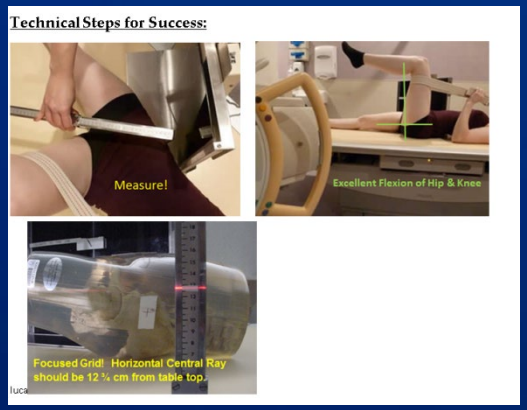
Expected Image Quality

References A "gold library" of images

Figure 1. This is the preferred image quality approved by MSK.

ID: testpt ID
Accession #testpatient
Date: 1/8/2016 (PACS)
1/8/2016 (Q-Reads)

Expected Positioning "rolodex" Online manual



Expected Technique Posted size-based charts

L-Spine				
AEC with grid		SID (in)	48	
Examination	Size	Focal Spot	kVp	AEC Cell(s)
Lumbar Spine				
Lumbar AP	<40cm	L	80	C
	>40cm	L	95	
Lumbar Oblique Lumbar Lat (Neutral)	<40cm >40cm	L	85 95	C
Lumbar Lat (Flex/Ext)		Pay attention to what mAs you get for the AEC Lateral view. Use this for the manual technique for flex/ext. Do not use AEC. You do not need to refer to the manual chart unless you didn't aquire a neutral		

Expected Exposures (EI)

EI Target = 300 (vendor dependent) *

Quality Expectations set by or confirmed with Designated Team Radiologist

* For anatomy where EI is seen to be meaningful. Good images can have EI vary greatly for some body parts.

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2. Review of Rejected Images and Data

February Target Anatomy: Lateral T-Spine

Of images sent to PACS in November:

Overall Rates	Inpatient	Outpatient
15.8%	15.5%	17.4%
Top Reject Reasons		
Patient Positioning	27.6% of rejects	
Incorrect Technique	27.6% of rejects	
Patient Motion	27.6% of rejects	

Yikes!

December Target Anatomy: Lateral Hip

Overall Rates	Inpatient	Outpatient
	17.8%	10.9%
Top Reject Reasons		
Patient Positioning	63% of rejects	
Incorrect Technique	14% of rejects	
Image Artifacts	6.2% of rejects	

Yikes!

What can we learn from reviewing rejected images?

Questions we try to answer

- Do we have accurate data ?
- Are we following the standard ?
- Are we rejecting good images ?
- What challenges are techs facing ?

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2. Review of Rejected Images and Data

Do we have accurate data?

Revised repeat categorization and added more detail

3 - passable
3 - collimation
11 - poor position
    7 - clipped head or acetabulum
    2 - bony superimposition - too perpendicular to pelvis
    2 - soft tissue overlap - hard to see hip
1 - technique (under)
4-(shutter failure not reprocessed)

What did we learn?

7 of 22 rejects could have been passed or made passable without retake

Lead Technologists' Review

Repeat Reason	*Comments*
Patient Positioning	? Shuttering issue not opened and re processed
Patient Motion	I do not see motion - would have passed. - (sometimes noise can mimic motion?)
Patient Positioning	Clipped acetabulum - CR too low and /or IP not high enough? -
Patient Positioning	? Shuttering issue not opened and re processed
Patient Positioning	Clipped head - CR too low and /or IP not high enough? -
Incorrect Technique Selected	should talk with this tech. this was a failed shuttering and then higher exposure on follow up. Was filter used? -
Incorrect Technique Selected	should talk with this tech. this was a failed shuttering and then higher exposure on follow up. Was filter used? -
Patient Positioning	did not open shutters post processing? -
Patient Positioning	Partial exposure or wrong exposure. Yes - also would have clipped. -
Patient Positioning	Almost identical issue from above. -
Patient Positioning	Anatomy overlap - tube not angled to bypass tissue - cannot see head. May have been clipped anyway. -
Noisy Image(s)	Anatomy overlap causing trouble seeing head - but it appears to be all there. Need more angle to bypass tissue and /or reprocess for head & send 2 images - 1 for femur, 1 for head. - (not ideal)
Incorrect Collimation	Beam too perpendicular to pelvis, bony superimposition over head. -
Patient Jewelry or Clothing	Not Artifact! Bony superimposition over head due to lack of beam angle.-
Patient Positioning	Clipped acetabulum. -
Noisy Image(s)	Underexp? Same case as above - re-processing might help salvage view? Soft tissue superimposition. -
Patient Positioning	Clipped head.
Patient Positioning	Underexp? Re-processing might help? -
Patient Positioning	Snap artifact; anatomy overlap - tube not angled to bypass tissue - can make out acetabulum.
Patient Positioning	Artifact? Pillow?
Patient Positioning	I would have passed this (after shuttering & reprocessing it) -
Patient Positioning	? Shuttering issue not opened and re processed

