Reducing Variability in Orthogonal Reformatted Image Quality Associated with Large Dataset (long z-axis) CT Angiography

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No pertinent disclosures or conflicts of interest

Background

- Interpretation of CT angiography (CTA) requires evaluation of both luminal narrowing and length of stenosis to accurately triage patients to the correct treatment strategy
- Vessels are often oblique to the axial plane of CT scan acquisition

Background

- Coronal and sagittal reformatted images are critically important to assess luminal narrowing and length of stenosis, particularly in long z-axis runoff studies
- Long z-axis reconstructions are complicated by inadequate matrix size due to limitations with modern CT scanner technology

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Purpose

- To reduce the variability in image quality for orthogonal reformatted images generated from long z-axis arterial CTA studies of the upper and lower extremities

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Methods

- Institutional review board approval was waived for this Health Insurance Portability and Accountability Act (HIPAA)-compliant prospective quality improvement study
- Study quality markers were assessed by direct review of the imaging data and interrogating the DICOM header data
- Venous extremity runoffs were excluded

Methods – Overview

- Data were collected by retrospective query of applicable Current Procedural Terminology (CPT) codes
- Study period (2/1/2014 to 7/31/2015, n=789)

Methods – Overview

- After the baseline period, follow-up monthly data was collected from 10/1/2014 to 7/31/2015 concurrent with three consecutive Plan-Do-Check-Act (PDCA) cycles and a subsequent maintenance period
- Data were monitored on a statistical process control chart

Time Period	Dates
Baseline period	2/2014 to 9/2014
Three consecutive PDCA cycles	10/2014 to 4/2015
Maintenance period	5/2015 to 7/2015

Methods – 1st PDCA Cycle

- PDCA cycle 1 extended from 10/2014 to 11/2014 (n=94)
- Consisted of an educational meeting with the 3D lab technicians as well as a hands-on workshop with practical tutorials on the 3D clients

Focused primarily on human variation

Methods – 2nd PDCA Cycle

- PDCA cycle 2 extended from 12/2014 to 1/2015 (n=92)
- Consisted of ensuring uniformity amongst the individual 3D lab user preferences, adjustments of vendor-specific settings, and a leadership meeting with the 3D lab

Focused primarily on technical variation

Methods – 3rd PDCA Cycle

- PDCA cycle 3 extended from 2/2015 to 4/2015 (n=114)
- Consisted of a follow-up leadership meeting with the 3D lab to review the current proportion of correctly performed examinations, and 3D lab technician feedback to reinforce the goals of the study

Focused primarily on human variation

Methods – Maintenance Period

- The maintenance period extended from 5/2015 to 7/2015 (n=138)
- No additional interventions were performed during this period

No additional interventions performed

Methods – Data Collection

- The following data were collected for each study:

1) Type of CTA (upper or lower extremity arterial)
2) Whether sagittal and coronal reformats were performed
3) Reformat slice thickness
4) Reformat matrix size
5) Whether the reformats were in a distance measurable format
6) 3D post-processing vendor used to create the reformats

Methods – Data Collection

- A CT examination was considered correctly performed if all three of the following parameters were met:
  1) Sagittal and coronal reformats were performed
  2) A high-resolution matrix (greater than 512x512) was used
  3) The images were in a distance-measurable format (i.e., DICOM-compatible)

Methods – Data Analysis

- The proportion of correctly performed studies was determined on a monthly basis by a senior radiology resident (PGY-V) by manual review of every eligible CTA
- Rates and sigmas (±) were calculated
- An iterative root-cause analysis was performed of the monthly data during each PDCA cycle and corrective actions were implemented

Methods – Data Analysis

- A statistical process control chart (p-chart) was generated to demonstrate longitudinal results:
  - 8-month baseline period
  - 7-month quality improvement period
  - 3-month maintenance period

- Adjustments to the upper (≥3 sigma) and lower (≤3 sigma) control limits were made on the basis of accepted criteria

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Methods – Baseline Data (Where We Started)

Baseline

- Reformats available for 78% (273/351) of exams
- Of the studies with reformats:
  - 74% (202/273) used a high-resolution matrix
  - 75% (206/273) permitted distance measurements
- Only 49% (135/273) of reformats were done correctly
- Monthly rate of correctly performed studies ranged from:
  - 7% (3/43) to 51% (20/39), with a monthly mean of 38±13%

