ACR® AMERICAN COLLEGE OF RADIOLOGY

QUALITY IS OUR IMAGE

American College of Radiology Dose Index Registry

NRDR DIR™ DOSE INDEX REGISTRY

AMERICAN COLLEGE OF RADIOLOGY

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Disclosures

- Nothing to Disclose

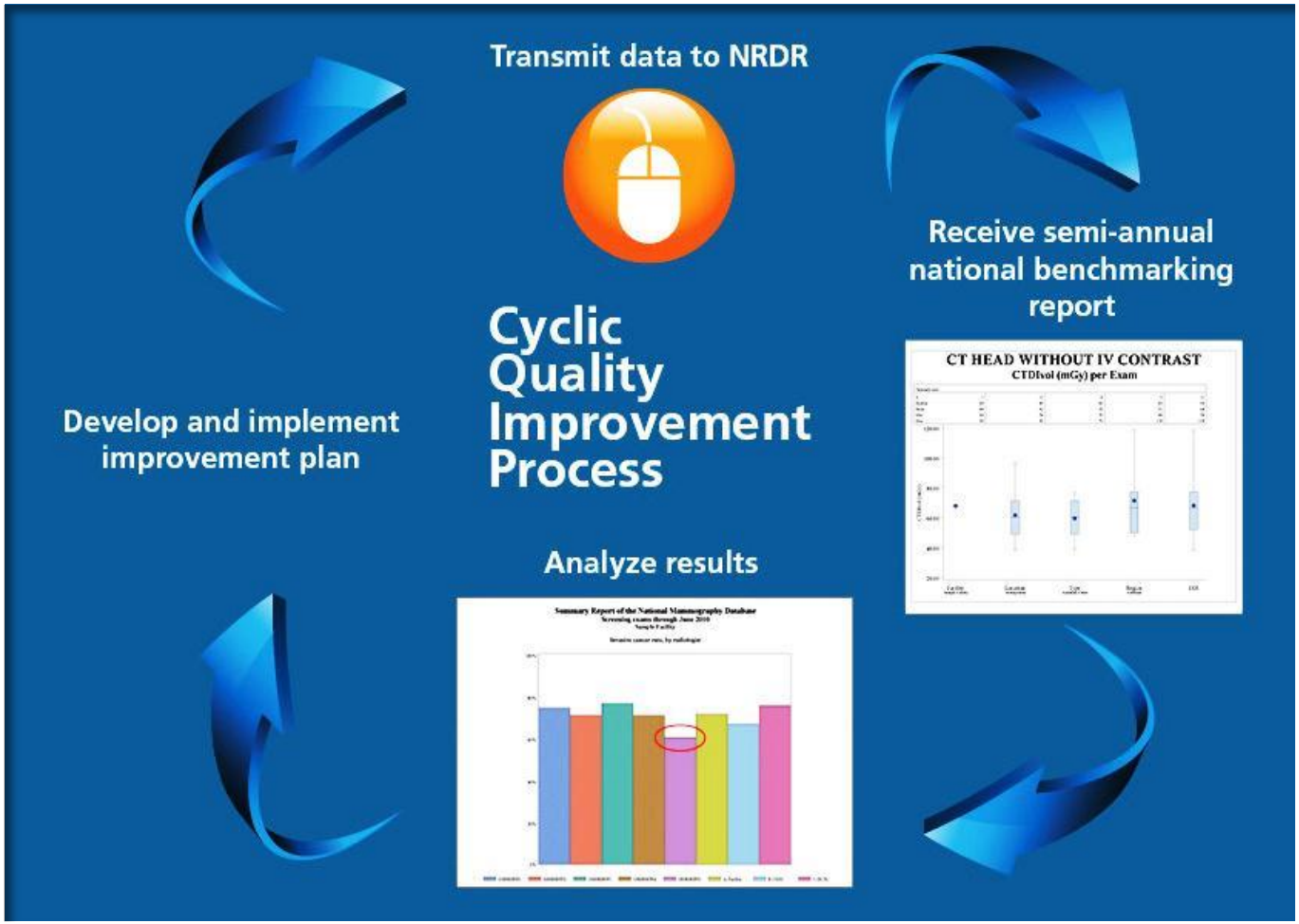
Learning Objectives

- To understand the purpose and implementation of dose index registries
- To recognize the challenges and limitations
- To learn to interpret the comparisons from registries with an understanding of potential inaccuracies

Outline

- Motivation
- Description of ACR Dose Index Registry
- Sources for inaccuracies and solutions
- How to interpret registry reports for quality improvement
- Future direction for the registry

Guiding principle behind registries



Motivation: What is the national average level of radiation administered by imaging facilities for a CT of the head?

