Case Reviews in CT and Fluoroscopy

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Disclosures

- Rani Al-Senan: None
- Karen Brown: None

Case 1: Noise fluctuation in CT

Reported by: CT technologist

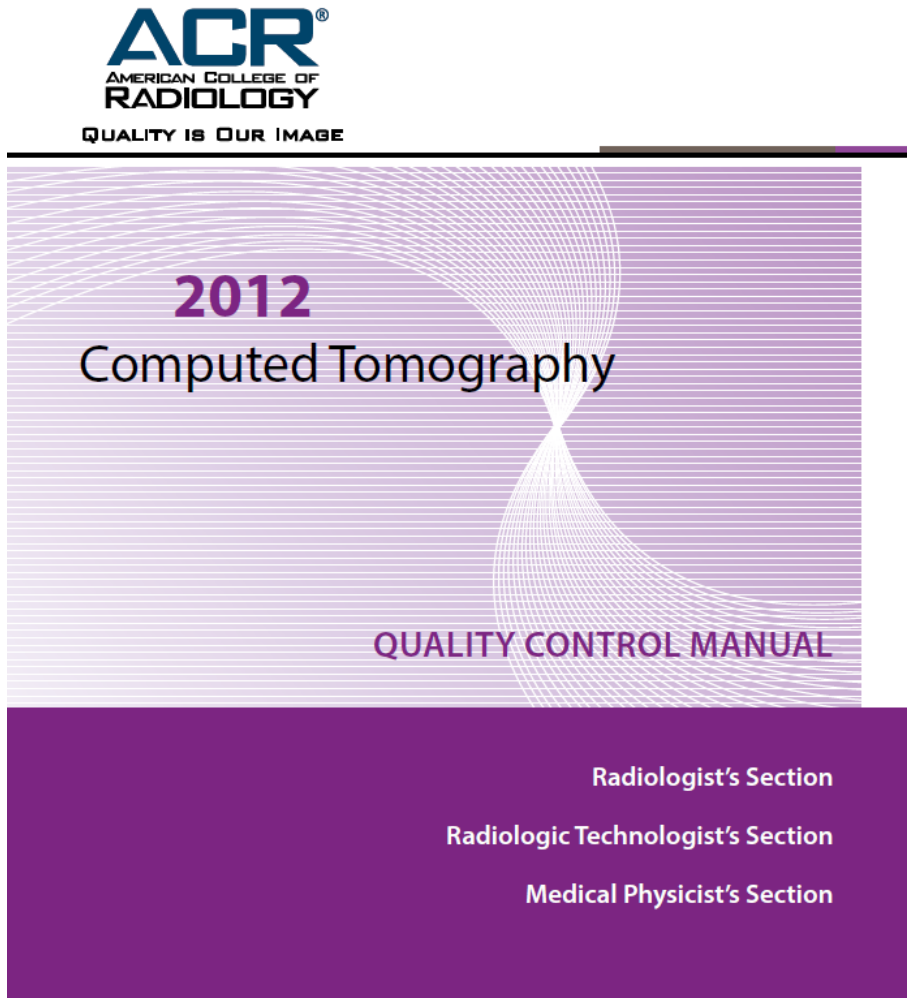
Problem: Axial water standard deviation out of tolerance 3 times within the last 7 days

Additional information: no service or maintenance had been recently conducted

Case 1: Noise fluctuation in CT

Background:

- Daily QC is performed using modified protocol found in the 2012 ACR CT Quality Control Manual and the manufacturer provided QC phantom
  - Mean water CT number and noise (standard deviation) measured in both helical and axial modes.
  - Measurements made on images from the center, and near the leading edge, of the scanned volume for helical scans and in a central image for the axial scan
  - Axial scan is also used to evaluate for artifacts
- 2017 ACR CT Quality Control Manual
  - Daily CT number and standard deviation measurements
  - Failures should be reported to QMP for guidance



Case 1: Noise fluctuation in CT

Investigation Step 1:

- Review daily QC records
  - Review data for entry errors
  - Trends
  - Abrupt changes
- Findings
  - First two dates values were just out of tolerance
  - Measurements were back in tolerance for two days and then went out again
  - Some inconsistencies in the slice that was selected for measurement

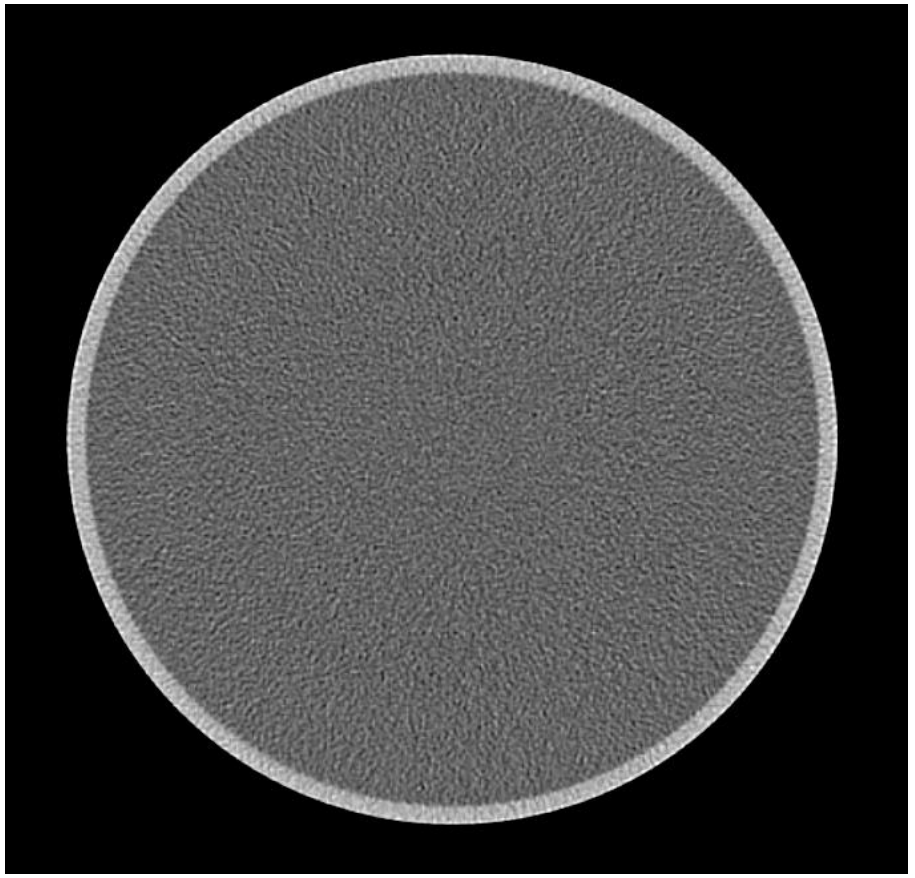
Facility:	Penn State Hershey Medical Center											Water CT# Tolerance:	0 ± 5
Scanner:	CT Rm 1 (previously CT4)											Water SD Tolerance(Helical):	5.0 ± 1.0
												Water SD Tolerance(Axial):	50 ± 10
Note:	**If any single Water CT# or SD value fails 3 days in a row or 3 times in any 7 day period notifiy senior techs.**												
	If artifacts are observed, clean the gantry ring, repeat the CT check-up, and repeat artifact scan. If artifacts remain, notify senior techs.												