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Results – 1st PDCA Cycle
(Focus: human variation)

PDCA 1

- Reformats available for 86% (81/94) of exams
- Of the studies with reformats:
  - 91% (74/81) used a high-resolution matrix
  - 57% (46/81) permitted distance measurements
- Monthly rate of correctly performed studies ranged from:
  - 32% (17/53) to 59% (24/41), with a monthly mean of 46±14%

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Results – 2nd PDCA Cycle
(Focus: technical variation)

PDCA 2

- Reformats available for 89% (82/92) of exams
- Of the studies with reformats:
  - 90% (74/82) used a high-resolution matrix
  - 80% (66/82) permitted distance measurements
- Monthly rate of correctly performed studies ranged from:
  - 40% (16/40) to 81% (43/53), with a monthly mean of 61±21%

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Results – 3rd PDCA Cycle
(Focus: human variation)

PDCA 3

- Reformats available for 90% (103/114) of exams
- Of the studies with reformats:
  - 89% (92/103) used a high-resolution matrix
  - 100% (103/103) permitted distance measurements
- Monthly rate of correctly performed studies ranged from:
  - 80% (33/41) to 82% (31/38), with a monthly mean of 81±0.9%

The upper and lower control limits of the p-chart were up-shifted following the 2nd and 3rd PDCA cycles

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Results – Maintenance Period
(Where We Ended)

Maintenance

- During the maintenance period, no further interventions were made
- Reformats available in 96% (132/138) of exams
- Of the studies with reformats:
  - 96% (127/132) used a high-resolution matrix
  - 99% (131/132) permitted distance measurements
- Monthly rate of correctly performed studies ranged from:
  - 90% (38/42) to 91% (48/53), with a monthly mean of 91±0.5%

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Results

- Characteristics of the analyzed CTA studies during the baseline period (n=351), three sequential PDCA cycles (n=94, 92, 114) and subsequent maintenance period (n=138)

CT Characteristics	Baseline	PDCA#1	PDCA#2	PDCA#3	Maintenance
Type of Arterial Runoff					
Upper Extremity (n [%])	15% (54/351)	26% (24/94)	26% (24/92)	22% (25/114)	22% (31/138)
Lower Extremity (n [%])	85% (297/351)	74% (70/94)	74% (68/92)	78% (89/114)	78% (107/138)
Mean Slice Thickness (mm)	2.2	1.9	2.2	2.2	2.1

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Results

- Characteristics of the analyzed CTA studies during the baseline period (n=351), three sequential PDCA cycles (n=94, 92, 114) and subsequent maintenance period (n=138)

CT Characteristics	Baseline	PDCA#1	PDCA#2	PDCA#3	Maintenance
3D Client Vendor					
GE Advantage Workstation (n [%])	55% (150/273)	33% (27/81)	49% (40/82)	45% (47/103)	45% (60/132)
Vital Vitrea Workstation (n [%])	45% (123/273)	67% (54/81)	51% (42/82)	55% (57/103)	55% (72/132)
Sagittal/Coronal Reformats Available	78% (273/351)	86% (81/94)	89% (82/92)	90% (103/114)	96% (132/138)
Reformat + High-Resolution Matrix	74% (202/273)	91% (74/81)	90% (74/82)	89% (92/103)	96% (127/132)
Reformat + Distance-Measurable	75% (206/273)	57% (46/81)	80% (66/82)	100% (103/103)	99% (131/132)

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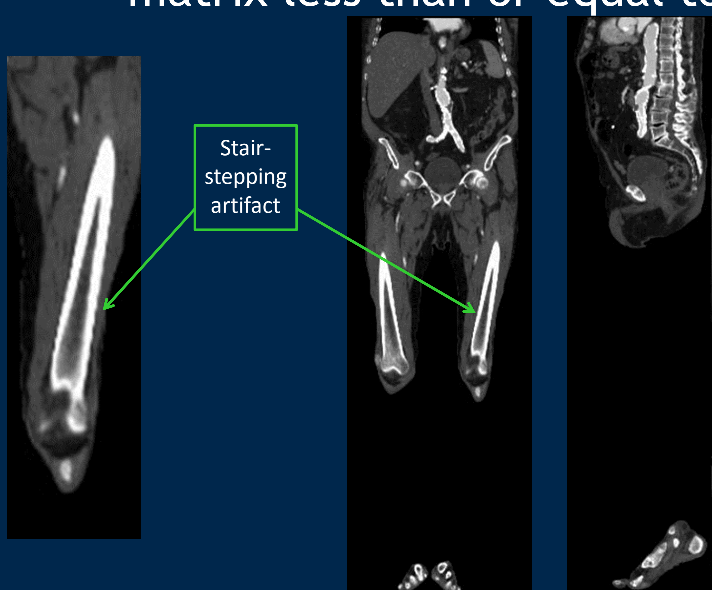
Results