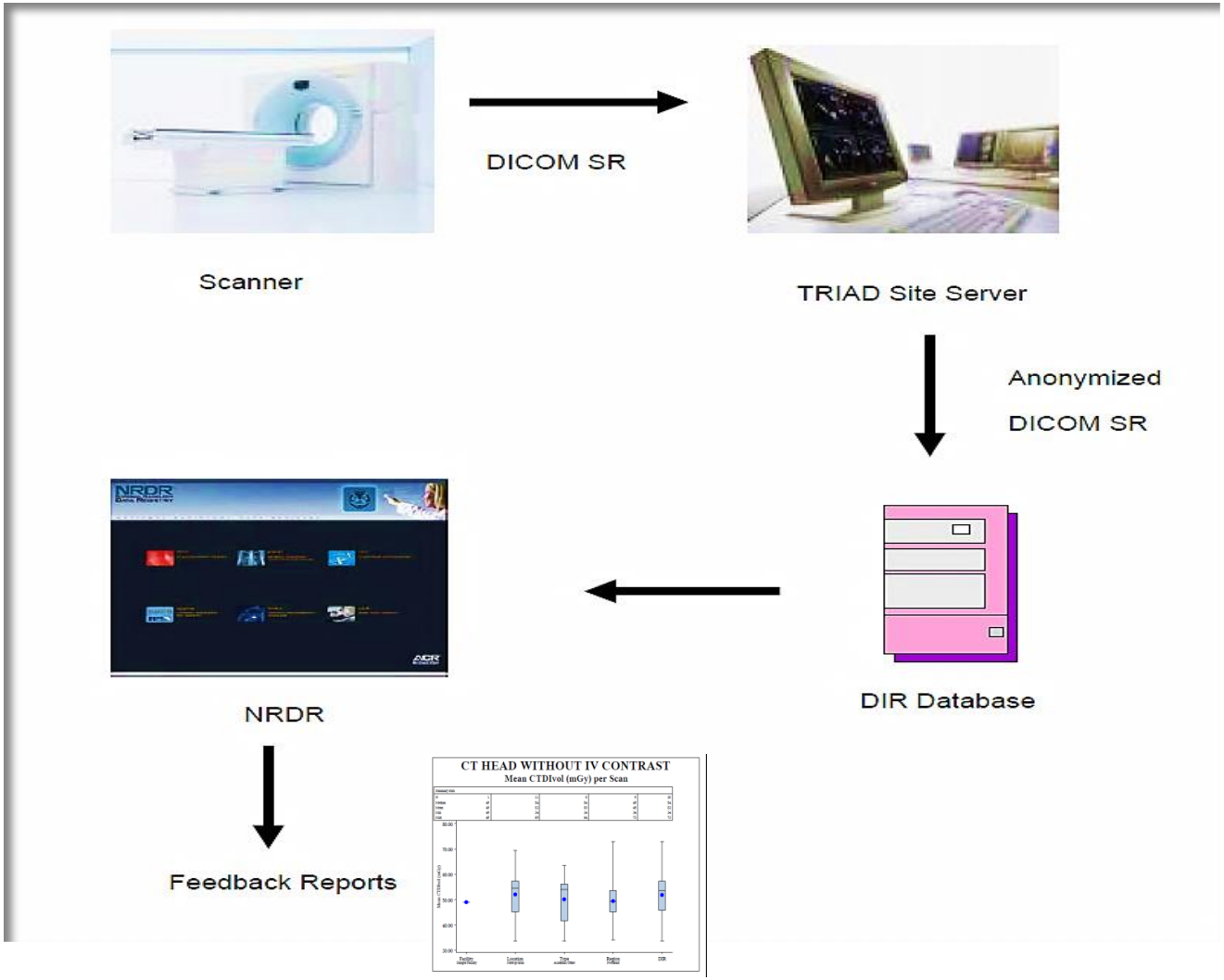
What is the ACR Dose Index Registry?

- A tool for quality improvement so facilities can review dose indices and optimize protocols
  - Collects and compares dose index information across facilities
  - Fully automated; uses standard methods of data collection and processing
  - Will help to develop size-specific reference levels
- Meets Joint Commission requirements for radiation dose monitoring
- CT DIR launched in May 2011

What the ACR Dose Index Registry is Not

- It does not collect individual patient doses; only dose indices
  - CTDIvol
  - DLP
  - SSDE (although getting closer with SSDE, still not there yet)
- It does not collect patient identifiable information
  - HIPAA (Health Insurance Portability and Accountability Act of 1996) privacy concerns
  - Participation agreement
- It is not a mechanism to track individual patient dose

How does the Dose Index Registry work?



Data Collection

- Data sources vary across facilities. Data submission may be
  - Directly from scanners,
  - From PACS, or
  - Through third-party dose monitoring tools
- Data format may be DICOM radiation dose structured reports (RDSRs) or dose screens
- ACR software to collect, anonymize, and transmit data may be installed on any computer at the facility, and works as a service in the background

Data Collection and Reporting

- What is collected
  - Data on dose indices for each exam, and each irradiation event
  - Characteristics of the exam to enable comparisons
  - Localizer image to measure patient width
- What is reported on
  - Average, $25^{th}/50^{th}/75^{th}$ percentile dose indices for facility and registry, for each protocol
  - Dose indices per scan, to help optimize protocols
  - Dose indices per exam, to assess performance across all scans per exam

Reports

- Semi-annual and Quarterly Feedback Report
  - PDF and Excel reports uploaded to registry website every six months
  - Excel reports only at the end of the first and third quarters
  - Available to all facility users
- Facility's own data available at all times
  - Web-based reports
  - Displays exam details and comparisons of scanners

