Providing Value Beyond Accreditation: Repeat/Reject Rate Analysis

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Disclosures

Author has a patent “Apparatus for Tomography Repeat Rate/Reject Capture”

Author has previously received grants from GE Healthcare outside the current work.

Outline

- Repeat/reject rate analysis in radiography
- Repeat/reject rate analysis in CT
- Future directions and discussion

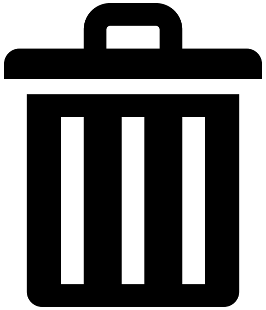
Historical RA in Radiography

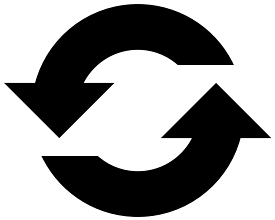
Repeat/reject rate analysis (RA) originated in the days of screen film

- Collected rejected films in a "reject bin"
- Had both financial and quality incentives
  - Screen film costs money
  - Could identify areas for improvement (mispositioning errors, over/under-exposure, etc.)
  - Every extra exposure is "unnecessary" dose

$$Reject\ rate = \frac{\#\ Rejected\ scans}{\#\ Scans\ total}$$

Count films in reject bin → Count total films consumed (purchased) → Divide to get repeat/reject rate





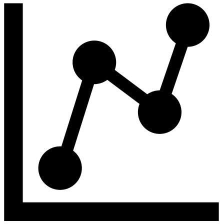
Digital Era RA in Radiography

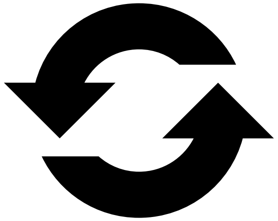
RA in the digital era is a bit more complicated

- Typically relies on scanner log files
- Still have quality incentive, but not as much financial
  - Acquiring an extra digital image doesn't cost more money
  - Can still identify areas for improvement (mispositioning errors, over/under-exposure, etc.)
  - Every extra exposure is still "unnecessary" dose

$$Reject\ rate = \frac{\#\ Rejected\ scans}{\#\ Scans\ total}$$

Collect log files from scanners → Do some fancy data analysis → Get repeat/reject rate





Digital Era RA in Radiography

Tons of great work on this topic (not a comprehensive list)

J Digit Imaging. 2002;15 Suppl 1:41-52. doi: 10.1007/s10278-002-5028-7. Epub 2002 Mar 21.

Is reject analysis necessary after converting to computed radiography?

Rosemary Honea [1], Maria Elissa Blado, Yinlin Ma

Journal of Digital Imaging

Digital Repeat Analysis; Setup and Operation

J. Nol, R.T., P.G.D., M.P.H.,[1] G. Isouard, B.Sc., M.H.A., Ph.D.,[2] and J. Mirecki, L.A.H, D.M.R.D[1]

Journal of Digital Imaging

Digital Radiography Reject Analysis: Data Collection Methodology, Results, and Recommendations from an In-depth Investigation at Two Hospitals

David H. Foos,[1] W. James Sehnert,[1] Bruce Reiner,[2] Eliot L. Siegel,[2] Arthur Segal,[3] and David L. Waldman[4]

Journal of Digital Imaging

One Year's Results from a Server-Based System for Performing Reject Analysis and Exposure Analysis in Computed Radiography

A. Kyle Jones,[1] Raimund Polman,[1] Charles E. Willis,[1] and S. Jeff Shepard[1]

Ongoing quality control in digital radiography: Report of AAPM Imaging Physics Committee Task Group 151

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ORIGINAL ARTICLE CLINICAL PRACTICE MANAGEMENT | VOLUME 14, ISSUE 2, P208-216, FEBRUARY 01, 2017

Unified Database for Rejected Image Analysis Across Multiple Vendors in Radiography

Kevin J. Little, PhD • Ingrid Reiser, PhD • Lili Liu, MS • Tiffany Kinsey, BS • Adrian A. Sánchez, PhD • Kateland Haas, MA • Florence Mallory, BS • Carmen Froman, MBA • Zheng Feng Lu, PhD • Show less

Published: September 20, 2016 • DOI: https://doi.org/10.1016/j.jacr.2016.07.011 • Check for updates