Date	Initials	Edge Slice Helical Scan			Center Slice Helical Scan			Center Slice Axial Scan			Axial Artifacts (P/F)	Notes
		Slice	Water CT#	Water SD	Slice	Water CT#	Water SD	Slice	Water CT#	Water SD		
11/1/2019	cmm	13	0.5	5.2	20	0.3	5	99	-0.1	54.4	p	
11/2/2019												
11/3/2019												
11/4/2019	cns	12	0.5	5	22	0.2	5.1	116	-0.3	40.3	p	
11/5/2019	amb	10	0.3	4.9	23	0.3	5.2	110	-0.2	44	p	
11/6/2019	cmm	14	0.1	5.2	20	-0.4	5.2	99	-0.2	54	p	
11/7/2019	amb	12	-0.7	5	19	0.4	5.1	91	-0.3	60.7	p	
11/8/2019	TB	15	0.3	4.7	24	0.2	5.2	140	0.5	61.9	p	
11/9/2019												
11/10/2019												
11/11/2019	hmk	15	-0.6	5.3	25	0.1	5.1	108	-0.1	55.7	p	
11/12/2019	cmm	13	-0.3	5.1	21	0.1	5.2	104	-0.7	55.9	p	
11/13/2019	amb	11	-0.9	4.9	18	-0.2	5.4	86	-0.4	67.6	p	

Case 1: Noise fluctuation in CT

Investigation Step 2:

- Review phantom QC Images
  - Look for artifacts
  - Any significant changes in image uniformity and/or noise
- Findings
  - Artifacts were not observed
  - Image uniformity and noise was visibly consistent



Case 1: Noise fluctuation in CT

Investigation Step 3:

- Review the QC protocol
  - Verify the correct protocol is being used consistently
  - Determine if any changes to the protocol were made
- Findings
  - Inconsistencies in protocol implementation were not identified
- Could the sharp reconstruction filter be a contributing factor to the noise variation being observed?

CT Daily QC Procedure

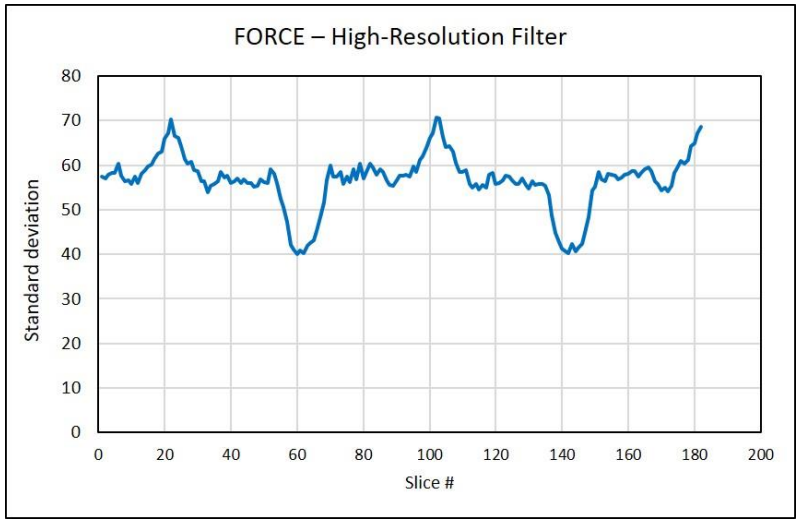
1. Wipe gantry ring to remove any contrast agent residue.
2. Perform CT check-up
3. Place QC phantom at scanner isocenter
4. Select daily qc protocol
5. Perform topogram
6. Plan scan through uniform section of the phantom. DO NOT change field of view.
7. Select slice near the beginning of the reconstructed data set
8. Select Image Graphics and click on the cross hair icon. Place the cross hairs at the center of the selected image
9. Draw an ROI and enlarge to 2 hash marks in all directions from the center of the image.
10. Record the mean CT# and standard deviation on the daily qc form
11. Select the center slice of the reconstructed data set
12. Select Image Graphics and click on the cross hair icon. Place the cross hairs at the center of the selected image
13. Draw an ROI and enlarge to 2 hash marks in all directions from the center of the image.
14. Record the mean CT# and standard deviation on the daily qc form
15. If either the mean CT number of the standard deviation is not within tolerance criteria for 3 days in a row or 3 times in a 7-day period report the problem to senior CT staff.
16. Perform axial scans overlapping and spanning the uniform section of the phantom. DO NOT change field of view.
    a. 120 kVp, 400 mAs, B70 reconstruction filter
17. Select the center slice of the axial data set
18. Select Image Graphics and click on the cross hair icon. Place the cross hairs at the center of the selected image
19. Draw an ROI and enlarge to 2 hash marks in all directions from the center of the image.
20. Record the mean CT# and standard deviation on the daily qc form
21. If either the mean CT number of the standard deviation is not within tolerance criteria for 3 days in a row or 3 times in a 7-day period report the problem to senior CT staff.
22. Carefully inspect each axial image in the data set for rings, streaks, lines, etc. that should not be in the image.
23. If artifacts are observed. Repeat the CT check-up procedure, repeat the axial scans, and re-evaluate the images for artifacts.
24. If artifacts persist, report to senior CT technologist. Do not use scanner for patient imaging unless directed.
25. Record results and comments on daily QC form.