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2. Review of Rejected Images and Data

Are we following the standard ?

In ensuring we have good data, we may also find ways that we aren't following the standard protocol

- ✓ **Select the appropriate view on the console!**
  - **Why?** View selection chooses the image processing. The images in Figure 2 show how this affects lateral knees.
  - **Why?** View selection affects reject rates. AP knees show a 13% reject rate at SMH. If laterals had not been run as AP, the reject rate for AP knee may be closer to 7.5%.

Original image, labeled as an AP view.

Same image, reprocessed as a Lateral view.

Figure 2. The view selection at acquisition affects processing and reject analysis, even when the technique is the same!

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2. Review of Rejected Images and Data

Are we rejecting good images?

We look for images that help radiologists' define the rejection criteria.

These images can then help communicate the rejection threshold with technologists.

QUALITY IMAGE CRITIQUE

By Your request: Tips for assessing if your positioning is acceptable

Correct Central Ray is at the level of the knee joints, ½" below the apex of the patella.

What is the acceptable 'range' when critiquing the AP Knee(s) view?

- Eye the image lengthwise into 3 equal parts (top, middle, and bottom).
- Do both entire knee joints (including approximately 1" of bony anatomy) fall within the middle third section of your image?
- If so, it should be passable as long as all other factors are good (ex: rotation, motion, mag mkr, etc.)

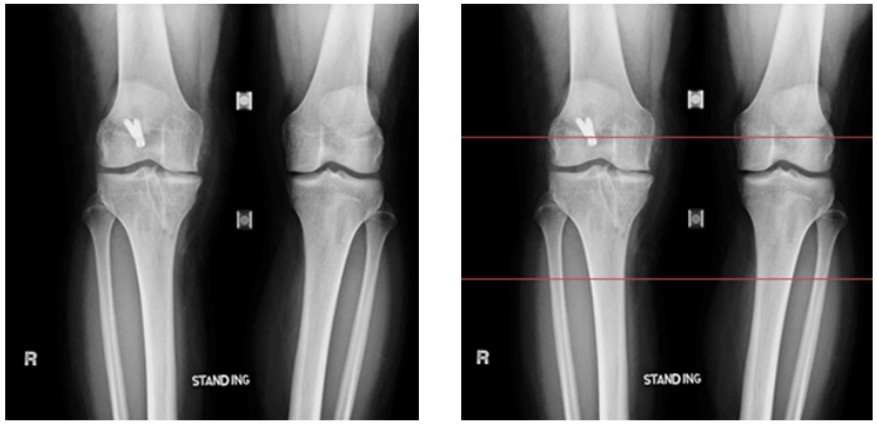

Figure 1. *Good image that was rejected. Centered a bit low, but would have been passable.*

The DR image at left was rejected; reason given: Positioning. Sometimes superimposition cannot be avoided, due to body habitus. If post-processing had been applied to this DR image, it may have been acceptable.

Repeat not needed

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2. Review of Rejected Images and Data

What challenges are technologists facing?

Examples:

- Motion on t-spines
- Shuttering failures
- Noisy AEC images with good positioning
- Frequently not being able to use the SID on the chart

Techniques and Tips for Lateral T-Spine Images

✓ Follow the technique charts!