Digital Era RA in Radiography

Selected results/recommendations from those works

From Report of TG 151

- Rejected image rates in digital departments have been reported to range from 4% to 8%
- This task group recommends that **8%** be used as target for overall rejected image rate, and **10%** as a threshold for investigation and possible corrective action

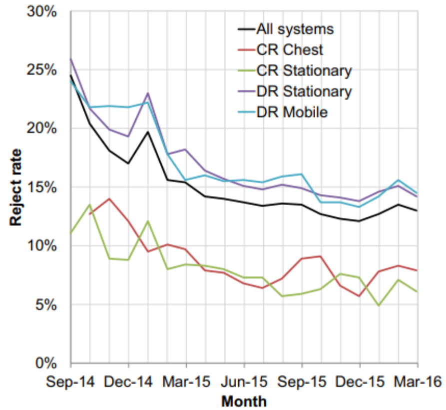
Most rejects are positioning errors

Table 2. Number of Rejected Images According to Reason for Rejection

Reason for rejection	Number of rejects	Percentage of rejects
Positioning	4,639	77.3
Exposure Error	588	9.8
None	571	9.5
Artifact	100	1.7
Test Images	54	0.9
Patient ID	50	0.8
Totals	6,002	100

Jones, A. K., Polman, R., Willis, C. E., & Shepard, S. J. (2011). One year's results from a server-based system for performing reject analysis and exposure analysis in computed radiography. *Journal of Digital Imaging*, *24*(2), 243–255. https://doi.org/10.1007/s10278-009-9236-2

Little et al. found higher reject rates on DR than CR



Little, K. J., Reiser, I., Liu, L., Kinsey, T., Sánchez, A. A., Haas, K., Mallory, F., Froman, C., & Lu, Z. F. (2017). Unified Database for Rejected Image Analysis Across Multiple Vendors in Radiography. Journal of the American College of Radiology, 14(2), 208–216. https://doi.org/10.1016/j.jacr.2016.07.01

Rates can vary substantially across protocols

Table 3. Rejected Images According to Intelligent Imaging Processing Menu Code

Menu code	Total images	Percentage of images	Total rejects	Percentage rejected	Percentage of total rejects
ABDOMEN, LT. DECUB	5,769	8.7	821	14.2	13.7
CHEST PORTABLE	26,400	40.0	799	3.0	13.3
ABDOMEN, GENERAL	6,177	9.4	617	10.0	10.3
ABDOMEN, RT. DECUB	3,024	4.6	470	15.5	7.8
PELVIS, GENERAL	1,650	2.5	311	18.8	5.2
CHEST, DECUBITUS	968	1.5	293	30.3	4.9

TG 305 – Development of Standards for Vendor-Neutral Reject Analysis in Radiography

Tasked to provide guidance document recommending standard information and an effective dataflow to enable vendor-neutral reject analysis

Outline

- Repeat/reject rate analysis in radiography
- Repeat/reject rate analysis in CT
- Future directions and discussion

Unjustified imaging and repeated studies in CT

Lots of work on unnecessary repeat imaging, "frequent flyers", repeats in trauma transfers, unindicated phases, etc.

Cumulative Radiation Exposure and Cancer Risk Estimates in Emergency Department Patients Undergoing Repeat or Multiple CT

Richard T. Griffey[1]
Aaron Sodickson[2]

AJR:192, April 2009

> Am J Surg. 2017 Aug;214(2):198-200. doi: 10.1016/j.amjsurg.2016.10.020. Epub 2017 Feb 17.

The salutary effect of an integrated system on the rate of repeat CT scanning in transferred trauma patients: Improved costs and efficiencies

Joseph Bledsoe [1], Amy E Liepert [2], Todd L Allen [3], Li Dong [3], Jamon Hemingway [3], Sarah Majercik [4], Scott Gardner [4], Mark H Stevens [4]

THE AMERICAN JOURNAL of MEDICINE®

Repeat Abdominal Imaging Examinations in a Tertiary Care Hospital

Ivan K. Ip, MD, MPH,[a,b] Koenraad J. Mortele, MD,[a,c] Luciano M. Prevedello, MD,[a] Ramin Khorasani, MD, MPH[a,c]

> Eur Radiol. 2009 May;19(5):1161-5. doi: 10.1007/s00330-008-1256-7. Epub 2009 Jan 21.