Sample Report Page

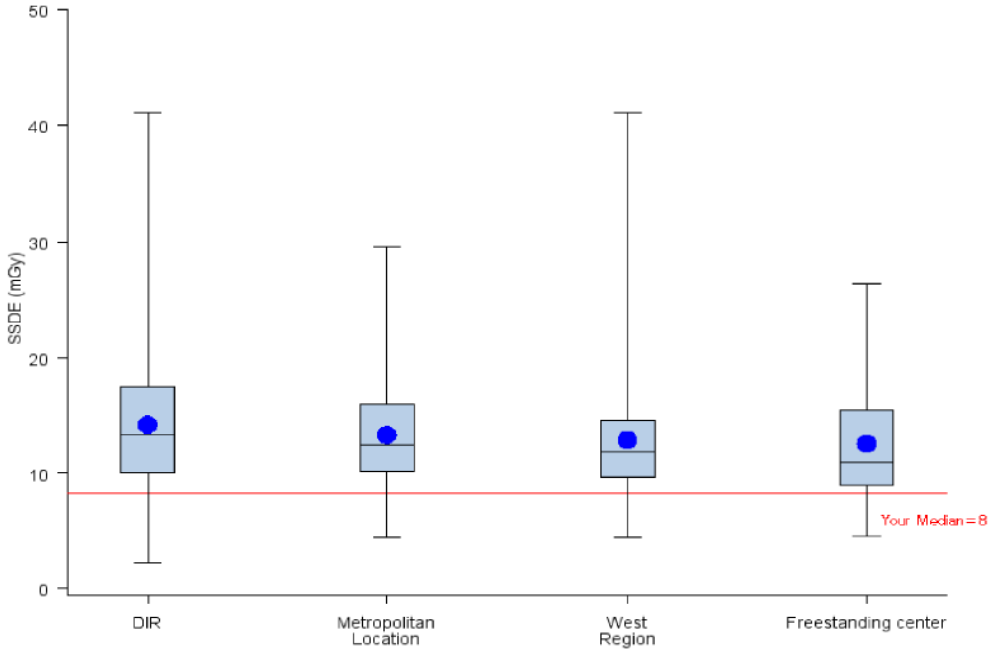
Executive Summary: Facility 999999
CTDIvol Per Scan (mGy)

RPID Shortname	1: Site 999999 (25th-Med-75th)	2: All DIR sites (25th-Med-75th)	3: Sites in location Metropolitan (25th-Med-75th)	4: Sites in the South (25th-Med-75th)	5: Sites of type Community hospital (25th-Med-75th)
CT ABD	(14/18/21)	(13/17/24)	(12/16/21)	(12/17/22)	(13/17/22)
CT ABD PELVIS KIDNEY CALC	(10/14/18)	(9/13/19)	(10/14/18)	(11/15/19)	(10/14/20)
CT ABD PELVIS W IVCON	(10/15/21)	(11/16/22)	(11/16/22)	(11/16/22)	(11/16/22)
CT ABD PELVIS WO & W IVCO	(11/17/28)	(13/19/25)	(14/19/26)	(14/20/27)	(13/20/26)
CT ABD PELVIS WO IVCON	(10/15/23)	(10/16/22)	(10/15/21)	(11/17/23)	(11/16/23)
CT C SPINE WO IVCON	(26/40/69)	(20/30/49)	(21/31/49)	(22/34/52)	(20/31/56)
CT CHST	(13/16/24)	(8/12/16)	(8/11/15)	(9/12/16)	(9/12/17)
CT CHST ABD PELVIS W IVCO	(12/17/24)	(12/16/22)	(12/15/22)	(13/17/24)	(11/16/22)
CT CHST ANGIO W IVCON	(13/14/18)	(13/18/27)	(13/17/23)	(13/16/24)	(13/17/26)
CT CHST PULM ARTS EMBO W	(17/25/36)	(13/21/33)	(14/22/33)	(14/23/36)	(13/22/35)
CT CHST W IVCON	(9/14/17)	(9/13/20)	(8/13/19)	(9/13/18)	(10/14/20)
CT CHST WO IVCON	(7/11/15)	(7/11/16)	(7/11/16)	(8/12/18)	(7/11/17)
CT HEAD BRN WO IVCON	(43/53/71)	(47/56/66)	(45/55/62)	(46/54/65)	(48/58/68)
CT HEAD SINUSES WO IVCON	(13/26/47)	(13/20/36)	(14/20/33)	(19/33/44)	(14/19/28)
CT L SPINE WO IVCON	(17/29/47)	(20/31/45)	(18/27/43)	(22/34/51)	(20/29/43)
CT NECK W IVCON	(14/19/48)	(14/20/36)	(14/21/41)	(13/22/48)	(14/19/33)

For Each Exam, Facility Data are Compared to that of Similar Facilities

Median CT CHST WO IVCON SSDE Per Scan

Category	Number of Facilities	Mean	Std Dev	Min	25th %ile	50th %ile	75th %ile	Max
DIR	183	14	6	2	10	13	17	41
Metropolitan	84	13	5	4	10	12	16	30
West	39	13	6	4	10	12	15	41
Freestanding center	65	13	5	5	9	11	15	26