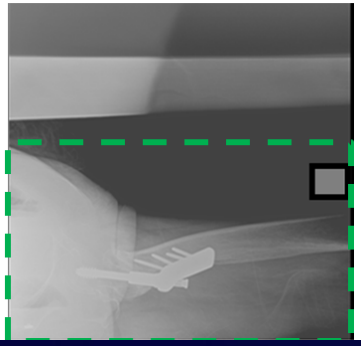
- Try AEC! We improved AEC to deliver better exposures for lateral T-spine. AEC is the best choice if you can center the t-spine so that the AEC cell is not exposed to raw radiation.
- We are moving to breath-held views only!

Techniques and Tips for Lateral Hip Images:

If you are struggling to get 48″ SID, a 55″ SID mAs has been provided as an option.

Remember processing:

If a hip looks washed out, it might be that the image processing misidentified where the hip was. On a GE unit, first check to make sure you have a good shutter (region of interest selection) then reprocess. On Philips, learn about the "green snow" and how to move it around.



The image at left looks like it has been underexposed or poorly penetrated. It has not. It is actually overexposed. It needs to be shuttered (to the area indicated by the green square) and reprocessed. If you have any questions about whether to reprocess or re-expose, contact a lead.

Using suggested techniques may also help in avoiding shuttering failure.

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3. Review of Accepted Images and Data

Lessons from team review of accepted images and data?

Questions we try to answer

-What is working well?

- Are we following the expected protocols?

- Does the protocol need optimization?

- What challenges are techs facing?

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3. Review of Accepted Images and Data

Are we following expected protocol ?

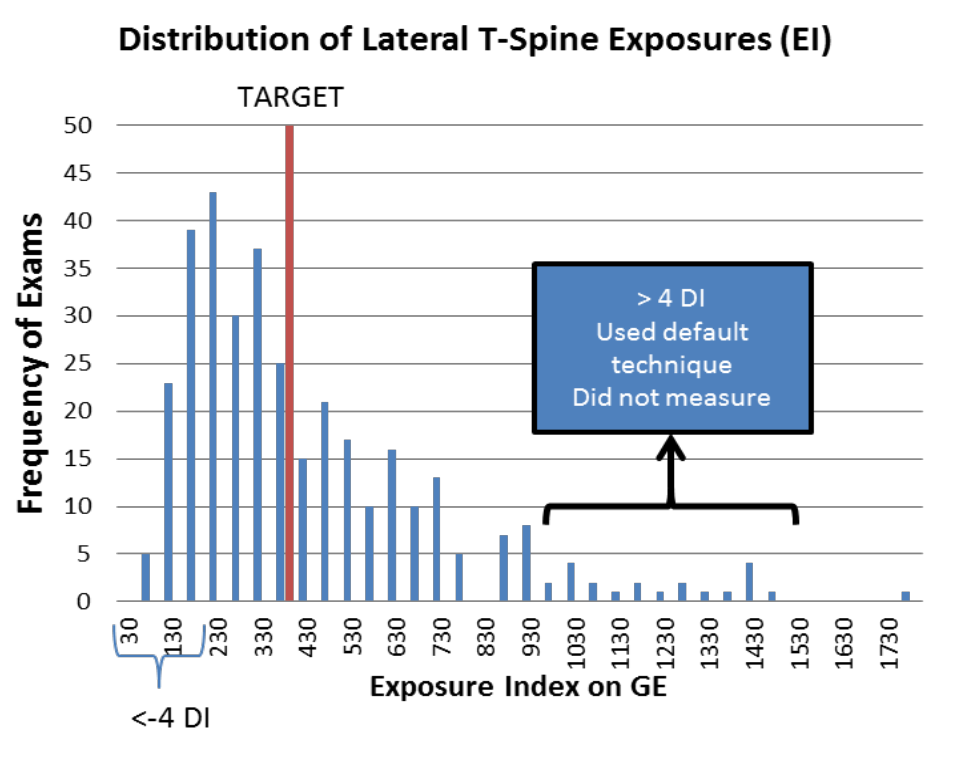

Image review is crucial for Exposure Index Analysis to understand the value and meaning as a metric of appropriate exposure.