Unjustified CT examinations in young patients

Heljä Oikarinen [1], Salme Meriläinen, Eija Pääkkö, Ari Karttunen, Miika T Nieminen, Osmo Tervonen

> Eur J Radiol. 2017 Mar;88:135-140. doi: 10.1016/j.ejrad.2017.01.007. Epub 2017 Jan 6.

Repeated CT scans in trauma transfers: An analysis of indications, radiation dose exposure, and costs

Ricarda Hinzpeter [1], Kai Sprengel [2], Guido A Wanner [3], Peter Mildenberger [4], Hatem Alkadhi [5]

JACR Journal of the American College of Radiology

Ionizing Radiation in Abdominal CT: Unindicated Multiphase Scans Are an Important Source of Medically Unnecessary Exposure

Kristie M. Guite, MD • J. Louis Hinshaw, MD • Frank N. Ranallo, PhD • Mary J. Lindstrom, PhD • Fred T. Lee Jr, MD

> AJR Am J Roentgenol. 2014 Jul;203(1):107-10. doi: 10.2214/AJR.13.10617.

Providing formal reports for outside imaging and the rate of repeat imaging

Michael T Lu [1], Wyatt M Tellis, David E Avrin

Not much out there on RA in CT

› J Am Coll Radiol. 2013 Jun;10(6):416-22. doi: 10.1016/j.jacr.2012.12.008. Epub 2013 Mar 13.

Radiology stewardship and quality improvement: the process and costs of implementing a CT radiation dose optimization committee in a medium-sized community hospital system

Jenifer R Q W Siegelman [1], Dustin A Gress

RA not primary purpose of paper, but reports reduction in repeat rate from 13/100 to 0/100 on head CT protocol after protocol optimization

American Journal of Roentgenology, November, Vol. 215, No. 5 : pp. 1123-1129

A Multiinstitutional Study on Wasted CT Scans for Over 60,000 Patients

Sean Rose, Ben Viggiano, Robert Bour, Carrie Bartels, and Timothy Szczykutowicz

https://doi.org/10.2214/AJR.19.22604

Validation study for an automated RA method based on DICOM metadata

JACR Journal of the American College of Radiology

Applying a New CT Quality Metric in Radiology: How CT Pulmonary Angiography Repeat Rates Compare Across Institutions

Sean Rose, PhD[a], Ben Viggiano[a], Robert Bour, MD[b], Carrie Bartels, RT (CT)[b], Jeff Kanne, MD[b], Timothy Szczykutowicz, PhD[a,b]

Looks at overall repeat rates and repeat rates for CTPA across 5 institutions.

Why do repeat/reject rate analysis in CT? Lots of *quality incentives*!

Causes of repeat scanning in CT	Impact to institution	Impact to patient
Scanner protocol error	Systematic issues likely with this scanner	Diagnostic utility of images decreased, may inhibit physician interpretation
Poor Training	Unpredictable variability with exam quality	Diagnostic utility of images decreased, may inhibit physician interpretation
Poor Protocol Instructions	Unpredictable variability with exam quality	Diagnostic utility of images decreased, may inhibit physician interpretation
Issue with contrast delivery	Possible patient safety concerns.	Extravasation related issues greatly reduce patient satisfaction.
Patient Motion	N/A	Diagnostic utility of images decreased, may inhibit physician interpretation
Error with scan execution	Unpredictable variability with exam quality	If patient realizes there was a mistake, patient satisfaction decreases

Effects of repeat scanning in CT	Impact to institution	Impact to patient
Longer exam times	Reduced revenue as less patients can be scanned	Satisfaction decreases as scheduled exam times are not met
Variable exam times	Scheduling templates exam time estimates needlessly inflated for non-repeat exams	Satisfaction decreases as scheduled exam times are not met
Re-dosing the patient with ionizing radiation	Data submitted to dose registries will be increased	Increased stochastic risk of cancer
Re-dosing the patient with Iodine contrast	Reduced profit as you cannot double bill for contrast	Increased risk of contrast induced complications (i.e. kidney issues)

Why do re eat/re rate analysis in CT? L f *incent es*!