Reports color coded based on performance relative to registry

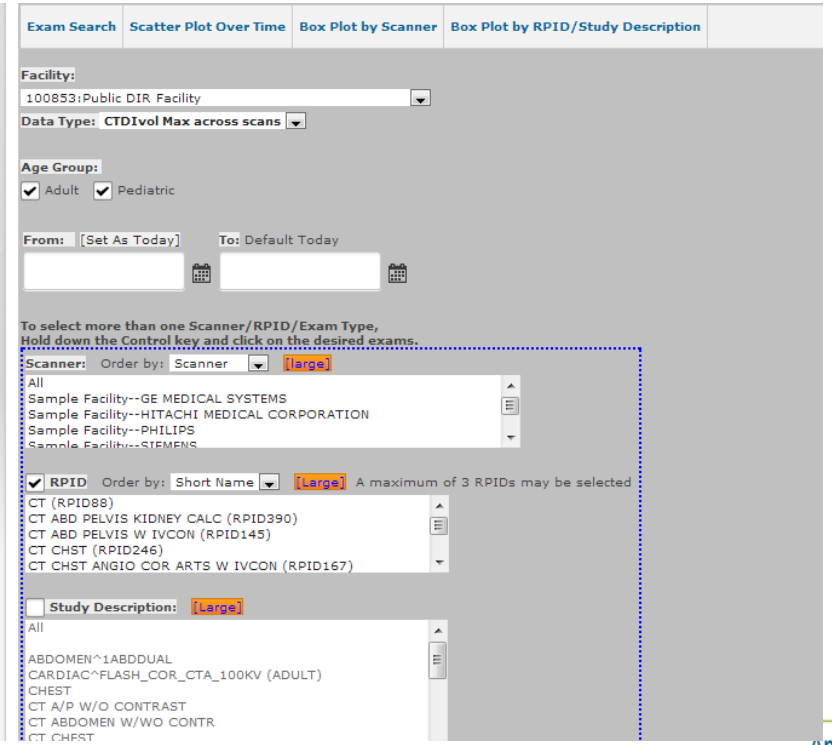
		1: Site 999999					2: All DIR sites			
CTDIvol per scan (mGy)	DIR Standing	N	25th %'ile	Median	75th %'ile		N	25th %'ile	Median	75th %'ile
CT ABDOMEN	25th-75th %'ile	2587	13	17	23		14381	12	16	22
CT ABDOMEN ANGIO W IVCON	25th-75th %'ile	94	9	15	23		1890	11	16	22
CT ABDOMEN ANGIO WO THEN W IVCON	Above 75th %'ile	21	16	24	32		773	13	18	24
CT ABDOMEN BIOPSY KIDNEY GUIDANCE	25th-75th %'ile	58	8	12	20		179	12	18	22
CT ABDOMEN BIOPSY LIVER GUIDANCE	Below 25th %'ile	36	10	16	19		165	17	22	26
CT ABDOMEN BIOPSY RETROPERITONEUM GUIDANCE	.	.	.	.	.		130	7	10	17
CT ABDOMEN KIDNEY ANGIO	25th-75th %'ile	30	13	19	23		183	13	20	26
CT ABDOMEN KIDNEY WO THEN W IVCON	25th-75th %'ile	11	16	20	24		723	12	16	23
CT ABDOMEN LE ANGIO W IVCON	.	.	.	.	.		120	6	9	12
CT ABDOMEN LIVER MULTIPHASE WO THEN W IVCON	25th-75th %'ile	24	8	14	18		1996	11	16	22
CT ABDOMEN PANCREAS	25th-75th %'ile	49	9	12	17		558	8	13	17
CT ABDOMEN PANCREAS MULTIPHASE WO THEN W IVCON	25th-75th %'ile	28	15	18	24		598	14	19	25
CT ABDOMEN PELVIS	.	.	.	.	.		3721	11	17	26
CT ABDOMEN PELVIS ANGIO	25th-75th %'ile	160	20	26	43		4395	15	20	32
CT ABDOMEN PELVIS ANGIO WO THEN W IVCON	25th-75th %'ile	349	11	15	20		2952	11	17	23
CT ABDOMEN PELVIS COLONOGRAPHY W IVCON	25th-75th %'ile	58	2	3	3		992	2	4	9
CT ABDOMEN PELVIS COLONOGRAPHY WO IVCON	Above 75th %'ile	2	34	40	47		393	4	5	8
CT ABDOMEN PELVIS ENTERO W IVCON	25th-75th %'ile	66	9	12	16		2551	7	11	17
CT ABDOMEN PELVIS KIDNEY CALC WO IVCON	25th-75th %'ile	4895	10	15	19		29725	9	14	20
CT ABDOMEN PELVIS LE ANGIO	25th-75th %'ile	76	17	26	42		1776	14	25	48
CT ABDOMEN PELVIS LE ANGIO W IVCON	.	.	.	.	.		324	8	11	16
CT ABDOMEN PELVIS LE ANGIO WO THEN W IVCON	Above 75th %'ile	1	17	17	17		784	8	11	16

Online reports

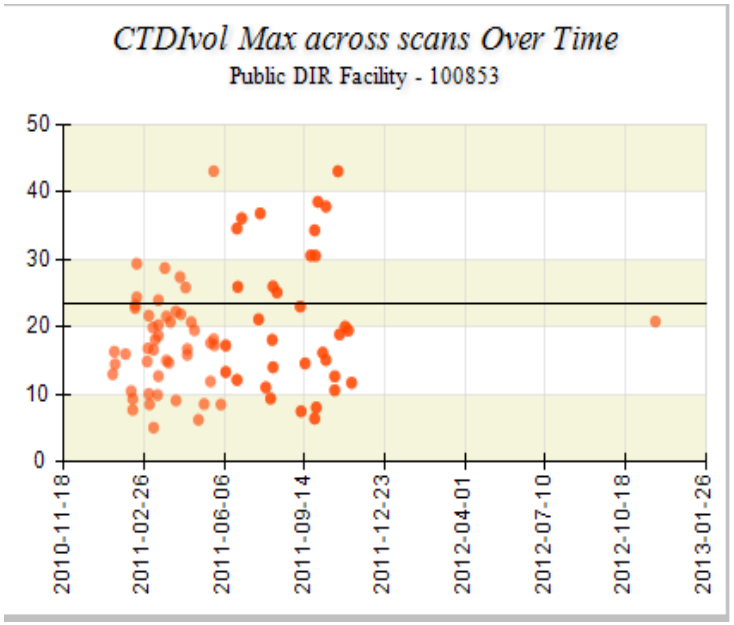
- Corresponds to semi-annual report measures
- Includes SSDE, CTDIvol and DLP
- Reports by RPID, Study Description, and Scanner