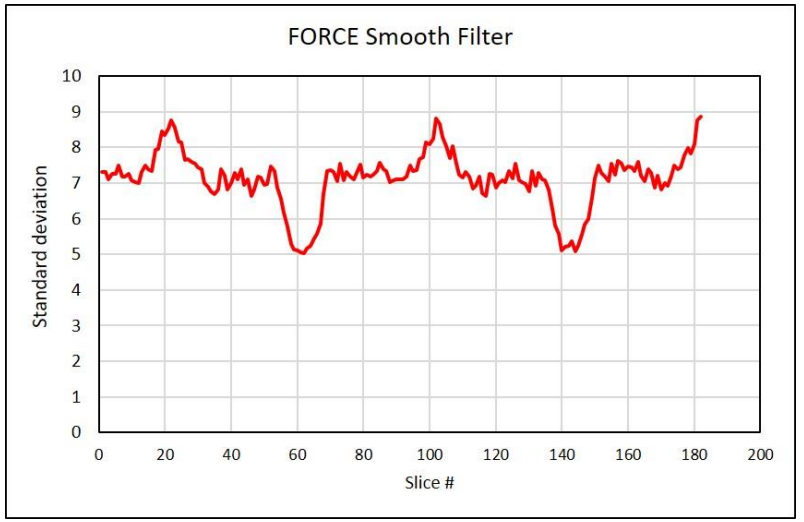
Case 1: Noise fluctuation in CT

Experiment:

- Acquire the QC phantom using sharp and smooth reconstruction algorithms to evaluate the effect on noise fluctuation.

- Finding:
  - A consistent pattern of noise fluctuation was observed.
  - Reconstruction filter affected the magnitude of standard deviation measurement as expected.
  - Noise fluctuation was not affected by the reconstruction filter



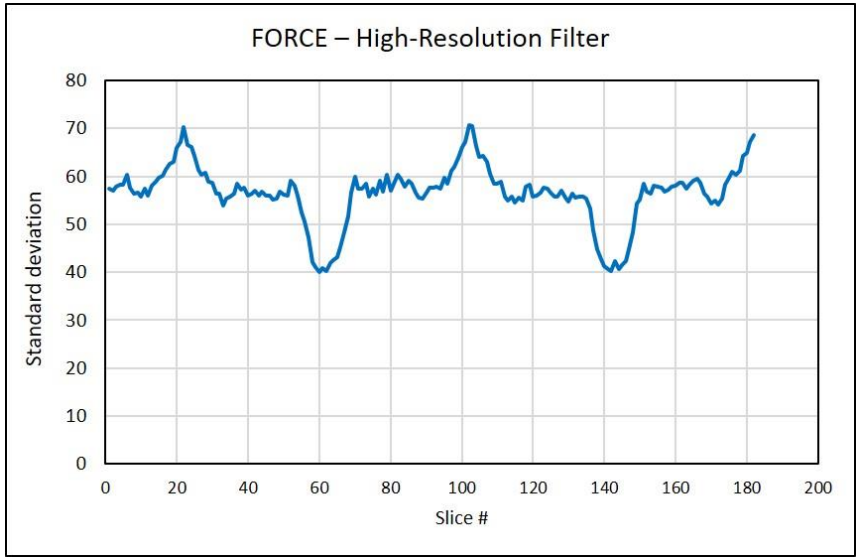


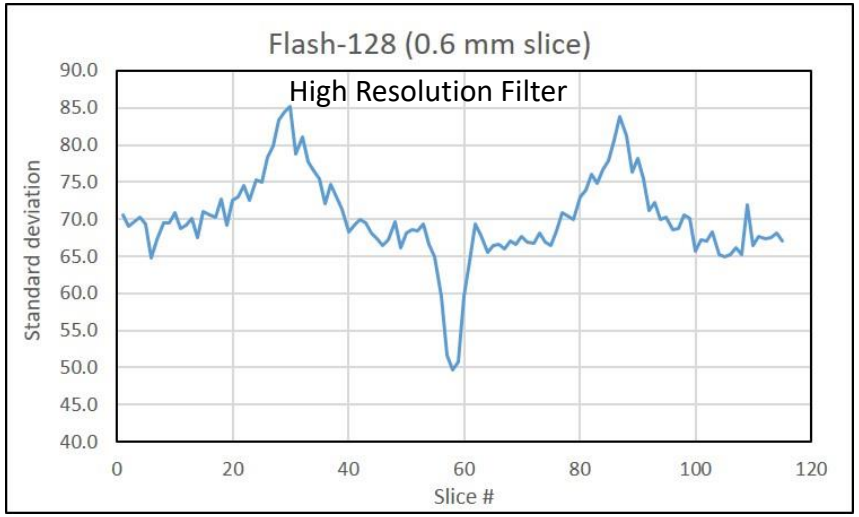
Case 1: Noise fluctuation in CT

Experiment:

- Acquire the QC phantom on all scanners to evaluate potential noise fluctuations

- Finding:
  - Consistent pattern of noise fluctuation was observed.
  - Spacing between peaks and valleys was consistent on all Flash-128 scanners
  - Peak spacing was extended on Force scanner
    - Difference in peak spacing was consistent with difference in width of detector array

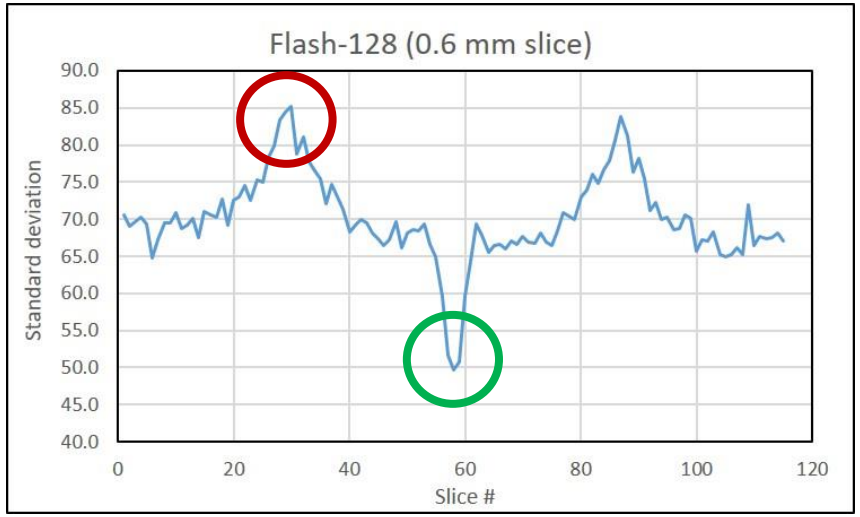




Case 1: Noise fluctuation in CT

Vendor confirmed:

- Peak increases in noise are due to missing cross-talk signal between two detector tiles used in the z-direction.
- Peak decreases in noise are due to overlapping scan data.
- Not considered an actionable item as the system is performing as intended and no clinical impact is expected.

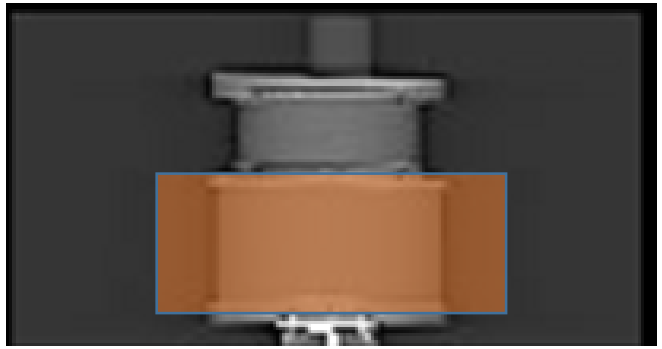


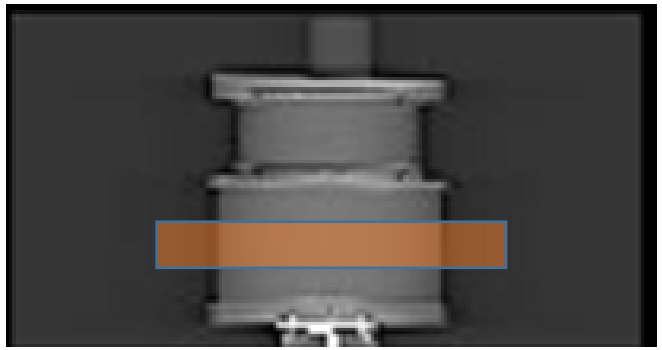
Case 1: Noise fluctuation in CT

Root cause:

- Procedure indicates the entire region of the uniform section should be scanned
  - Requires 3+ rotations of the beam to cover
  - Produces over 200 images
- Technologist selects slice at their own discretion near the middle of the scanned volume
  - Slice selected occasionally falls on an image at either end of a beam path where the fluctuations in noise are most severe.

- Corrective actions:
  - Change the QC protocol to indicate only one axial rotation through the center of the uniform section.
  - Identify a specific slice for measurement of noise standard deviation.





Case 2: CT Streak Artifacts

Identified by: Physicist

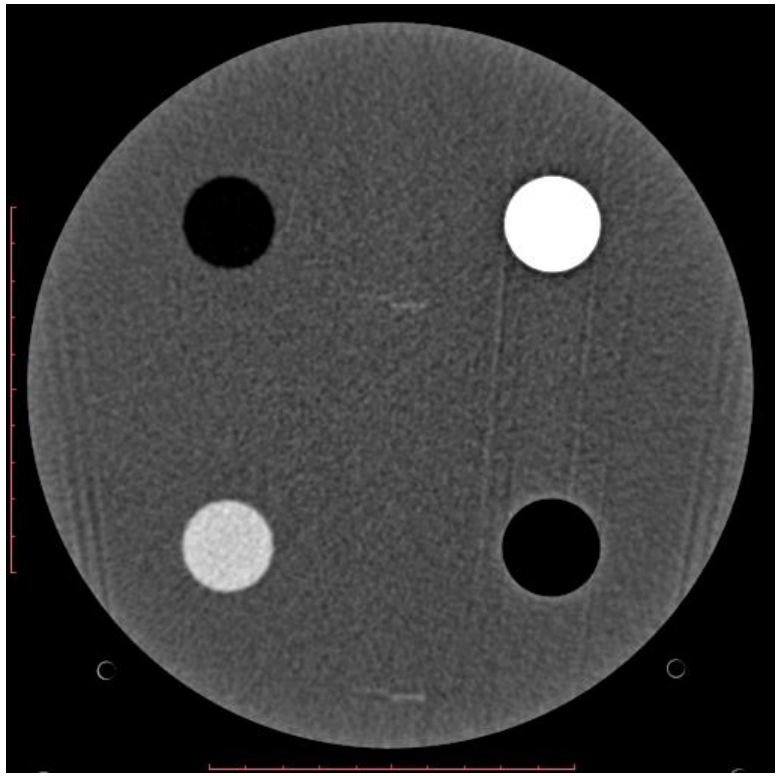
Problem: Streak artifacts were identified during ACR accreditation renewal phantom testing

Additional information: no equipment problems or artifacts from this unit had been reported to physics

Case 2: CT Streak Artifacts

Investigation Step 1:

- Review all ACR phantom images
  - Determine type and extent of artifacts
- Findings
  - Artifacts were present on pediatric brain and adult brain phantom scans but were not seen on adult or pediatric abdomen phantom scans.
  - Artifacts were not present in all images within the scans
- Tube arcing was suspected due to random appearance through images
  - Were we seeing these artifacts on daily QC and clinical images?
  - If so, for how long?