For many body parts, appropriately acquired images may show high variability in EI*

* Jamil A, Mohd MI, Zain NM J Med Radiat Sci 66 (2019) 38–43

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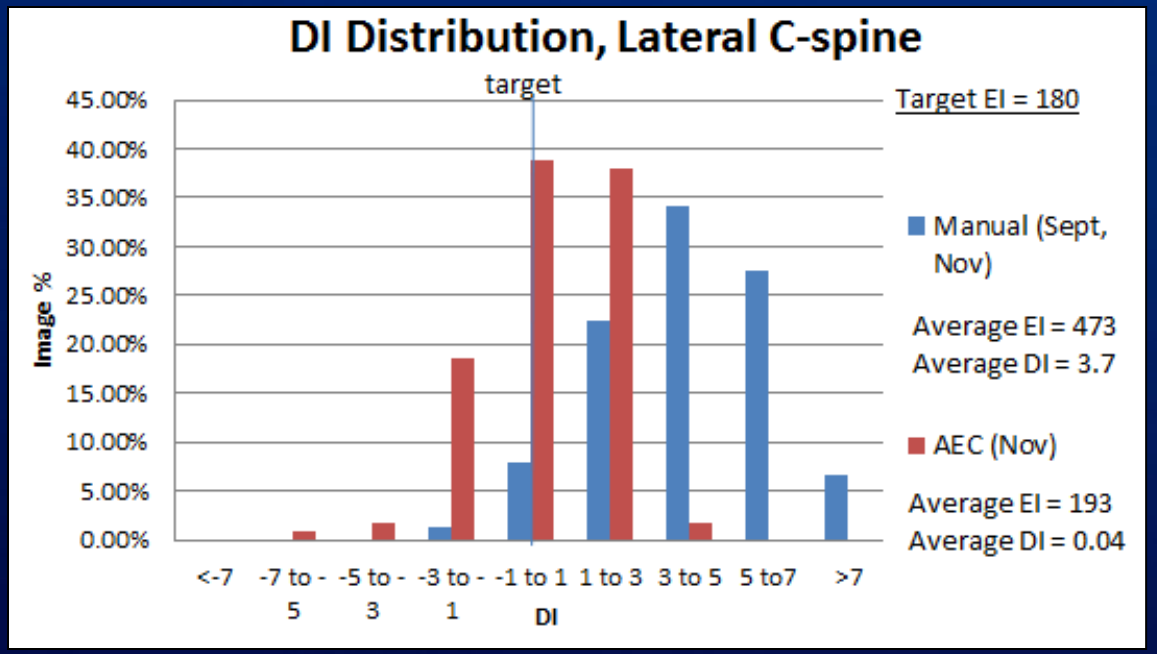
3. Review of Accepted Images and Data

Does the standard protocol need optimization?



Manual techniques are too high.

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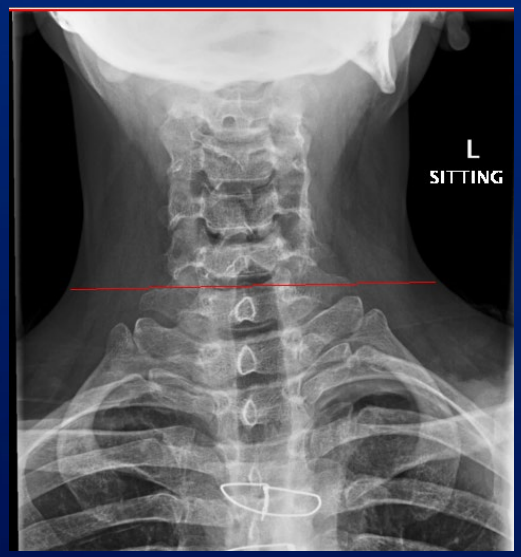
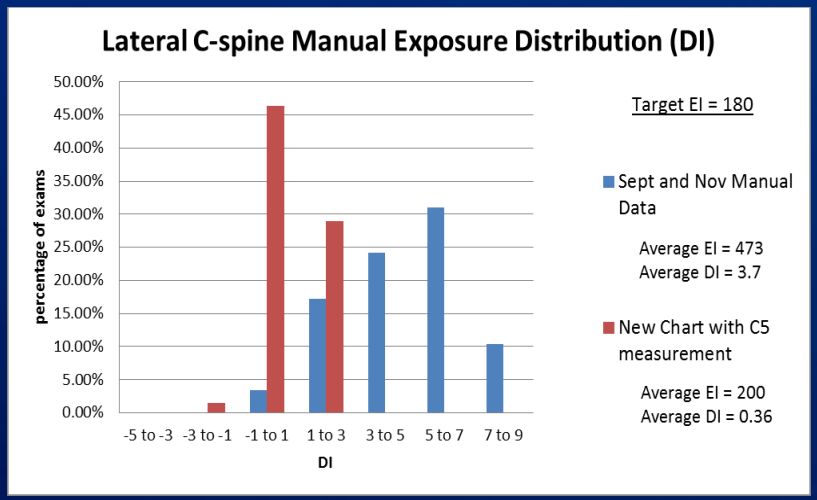
3. Review of Accepted Images and Data