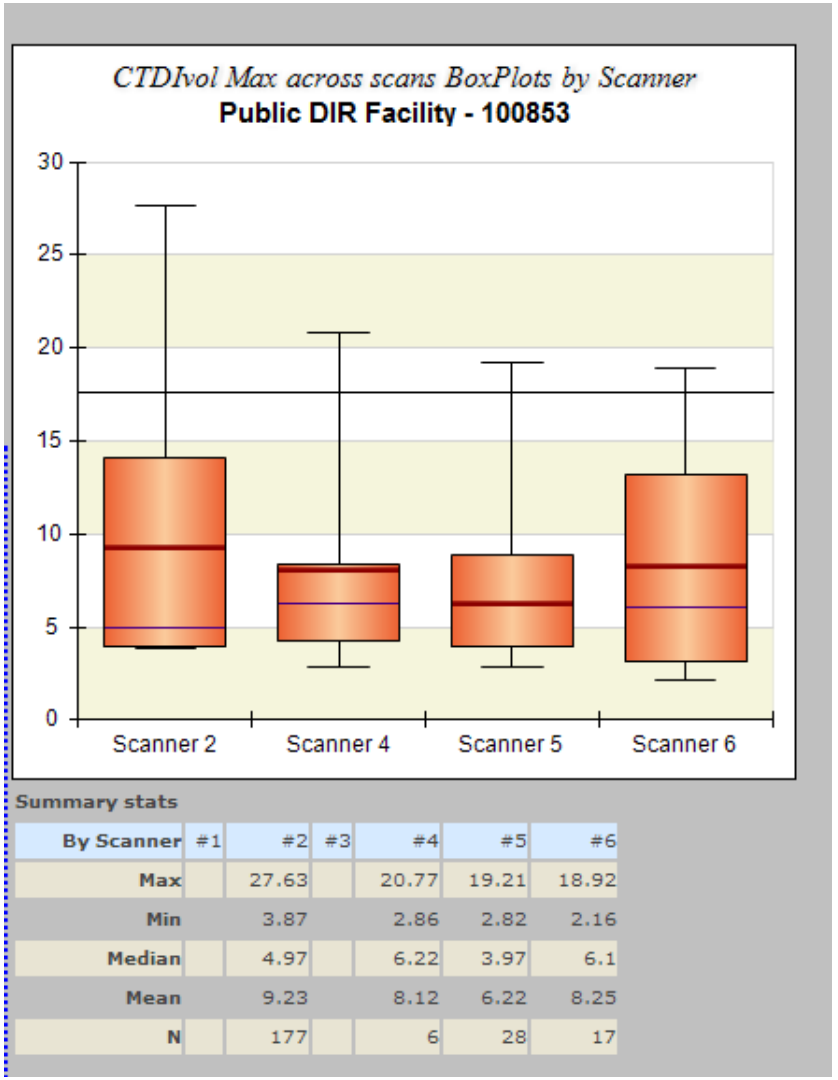
NRDR DIR™

- Exam Search
- Scatter Plot Over Time
- Box Plot by Scanner
- Box Plot by RPID/Study Description



Online reports





Summary stats

By Scanner	#1	#2	#3	#4	#5	#6
Max		27.63		20.77	19.21	18.92
Min		3.87		2.86	2.82	2.16
Median		4.97		6.22	3.97	6.1
Mean		9.23		8.12	6.22	8.25
N		177		6	28	17

Horizontal line on chart = Registry median

Standardization for Comparison: Challenges and Solutions

1. Capture of standard data from all participants
2. Patient size adjustment
3. Normalizing for phantom size
4. Monitoring runs
5. Procedure name standardization

1. DICOM Standard: Radiation Dose Structured Report

TID 10012
CT ACCUMULATED DOSE DATA

	Concept Name	Value Set Constraint	
1	CT Accumulated Dose Data		
2	Total Number of Irradiation Events	Units = events	Total Number of CT irradiation events . A CT irradiation event is one continuous irradiation procedure and is defined through consistent acquisition parameters. In the case of dose modulation the calculations are base the effective mA recorded in the Mean X-ray Tube Curre are consistent.
3	CT Dose Length Product Total	Units =mGycm	The Dose Length Product (DLP) is calculated for every Product Total is the sum of the DLP values. The calcula each irradiation event.
4	CT Effective	Units =mSv	Effective dose (E, in units of mSv) evaluated as a total c

TID 10013 CT Irradiation Event Data

A CT irradiation event is the occurrence of irradiation being applied to a patient in single continuous time-frame between the start (release) and the stop (cease) of the irradiation. Any on-off switching of the radiation source during the event shall not be treated as separate events; rather the event includes the time between start and stop of radiation as triggered by the user, e.g., a single sequence of scanning comprised of multiple slices acquired with successive tube rotations and table increments shall be treated as a single irradiation event. Depending on the examination workflow and the anatomical target region the CT irradiation event data may split into multiple instances of this template for better dose estimation. The irradiation event is the "smallest" information entity to be recorded in the realm of Radiation Dose reporting. Individual Irradiation Events are described by a set of accompanying physical parameters that are sufficient to understand the "quality" of irradiation that is being applied. This set of parameters may be different for the various types of equipment that are able to create irradiation events.