- Characteristics of the analyzed CTA studies during the baseline period (n=351), three sequential PDCA cycles (n=94, 92, 114) and subsequent maintenance period (n=138)

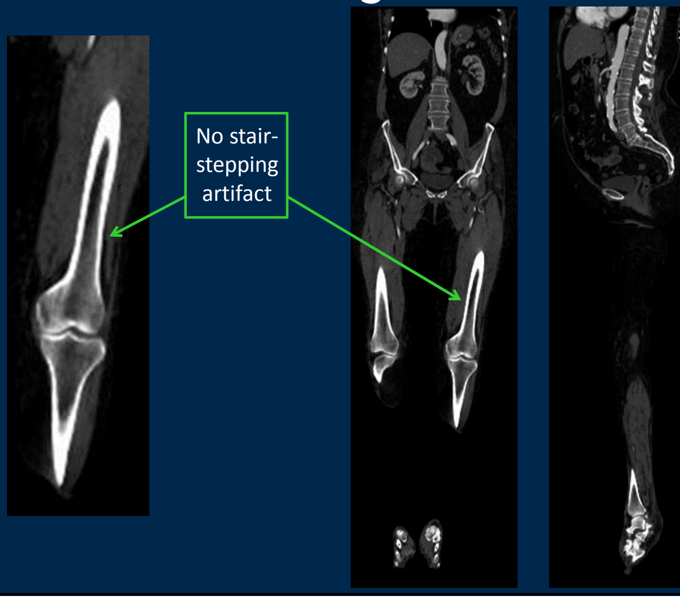
CT Characteristics	Baseline	PDCA#1	PDCA#2	PDCA#3	Maintenance
Reformats correctly performed	38% (135/351)	44% (41/94)	64% (59/92)	81% (92/114)	91% (126/138)