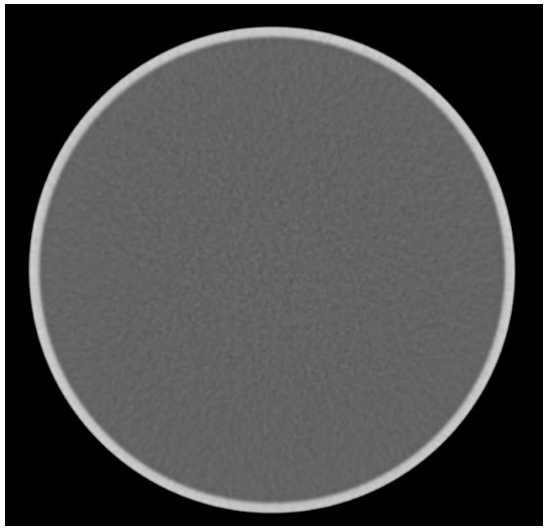


Case 2: CT Streak Artifacts

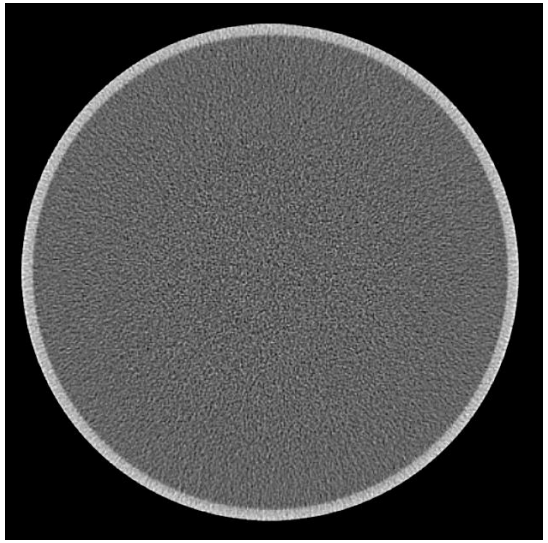
Investigation Step 2:

- Review daily QC phantom images
  - Review helical and axial images
  - Determine if artifacts are present and to what extent
- Findings
  - Artifacts were not observed
  - Helical and axial QC scans are acquired using a modified abdomen protocol
  - QC images from the previous two days were available for review
  - Older QC images had been deleted from the scanner

Helical QC Scan



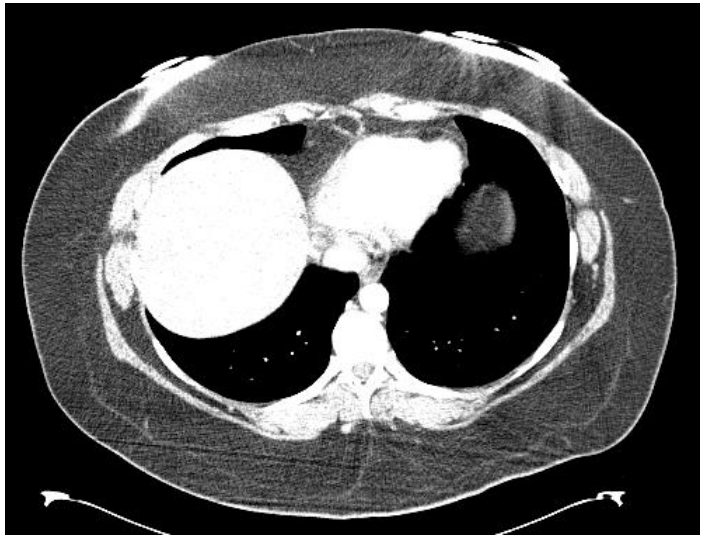
Axial QC Scan



Case 2: CT Streak Artifacts

Investigation Step 3:

- Review clinical images
  - Determine if artifacts are present and to what extent
  - Start review on date of testing and work backward chronologically
- Findings
  - Observed artifacts on some clinical images and not on others
  - Artifacts were isolated to a few images within the scan range
  - Artifact was observed on scans several days prior to identification by the physicist



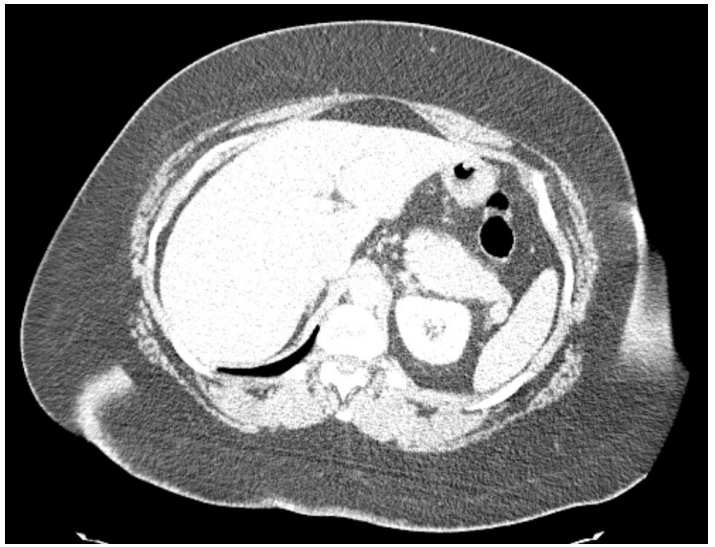
Case 2: CT Streak Artifacts

Re-defining the problem:

- Streak artifacts were present on clinical images several days prior to identification by the physicist
- Why had the problem not been reported to physics or clinical engineering?

Clinical examples of artifacts were presented to technologists and physicians

- Were able to recognize artifacts in the images
  - Artifacts appeared similar to metal streak artifacts which they are accustomed to seeing
  - Artifacts did not interfere with clinical interpretation



Case 2: CT Streak Artifacts

Root cause:

- Tube arcing was suspected; not confirmed with vendor

Corrective actions:

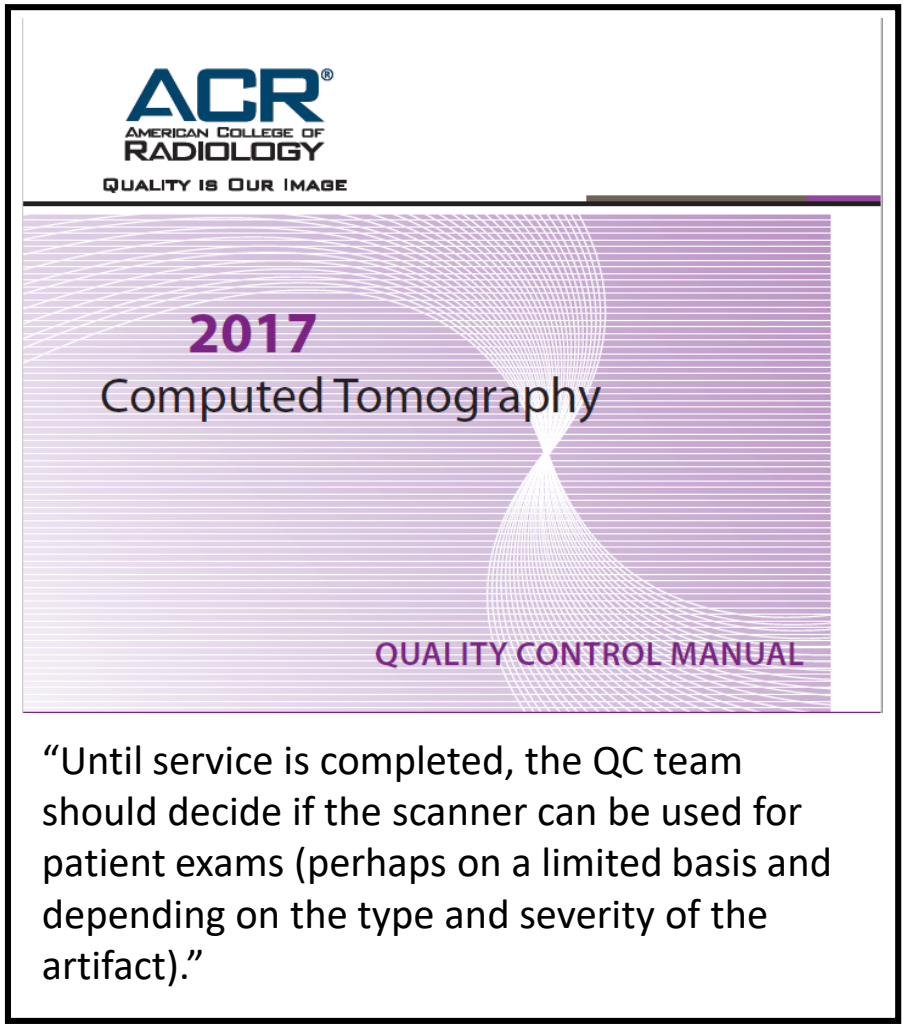
- X-ray tube replaced, ACR testing repeated with adequate results

The BIGGER problem!

- Clinical staff seemed indifferent to presence of the artifacts or the need to report the issues

Corrective actions

- Identify a process for identifying, reporting, and responding to artifacts
- Have daily phantom QC images sent to AQNET server for review by an imaging physicist



"Until service is completed, the QC team should decide if the scanner can be used for patient exams (perhaps on a limited basis and depending on the type and severity of the artifact)."

Case 3: Fluroscopy Temporal Resolution

Reported by: Physician

Problem: Poor temporal resolution in video fluoroscopic feeding studies

Additional information: Speech therapy communicated the issue to the Radiologists

Case 3: Fluoroscopy Temporal Resolution

Background:

- Speech therapy personnel indicated that the “national standard” for these studies was to use 30 pps for image acquisition
- The physician provided the following information:
  - Exams were currently acquired at 7.5 pps
  - Had been told the system had a 15 pps setting but was skeptical about increasing due to patient dose concerns
  - The studies normally used 2-3 minutes of fluoroscopy time
  - His questions for us were:
    - What is the difference in radiation dose between 30 pps and continuous fluoroscopy?
    - Should we be using a higher pulse rate setting or continuous fluoroscopy for these studies?
- There was only one fluoroscopy unit used to perform these procedures

Case 3: Fluoroscopy Temporal Resolution

Investigation Step 1:

- Review the last radiation output check for the equipment in question
  - Compare outputs at different pulse rates
  - Determine if another setting may give similar dose rate but with higher temporal resolution
- Findings:
  - The highest pulse rate setting on the report was 7.5 pps

PATIENT ENTRANCE EXPOSURE:

Mode:	Continuous fluoro			Mode:	Continuous Low			Mode:	7.5 pps normal			Mode:	3.5 pps, normal		
Mag	mR/min	kVp	mA	Mag	mR/min	kVp	mA	Mag	mR/min	kVp	mA	Mag	mR/min	kVp	mA
N	2179	79	1.7	N	1503	72	1.4	N	1983	76	1.6	N	1527	78	1.2
1	2429	81	1.8	1	1663	74	1.5	1	2236	78	1.7	1	1741	80	1.2
2	2692	83	1.9	2	1822	76	1.5	2	2512	80	1.9	2	1823	82	1.3
3	3556	89	2.2	3	2358	81	1.7	3	3226	85	2.2	3	2520	87	1.6
4				4				4				4			
5				5				5				5			
Max	8605	110	3.5	Max	8505	110	3.5	Max	8896	110	3.5	Max	8952	110	3.5

Mode:	1.5 pps, normal			Mode:	7.5 pps, low			Mode:	3.5 pps, low			Mode:	1.5 pps, low		
Mag	mR/min	kVp	mA	Mag	mR/min	kVp	mA	Mag	mR/min	kVp	mA	Mag	mR/min	kVp	mA
N	857	81	0.7	N	1334	70	1.3	N	1010	72	0.9	N	670	75	0.5
1	1009	84	0.7	1	1487	72	1.4	1	1132	73	1.0	1	752	77	0.6
2	1124	86	0.8	2	1645	73	1.4	2	1211	75	1.0	2	804	78	0.6
3	1509	92	0.9	3	2110	77	1.7	3	1620	79	1.2	3	985	83	0.7
4				4				4				4			
5				5				5				5			
Max	9295	110	3.5	Max	8949	110	3.5	Max	8940	110	3.5	Max	8653	110	3.5

Mode:	7.5 pps, +			Mode:	3.5 pps, +			Mode:	1.5 pps, +			Mode:	Continuous small - large pt		
Mag	mR/min	kVp	mA	Mag	mR/min	kVp	mA	Mag	mR/min	kVp	mA	pt size	mR/min	kVp	mA
N	2481	79	1.9	N	1871	81	1.3	N	1131	85	0.8	small	1068	85	1.5
1	2814	81	2.0	1	2141	83	1.4	1	1301	88	0.8	•	1066	85	1.5
2	3023	83	2.1	2	2301	85	1.5	2	1363	90	0.9	•	1088	85	1.5
3	3790	94	2.1	3	3154	92	1.8	3	1582	99	1.0	med	2176	79	1.7
4				4				4				•	2179	79	1.7
5				5				5				•	2178	79	1.7
Max	8880	110	3.5	Max	8910	110	3.5	Max	8445	110	3.5	large	2187	79	1.7