TID 10013
CT IRRADIATION EVENT DATA

	Concept Name	Value Set Constraint	
1	CT Acquisition		
2	Acquisition Protocol		User-defined type of clinical acquisition protocol for creating images or image-derived measurements. May be taken from Protocol Name (0018,1030) or from Performed Procedure Step Description (0040,0254).
3	Target Region	CT and MR Anatomy Imaged	The target region is the anatomy exposed.
4	CT Acquisition Type	CT Acquisition Types	Description of the method used during acquisition of this CT irradiation event, may be derived from Acquisition Type (0018,9302).
5	Procedure Context	Contrast Imaging Technique	The acquisition was performed with or without contrast medium application.
6	Irradiation Event UID		
7	CT Acquisition Parameters		

1. Data Capture: Variety of scanners/models

New and old, all major manufacturers

- DIR accepts DICOM radiation dose structured reports (RDSRs) from new scanners with the capability to generate them.
- Older scanners provide dose screens that are processed and converted to DICOM RDSRs.
- Manufacturers of scanners currently sending data to DIR:
  - GE
  - Siemens
  - Philips
  - Toshiba
  - Neurologica

1. Data capture challenges

- Despite use of industry standards and automation
  - Non-RDSR dose screens not always uniform for scanners from the same manufacturer
- Even scanners producing RDSRs do not adhere comprehensively to standard
  - Meet required criteria but not optional, and we find that facilities need the optional fields to fully characterize their data
  - Example: ProtocolName

2. Patient Size Adjustment

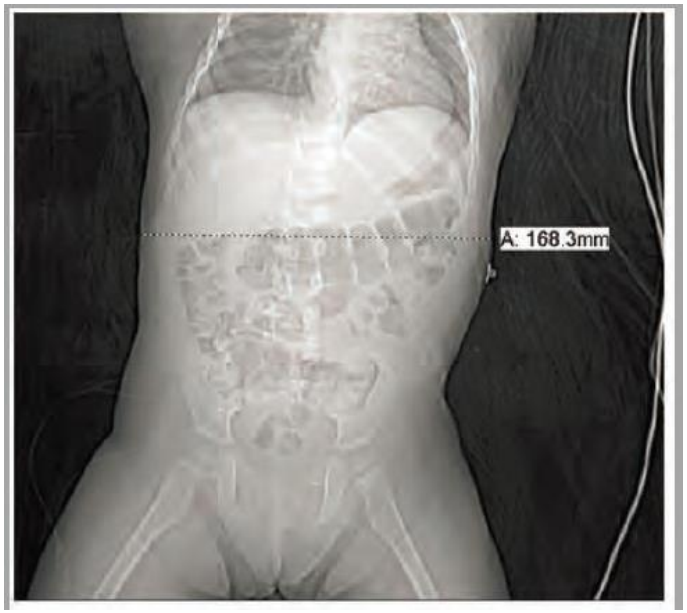
Size-Specific Dose Estimate (SSDE)

- Patient sizes may vary widely and require different dose indices to obtain comparably diagnostic images across patients.
  - Same dose index results in different doses for patients of different sizes.
- Size-Specific Dose Estimate measures developed by American Association of Physicists in Medicine (AAPM)
  - Empirical measure based on calculating radiation doses using four different methods, and a variety of scanners
- DIR uses normalized dose conversion factor from AAPM TG204 report to convert CTDIvol to SSDE

2. Patient Size Adjustment

Size-Specific Dose Estimate (SSDE)

- DIR allows sites to submit localizer images along with Dose Report to measure patient thickness



The automated patient size estimation is courtesy of Duke University Clinical Imaging Physics Group. *Details in Christianson O, Li X, Frush DP, Samei E. Automated patient-specific CT dose monitoring system: assessing variability in CT dose. Medical Physics 39(11): 7131-7139. 2012*

3. Normalization for Phantom size

- CTDIvol is measures using different phantoms based on protocol.
  - Adult body – 32cm phantom
  - Adult and pediatric head – 16 cm phantom
  - Pediatric body – some manufacturers use 16cm and some use 32cm
    - DIR normalizes all body exams to 32 cm phantom
- Empirical conversion factor of 2.3 based on measurements from a variety of scanners
  - divide by 2.3 to convert CTDIvol and DLP from 16cm to 32cm phantom
  - multiply by 2.3 to convert CTDIvol and DLP from 32cm to 16 cm phantom

4. Timing/Monitoring runs

- Some exams have monitoring runs that do not really represent dose to patient and must be excluded from dose estimates
  - Exclude exams that have CTDIvol > DLP
  - Use Acquisition Protocol to identify timing runs for exclusion, but field is not always populated