What challenges are technologists facing in meeting the standard?





With exposure (EI)* data we can estimate mAs needed to achieve EI target. We can see cases where no matter how accurately we measure, manual techniques don't give consistent results.

Previously measuring at C6 led to high variability in manual exposures. Using C5 was better. Though AEC was better yet!

* If the EI data is demonstrated to have good correlation with quality of exposure

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4. Discuss and Summarize Gaps

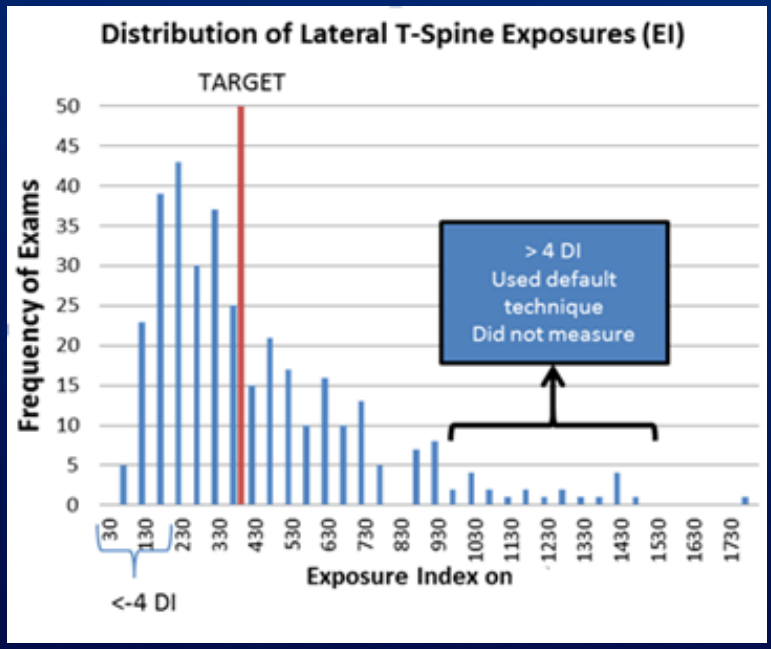
Collaboration between technologists and physicists helps create meaningful understanding of quality gaps.

Common lore that AEC didn't work well for lat t-spines

	Apr to Nov 2016
AEC usage %	4%

For lateral t-spine images from all of last year:

- 95 % were shot manual
- 60% of manual exams used the default generator technique that was **not** listed on the charts



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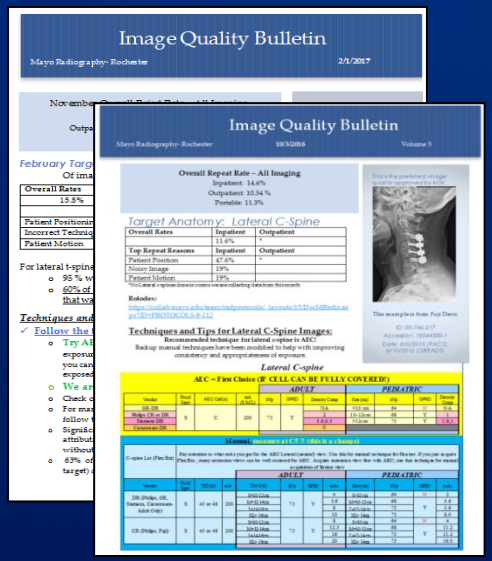
5. Interventions