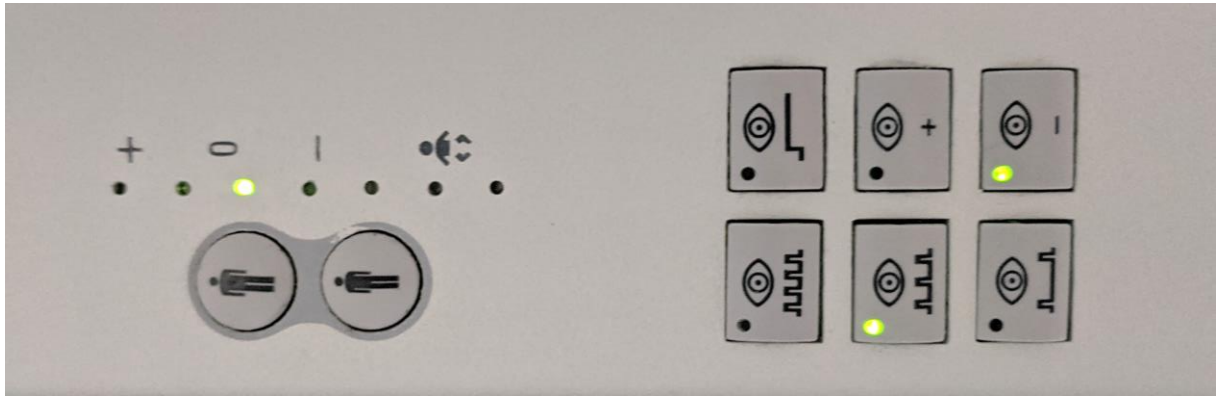
Case 3: Fluoroscopy Temporal Resolution

Investigation Step 2:

- Look at the equipment to determine what settings are available on the unit
- Ask the technologist what settings they use for swallow studies

Findings:

- The button icons were not very helpful
- The technologist indicated they set the system as shown in the diagram
- Correlating to the report that would be 3.5 pps low dose



Case 3: Fluoroscopy Temporal Resolution

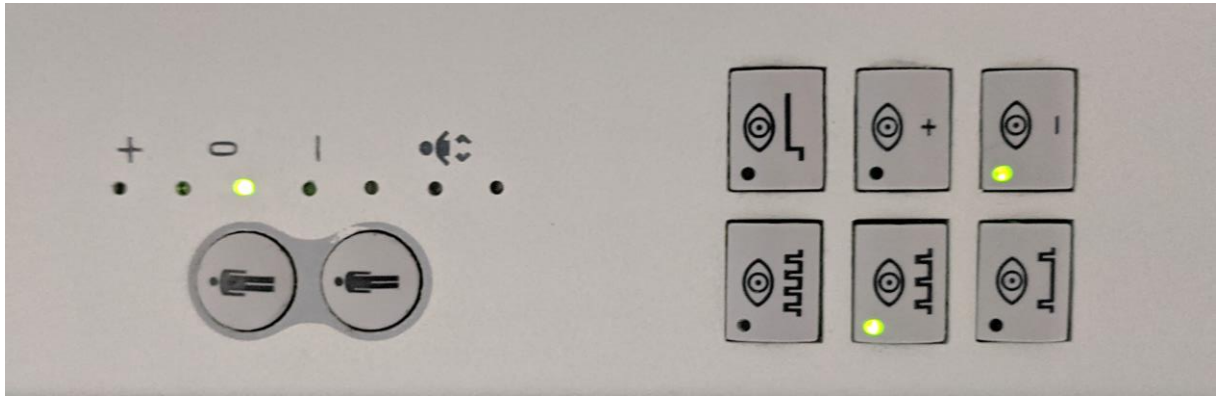
Investigation Step 3:

Check the operating console

- Can the pulse rate settings be adjusted at the console?
- Does the procedure selected affect the pulse rates available?

Findings:

- Pulse rates do change depending on the procedures selected
- The setting for “Swallow” studies changes the pulse rates to 15 pps, 7.5 pps, and 3.5 pps



Case 3: Fluoroscopy Temporal Resolution

Follow-up:

Re-measure the output rates on the swallow setting

Findings:

- The output rate at 15 pps was slightly higher than in continuous mode
- Which mode should be used? Continuous or 15 pps?

PATIENT ENTRANCE EXPOSURE:

Mode:	Continuous			Mode:	Continuous Low			Mode:	15 fr/sec		
Mag	mR/min	kVp	mA	Mag	mR/min	kVp	mA	mA	mR/min	kVp	mA
N	2471	84	1.9	N	1687	74	1.6	N	2974	80	2.3
1	2667	83	1.8	1	1791	75	1.5	1	3195	82	2.2
2	2883	84	1.9	2	1924	76	1.6	2	3325	85	2.2
3	3661	89	2.2	3	2407	81	1.7	3	3830	96	2.0
4				4				4			
5				5				5			
Max	8982	110	3.6	Max	8906	110	3.5	Max	8336	110	3.5

Mode:	7.5 pps			Mode:	7.5 pps Low			Mode:	3.5 pps		
Mag	mR/min	kVp	mA	Mag	mR/min	kVp	mA	mA	mR/min	kVp	mA
N	2159	78	1.7	N	1450	72	1.3	N	1645	80	1.2
1	2353	79	1.8	1	1549	73	1.4	1	1787	81	1.3
2	2569	80	1.9	2	1682	74	1.5	2	1969	83	1.4
3	3370	85	2.2	3	2163	77	1.7	3	2560	87	1.6
4				4				4			
5				5				5			
Max	8875	110	3.5	Max	8832	110	3.5	Max	8895	110	3.5