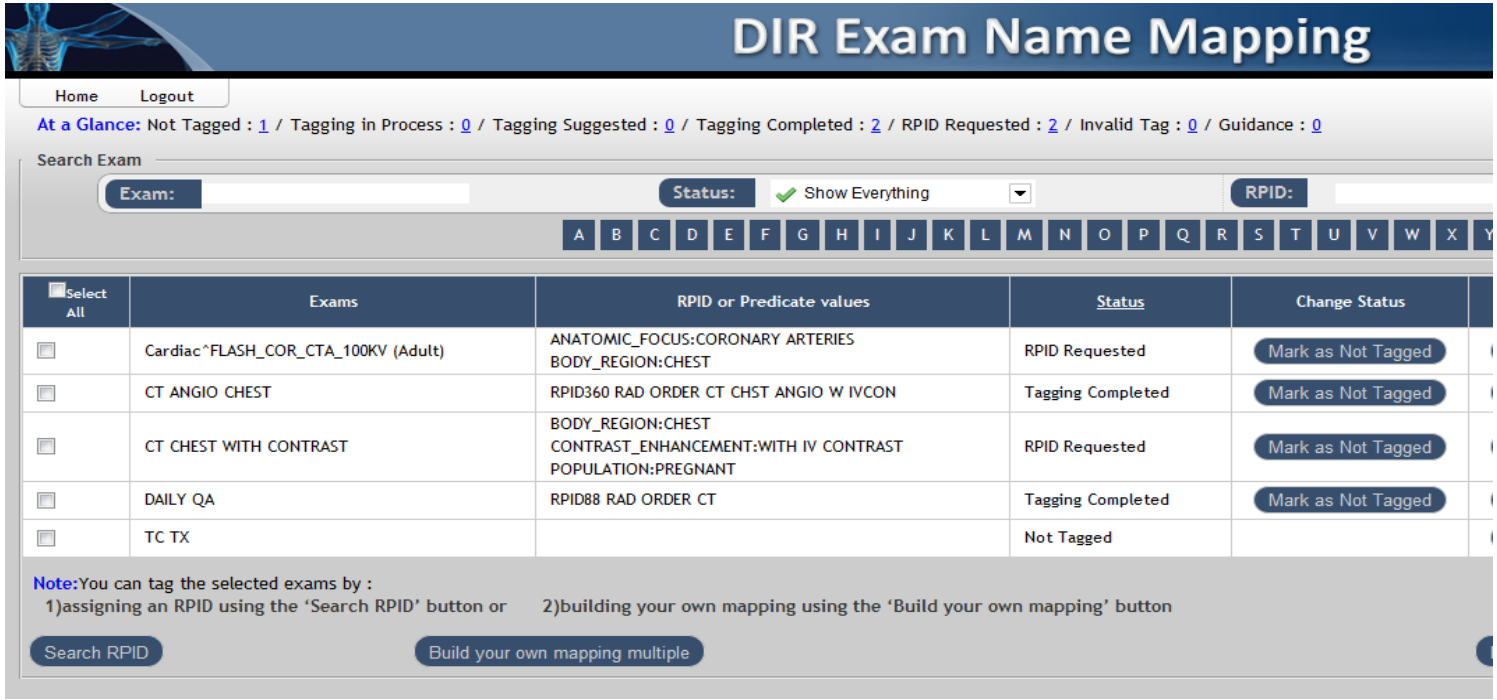
5. Procedure Name Standardization

- Exam names mapped to Radlex Playbook
  - http://playbook.radlex.org
- ACR used external vendor, RadMapps, to map all exam names in the registry at a point in time.
  - ~ 21,000 unique exam names
- After that, facilities map their own exam names using a mapping tool on website. Suggested tags are provided if an exam name is already in the database.

5. Mapping Exam Names

Procedure Name Standardization

- Exam names mapped to Radlex Playbook (playbook.radlex.org)
- Online tool to map procedure names to standard terminology.