Causes of repeat scanning in CT	Impact to institution	Impact to patient
Scanner protocol error	Systematic issues likely with this scanner	Diagnostic utility of images decreased, may inhibit physician interpretation
Poor Training	Unpredictable variability with exam quality	Diagnostic utility o images decreased, ma inhibit physician interpretation
Poor Protocol Instructions	Unp table lity wit	Diagnostic utility i ges decreased, m nhibit physician
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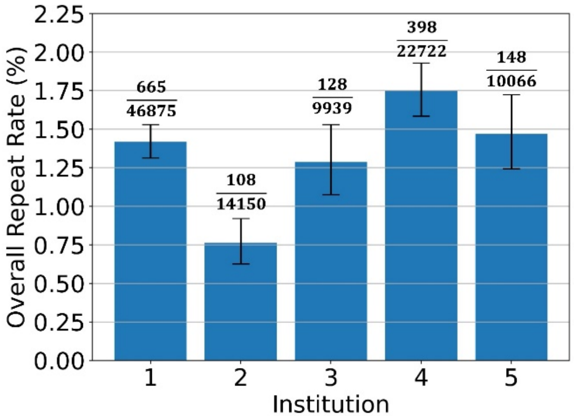
Elevated repeat rates indicate poor protocol design and/or poor technologist performance

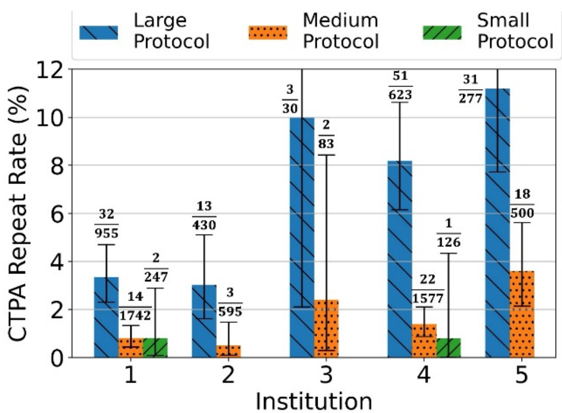
EVERY instance of a repeat in CT means unnecessary patient dose

Selected results for RA in CT



Of 103,752 exams, 1,447 contained repeated helical scans (1.4%). Overall helical repeat rates differed among institutions ($p < 0.001$) ranging from 0.8% to 1.8%.

Overall helical repeat rates typically <2%



Repeat rates can be much higher for a given protocol

Large patient CTPA repeat rates ranged from 3.0% to **11.2%** with the odds of a repeat being 4.8 [3.5, 6.6] times higher for large relative to medium patient CTPA protocols!

$$Repeat\ rate = \frac{\#\ studies\ containing\ repeated\ helicals}{\#\ total\ studies}$$

Different definition than traditionally used in radiography!

Rose, S., Viggiano, B., Bour, R., Bartels, C., Kanne, J. P., & Szczykutowicz, T. P. (2021). Applying a New CT Quality Metric in Radiology: How CT Pulmonary Angiography Repeat Rates Compare Across Institutions. *Journal of the American College of Radiology*, *16*. https://doi.org/10.1016/j.jacr.2021.02.014

Outline

- Repeat/reject rate analysis in radiography
- Repeat/reject rate analysis in CT
- Future directions and discussion

Physicist's role in RA

- Radiography (recommendations from TG151)
  - QMP should design and implement RA program
  - Should involve radiologist and QC technologist
  - QMP should participate in the analysis
- CT (my opinions)
  - RA becoming available as part of some vendors' dose monitoring software
  - We can be the owners of this data and analysis, providing actionable info to managers, radiologists, and technologists

RA in CT: Should we be quantifying wasted contrast?

- 100mL and 150mL contrast vials are typically single use
- Consider scanner doing 10,000 exams per year, 60% with contrast
  - Assume contrast costs ~$0.14/mL ←
  - Assume we're only using single use 100mL vials

Robinson, J. D., Mitsumori, L. M., & Linnau, K. F. (2013). Evaluating contrast agent waste and costs of weight-based ct contrast bolus protocols using single-or multiple-dose packaging. American Journal of Roentgenology, 200(6), 617–620. https://doi.org/10.2214/AJR.12.9479

- Cost of 5% repeat rate

$$\frac{10{,}000}{\text{year}} \times 0.6 \times 0.05 \times \$14 = \frac{\$4200}{\text{year}}$$

- Cost of 1.5% repeat rate

$$\frac{10{,}000}{\text{year}} \times 0.6 \times 0.015 \times \$14 = \frac{\$1260}{\text{year}}$$

Could potentially save around **$3000** per scanner annually by reducing repeat rate from 5% to 1%

Should we be looking at MRI?