- Technique Chart Changes
- AEC response Changes
- System Default Changes
- Image Processing Changes
- Technologist Education

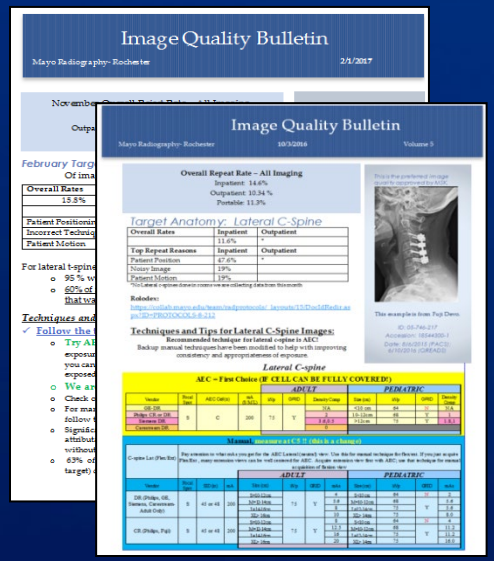


Bimonthly bulletin summarized system changes and tips and tricks

5. Interventions

Bimonthly Image Quality Bulletin summary

- Baseline reject and other QA data for one anatomical-view
- Follow-up reject and other QA data (post intervention) for another anatomical-view
- System changes and tips and tricks