Low-Resolution Reformats

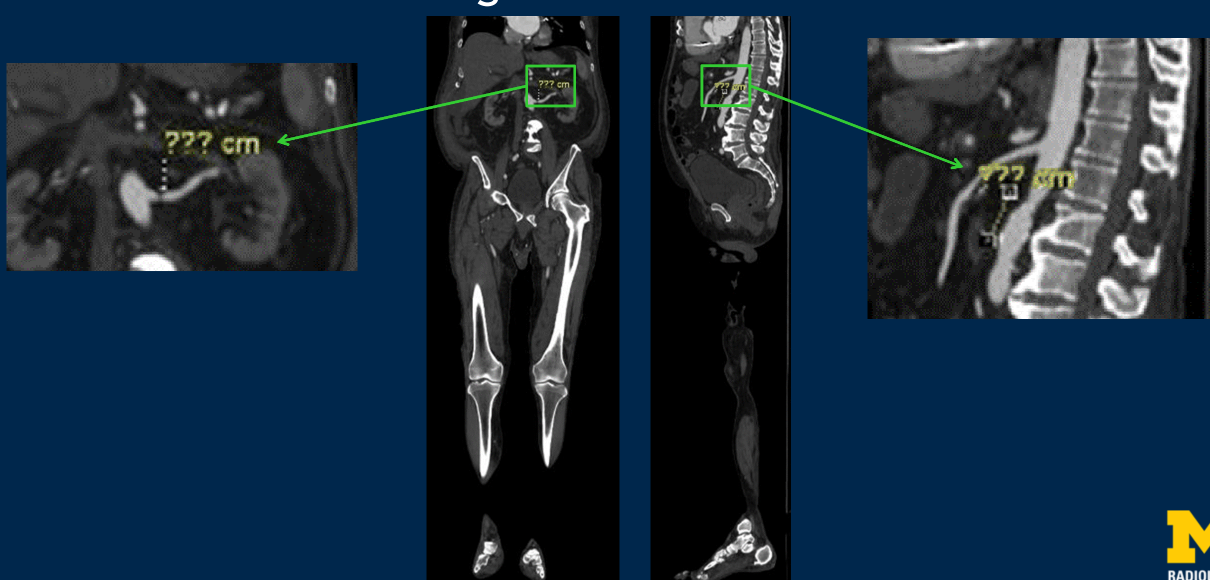
matrix less than or equal to 512 x 512



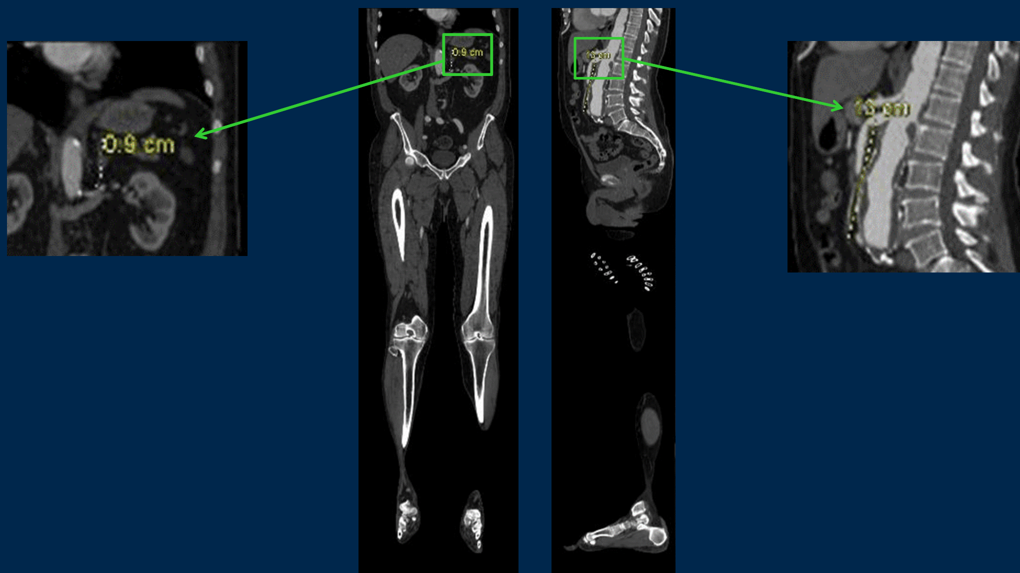
High-Resolution Reformats
matrix greater than 512 x 512



Nonmeasurable Reformats
with high-resolution matrix

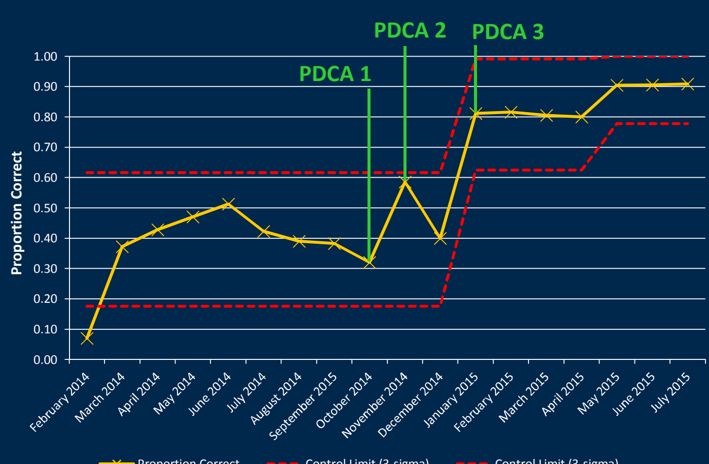


Distance Measurable Reformats
with high-resolution matrix



Process Control Chart (P-Chart)

- The percentage of correctly implemented multi-planar reconstructions on upper and lower extremity CT angiograms from February 2014 through July 2015



PDCA 1: Lecture material and in-service training

PDCA 2: Multi-vendor 3D client software version control and vendor specific setting adjustments

PDCA 3: Leadership meeting

Selected References

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Thank You

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