- Andre et al. investigated prevalence of motion artifact in 1 week's worth of MR exams across 3 scanners
- 19.8% of examinations (38 of 192) contained repeat sequences
  - There were 68 repeat sequences across these 38 exams
  - 203 sequences contained moderate or severe motion artifact (authors' criteria states these should have been repeated)
- 68 repeats required 278.5 minutes of additional scan time
- Assuming a cost of $444.32 for a 45 minute exam, this translates to about $917 per scanner per week
- Around **$40,000-$50,000** per scanner annually. Andre et al. estimated $140,000 for their 3 scanners

Including the sequences that "should" have been repeated, Andre et al. estimated cost of **>$115,000** per scanner annually

> J Am Coll Radiol. 2015 Jul;12(7):689-95. doi: 10.1016/j.jacr.2015.03.007. Epub 2015 May 9.

Toward Quantifying the Prevalence, Severity, and Cost Associated With Patient Motion During Clinical MR Examinations

Jalal B Andre [1], Brian W Bresnahan [2], Mahmud Mossa-Basha [2], Michael N Hoff [2], C Patrick Smith [3], Yoshimi Anzai [2], Wendy A Cohen [2]

Providing Value Beyond Accreditation: CT Scanner Purchases

Sean Rose, Ph.D.

UTHealth The University of Texas Health Science Center at Houston | McGovern Medical School

Physicist’s role in equipment purchasing decisions

- From ACR 2017 CT QC manual

  procedural or equipment errors. The QMP tests are also useful to help to understand the design strategy used in producing a particular CT scanner and recommend the equipment specifications most appropriate for a given practice.

- From ACR Guide to Professional Practice of Clinical Medical Physics (2018)

  D. General Responsibilities

  Some typical responsibilities of a medical physicist may include, but are not limited to, the following items. The scope of these varies widely based on the size and staffing of the institution.

  1. Performance of acceptance testing, calibration, and safety surveys of imaging and radiation therapy equipment.
  2. Participation in the development of purchasing and acceptance specifications for imaging and radiation therapy equipment.

- Does this happen in practice?
  - My personal experience: Highly dependent on institution, radiologists, managers, culture, etc.
  - We need to demonstrate value to be brought to the table!

How can we be useful?

Szczykutowicz, T. P. (2020). *The CT Handbook: Optimizing Protocols for Today's Feature-Rich Scanners*. Medical Physics Publishing.

- The fundamentals: Know what scanner options are required for different exam types!
  - Scanners come with different "options bundles"
  - E.g., a vendor may have a cardiac bundle that includes cardiac gating and metal artifact reduction. A model with wide axial collimation would also be beneficial for cardiac
  - As physicists, we can be the gatekeepers that make sure a site doesn't buy a scanner that doesn't have the options they need!
  - Work with sales reps
- Lots of resources
  - Textbooks
  - ACR practice parameters
  - Buyer's guides

Block Imaging. (2016). CT Scanner Buyer's Guide (2nd ed.). https://www.blockimaging.com/ct-scanner-buyers-guide

Table 17.1 A mapping of indications to scanner options. Note: this table deals only with scanner options; additional software packages may be needed to realize the listed indications. For example, to obtain a perfusion map, the scanner will need a perfusion acquisition mode and the data will need to be processed with a perfusion map creation software.