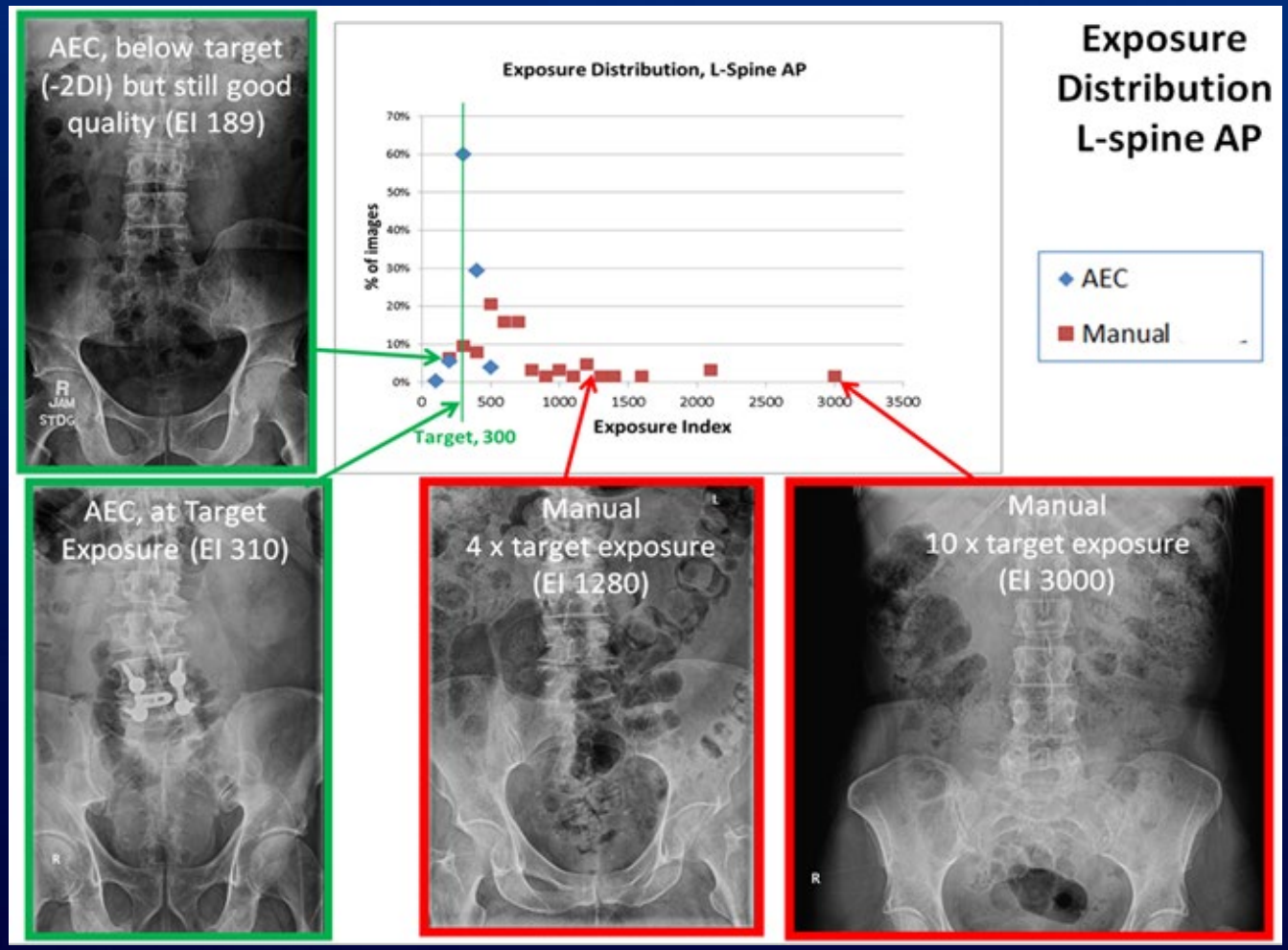


Review of the bulletin prior to publishing facilitated conversation between radiologists and technologists about quality and ideas for improvement

Focused on a specific anatomical view

5. Interventions

Image-based Education

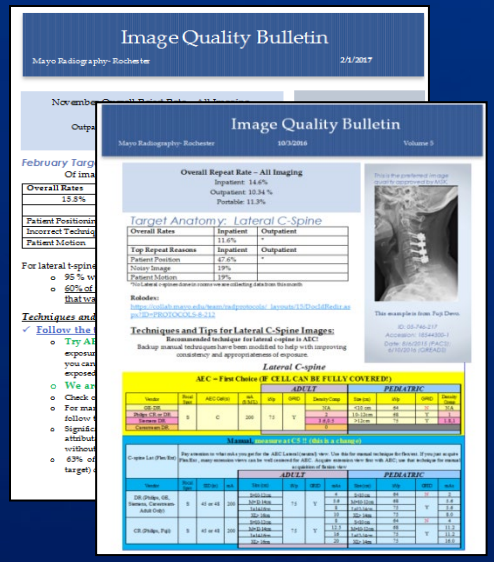


5. Interventions

We posted "nuggets" from techs who were finding success in areas identified as challenges

Technologist's Nugget

"If they have a knee replacement, I tend to internally rotate that knee a bit. I usually use the scar on the leg as a guide, but not as an absolute. I feel you really have to visualize the knees and not go by what the feet are doing. Even if the feet were parallel, that doesn't always make the knees AP. So I focus on both knees and move them accordingly to make each knee AP." -



Here are Pete's hints: *'For challenging patients, 2 techs are better than 1 for getting patients sitting as upright as possible. As far as the backboard, the one thing I ALWAYS do is to make sure it is centered on the patient and perpendicular to the chest machine.'* Thanks, Pete!

"The last thing I do is look at my filter and see where the filter shadowing is on the body. I want to make sure the light is shining just underneath the shoulder. And if that seems high or low, I reposition the bucky up or down. Ultimately I feel like I shoot my AP first to see if I need to go up or down. (This is if I'm only doing a T-spine exam.) Concerning front to back, I feel like the patient has to step forward a bit. The central ray needs to be more posterior because much of the T-spine is more posterior."