Case 3: Fluoroscopy Temporal Resolution

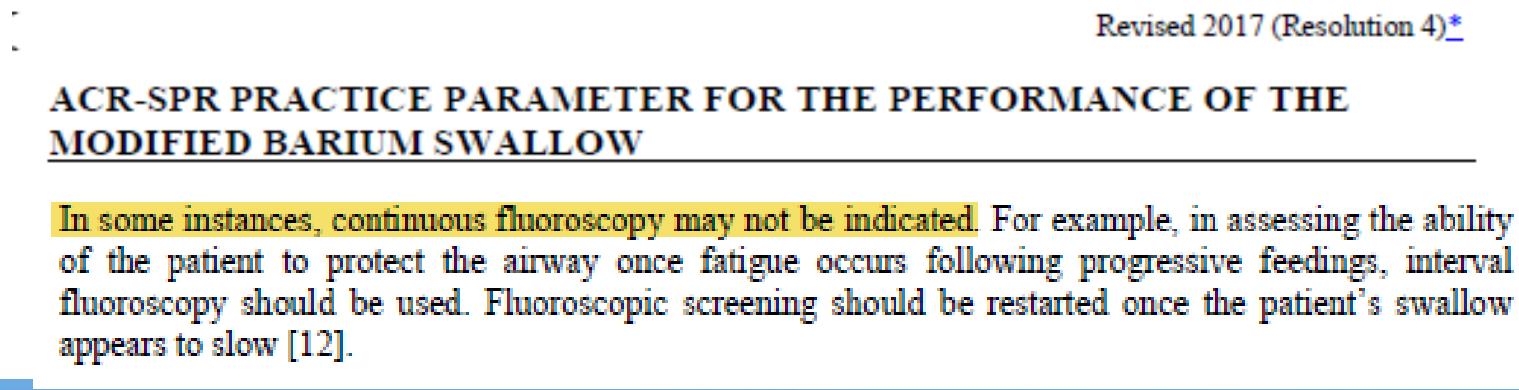
Investigation Step 4

Perform a literature search

- Verify the claim that 30 pps is the standard for these studies

Findings:

- Many GI publications indicated continuous or 30 pps fluoroscopy should be used
- Radiology publications – record at 30 pps (not less than 15 pps)
- ACR-SPR Practice parameter – “suggests” continuous fluoroscopy is normally used



Revised 2017 (Resolution 4)*

ACR-SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF THE MODIFIED BARIUM SWALLOW

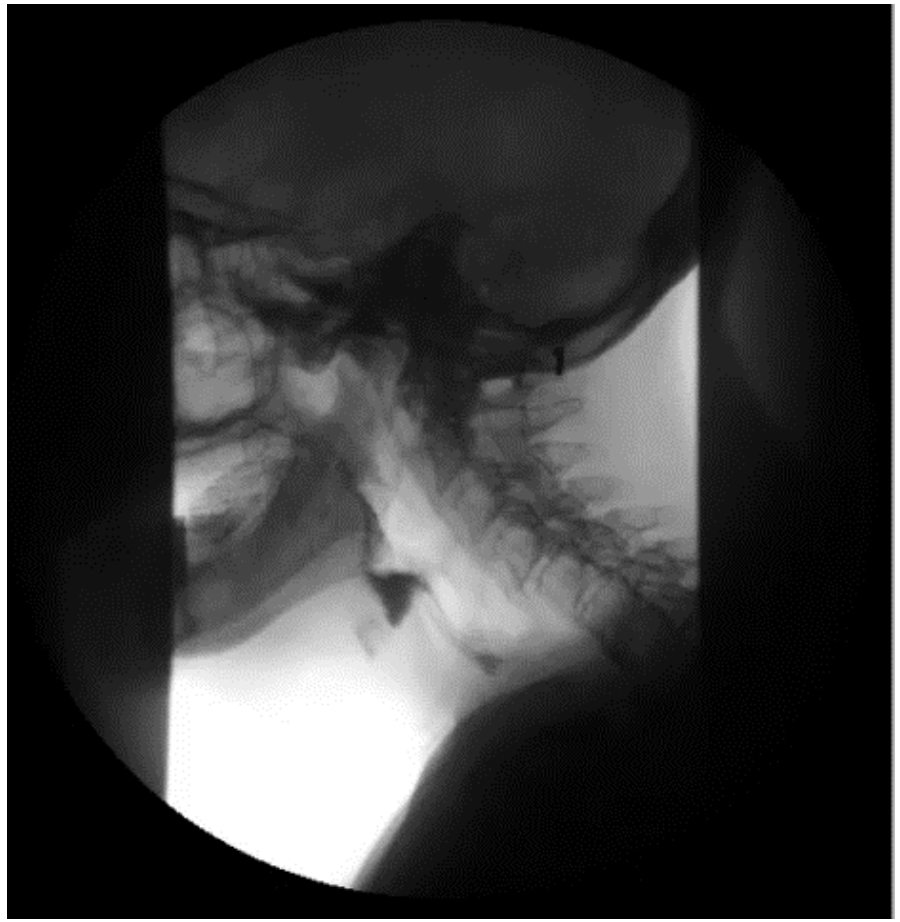
In some instances, continuous fluoroscopy may not be indicated. For example, in assessing the ability of the patient to protect the airway once fatigue occurs following progressive feedings, interval fluoroscopy should be used. Fluoroscopic screening should be restarted once the patient's swallow appears to slow [12].

Case 3: Fluoroscopy Temporal Resolution

Several cases completed using continuous, low dose setting

- Improved temporal resolution
- Increased spatial blurring
- Significant increase in number of images
  - Storage issues

Final compromise was to acquire at 15 pps



Case 3: Fluoroscopy Temporal Resolution

Final Outcomes:

- 30 pps acquisition would likely have provided the temporal resolution and adequate spatial resolution desired
  - Equipment with these capabilities was not available

Corrective actions:

- Involve physicist in equipment purchase decisions
- Physicist involvement in vendor applications training

References

- Jaffer, N et al, Fluoroscopic Evaluation of oropharyngeal Dysphagia: Anatomic, Technical, and Common Etiologic Factors, *AJR*: 204, 2015
- Cohen, M.D., Can we used pulsed fluoroscopy to decrease the radiation dose during video fluoroscopic feeding studies in children, *Clinical Radiology*: 64, 2009
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- ACR CT Quality Control Manual, 2012 & 2017

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