Indication/ Task	Perfusion	Cardiac Gating	Fluoroscopy	Respiratory Gating	MAR	Gantry Tilt	Wide Bore	Long Table	Wide Axial Collimation	Bariatric Table	Dual Energy	High-Power Tube[a]	Fast Scanning[b]	Extended FOV	Extended CT #	Flat Table
Brain perfusion	M	–	–	–	–	–	–	–	P	+	–	+	–	–	–	–
Brain multi-phase CTA	–	–	–	–	P	+	–	–	+	+	+	+	+	–	–	–
Abdominal organ perfusion	M	–	–	–	+	–	+	–	P	+	+	+	–	–	–	–
Lower extremity CTA	–	–	–	–	+	–	+	M	+	+	+	P	P	–	–	–
CTA/arterial imaging (+ surg. planning)	–	–	–	–	P	–	+	–	+	+	+	P	+	–	–	–
MSK	–	–	–	–	P	–	+	–	–	+	+	–	–	–	–	–
Spinal imaging with fixation hardware	–	–	–	–	M	–	+	–	–	+	+	–	–	–	–	–
Head & Neck with dental amalgam	–	–	–	–	P	P	+	–	+	+	+	+	+	–	–	–
Multiphase imaging	–	–	–	–	+	–	+	–	P	+	P	P	P	–	–	–
Trauma (MVC imaging)	–	–	–	–	P	+	+	P	+	P	+	M	P	P	–	–
Orthopedic surgery planning	–	–	–	–	P	P	+	–	–	+	+	–	–	+	–	–
Radiation therapy	–	–	–	M[c]	P	+	P	+	+	+	+	–	–	M	P	M
PE/triple rule out	–	–	–	–	+	–	+	+	P	+	P	P	P	+	–	–
Pediatric non-sedated	–	–	–	–	+	–	–	–	P	–	–	P	P	–	–	–
CTA chest	–	P	–	–	P	–	+	–	P	+	P	P	P	–	–	–
CTA coronaries	–	M	–	–	P	–	+	–	P	+	+	P	P	–	–	–
CT interventions	+[d]	–	M[e]	–	P	P	M	–	–	+	+	–	–	–	–	–
Virtual colonoscopy	–	–	–	–	+	–	+	–	+	+	–	+	+	–	–	–
Bariatrics	–	–	–	–	+	+	P	+	+	M	–	M	+	P	+	–

Key: – = not needed
+ = not needed but would produce better exam quality in some or all cases
M = mandatory (i.e., performing this indication without the listed option would be impossible or severely limit the diagnostic utility of the resulting images)
P = preferred (i.e., while not required to realize the listed indication, use of this option greatly improves the diagnostic utility of the resulting images)

a When multiple people need to receive multiple body region exams which may involve multiple phases per region, a high tube power rating is needed to avoid tube heating issues causing scan delays.
b Fast scanning may be achieved using high-pitch modes (i.e., dual-source scanners) using wide axial scanning or using wide collimation and high pitches (e.g., 8 cm collimation and 1.5 pitches).
c Mandatory if your clinic desires 4DCT planning. Not needed otherwise.
d Organ perfusion is something used by some clinics for interventional CT.
e Many interventional procedures (e.g., ablation, biopsy, arthrogram) can be performed without a dedicated interventional package if your physicians do not use in-room CT fluoroscopy, although they may still want to use the device trajectory planning software that usually comes with the in-room CT fluoroscopy package.

ACR–ASNR–SPR PRACTICE PARAMETER FOR THE PERFORMANCE OF COMPUTED TOMOGRAPHY (CT) PERFUSION IN NEURORADIOLOGIC IMAGING

For patient imaging, the CT scanner should meet or exceed the following specifications:

1. Tube rotation time should not exceed 1 second.
2. Helical and cine imaging should be available. Continuous cine imaging should be possible for a minimum of 50 to 60 seconds. "Toggle table" or "shuttle mode" technique is optional.
3. A multidetector-row CT scanner with either cine and axial or volumetric toggling scanning capability is preferable.
4. A power injector for contrast administration must be used; a dual-bore injection pump is preferable.

How can we be *more* useful?