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6. Results and Control

Table 1: Noisy image repeats resolved

Lateral C-Spine

July Reject Rate: 11.6%	*November Reject Rate: 7.9%*
Noisy Image % of rejects: 19%	*Noisy Image % of rejects: 0%*

LATERAL C-SPINE		AEC	Manual
July 2016	Average EI	184.6	412.6
	Std Dev EI	65	262.9
March + April 2017	Average EI	206	219
	Std Dev EI	72	115

Table 2:

Manual excess exposure reduced by 83 %

Manual exposure variability reduced by 56%

	Baseline	Post-Intervention
	July, Aug, Sept	Nov, Jan, Feb, Mar
Total Image Count	402	511
Rejected Images	54	51
Reject Rate	13.4%	10.0%
Accepted Images Reviewed	86	216
Quality Rank of 3+	97.7%	96.7%

Figure 7:

Modest reject rate reduction seen with continued follow-up. Quality rank either not affected or not sufficiently sensitive

6. Results and Control

Follow-up Anatomy: Lateral T-Spine

November 2016 (N=184 images)			March 2017 (N= 136 images)		
Overall Rates	**Inpatient**	**Outpatient**	**Overall Rates**	**Inpatient**	**Outpatient**
15.8%	15.5%	17.4%	14.3%	14.9%	12.2%
Top Reject Reasons			**Top Reject Reasons**		
Patient Positioning	27.6% of rejects		Patient Positioning	52.6% of rejects	
Incorrect Technique	27.6% of rejects		Artifacts	10.5%	
Patient Motion	27.6% of rejects		Patient motion	10.5%	

1. After techs were encouraged to use AEC for lateral T-spine, AEC usage increased significantly!

	Apr to Nov 2016	March 2017
AEC usage %	4%	56%

With additional data from AEC, we were better able to set our exposure targets. New EI target set for GE DR of 225 for adult lateral T-spines shot at 70kVP.

6. Results and Control

- We didn't always see a reject rate reduction
- But we did learn many things to help us improved toward image quality standardization and better optimization.

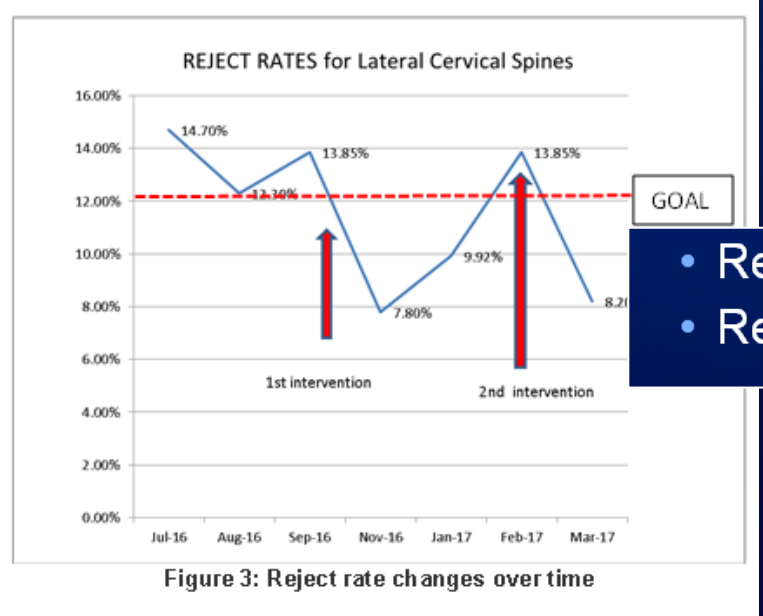

Figure 3: Reject rate changes over time

- Reduced manual over-exposure by 55%
- Reduced manual variability in exposure by 30%

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Considerations

Comprehensive DR QA can be time consuming and complicated.

Structure is needed for effective and viable program.

Keys findings:

1. Structure program to realistically pair resources with activity: break-it-down to meaningful bites.
2. Assign dedicated people including techs, physics and radiologists.
   - DR systems can be complicated, find good system experts.
   - Work with techs who have a good pulse on the practice, who are active in the practice, who understand tech challenges
   - Radiologists can have different preferences, talk with practice about working with one who can make the calls rather than continually chasing different targets .
3. Informatics tools can save time and uncover patterns. Talk with the vendors about getting easier access to your image data!

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Summary

Because of the challenges inherent with DR, QA review (quality feedback loop) is essential for standardization

QA review assists techs:

- to have similar ideas about targets
- to understand how and why to achieve targets

QA review helps ensure:

- systems are set up properly for standard work

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Questions & Discussion