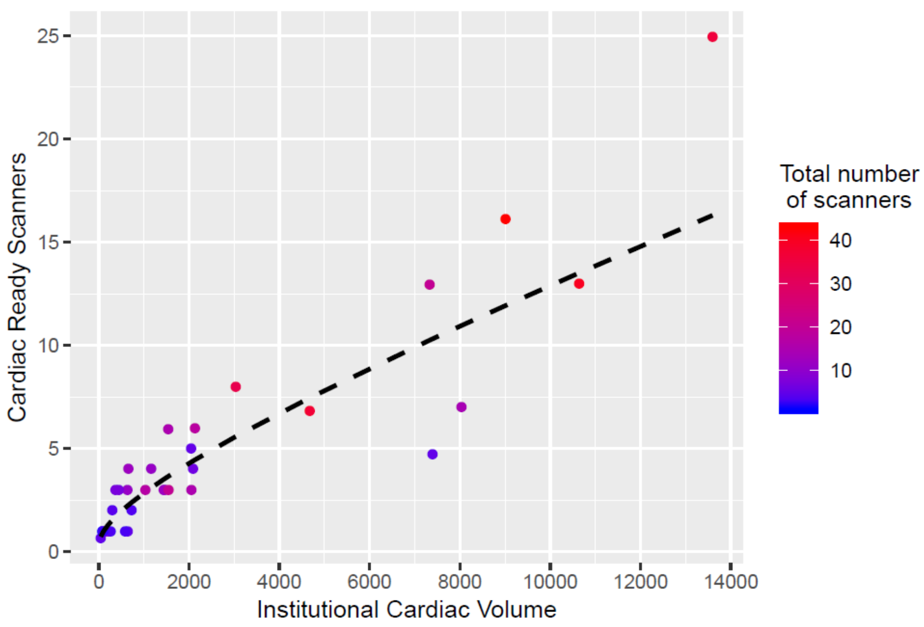
- Know what scanner options a site ***doesn't need*** on a new scanner
- This has traditionally been a role more suited to managers
- Thanks to dose monitoring software, we are now in a unique position to do this. We are the "owners" of some very useful data
  - We can review historic exam volumes and see which scanners are being used for what
  - We can talk to managers about what the intended uses are for a new scanner
  - Depending on use case, this could mean saving on the order $10,000-$100,000 on a new scanner!
- Examples
  - Many sites perform all or almost all of their CT guided interventions on one scanner
    - Not necessary to buy CT Fluoroscopy package on all scanners
  - Is it possible for a site to direct most of the cardiac workload to one or two scanners?
    - This could mean not buying a cardiac gating package on multiple scanners
  - Is it possible to do all of your neuro perfusion scans on one or two scanners?
    - Similar to cardiac case, may not need perfusion package on multiple scanners in your fleet

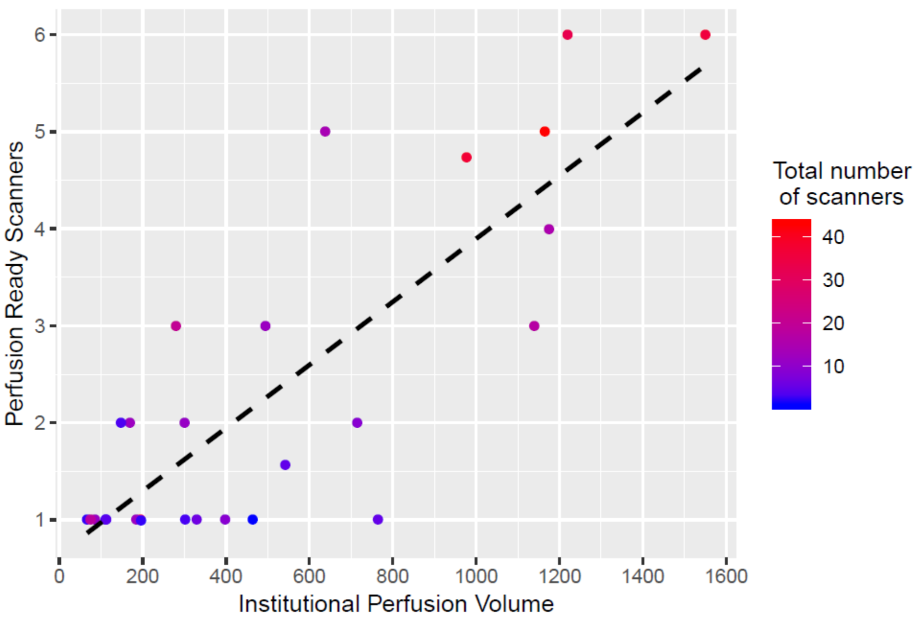
How many cardiac (perfusion) capable scanners do you need?

Preliminary results

Data provided by Imalogix Research Institute

- 63 institutions, 330 locations, 583 scanners, 6 months of data
- Cardiac (perfusion) ready defined as doing more than 1 gated cardiac (perfusion) exam per week over the scanner's active lifespan





How many cardiac (perfusion) capable sites do you need?

Preliminary results

Data provided by Imalogix Research Institute

- 63 institutions, 330 locations, 583 scanners, 6 months of data
- Cardiac (perfusion) ready site defined as having at least one cardiac (perfusion) ready scanner