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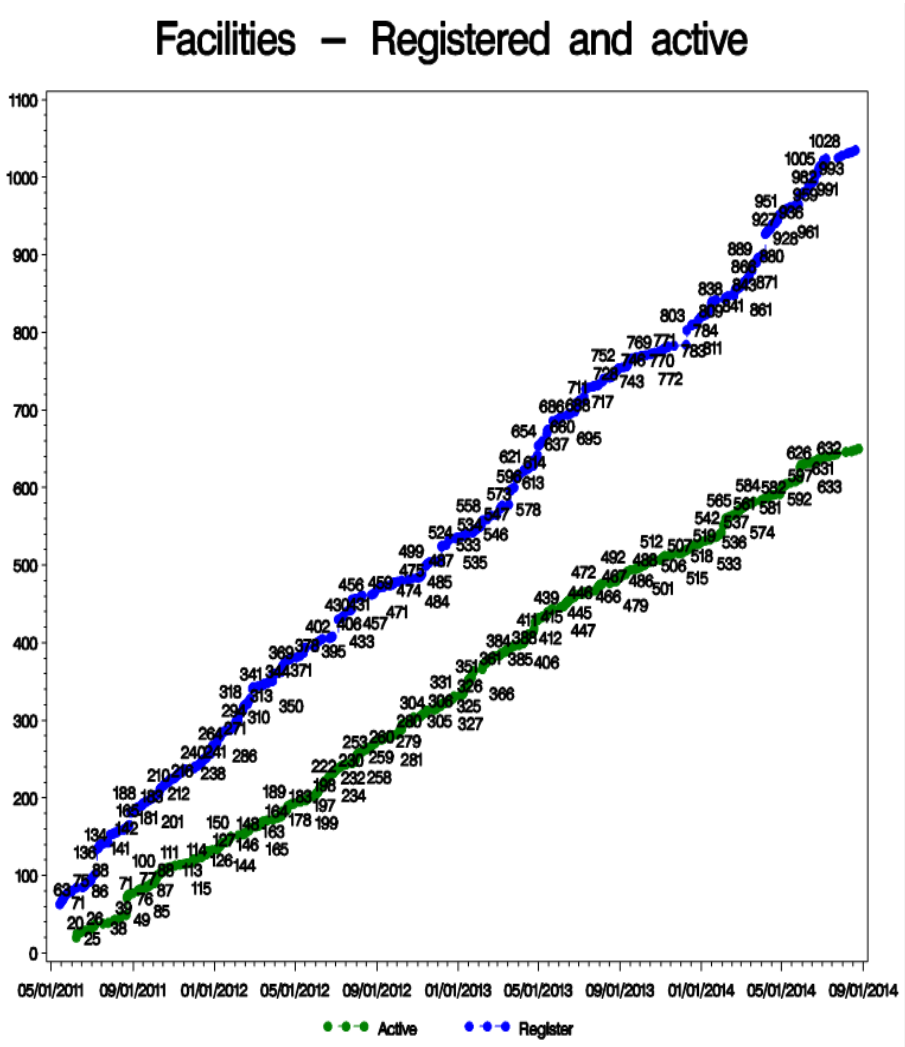
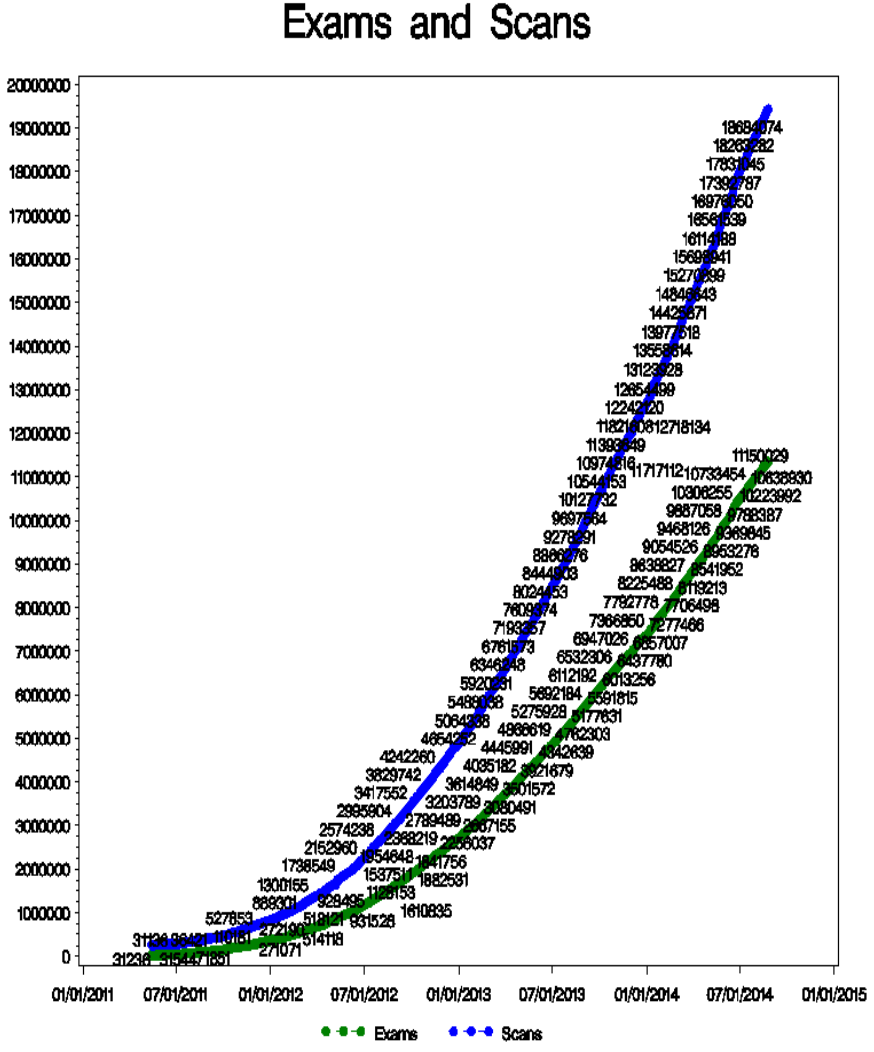
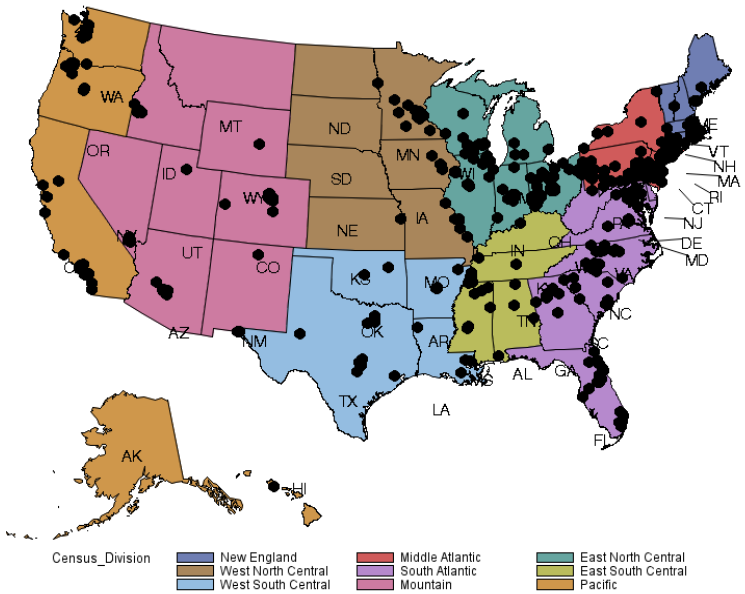
August 2014

1035 facilities/650 fully active; 11.3 million exams/19.4 million scans



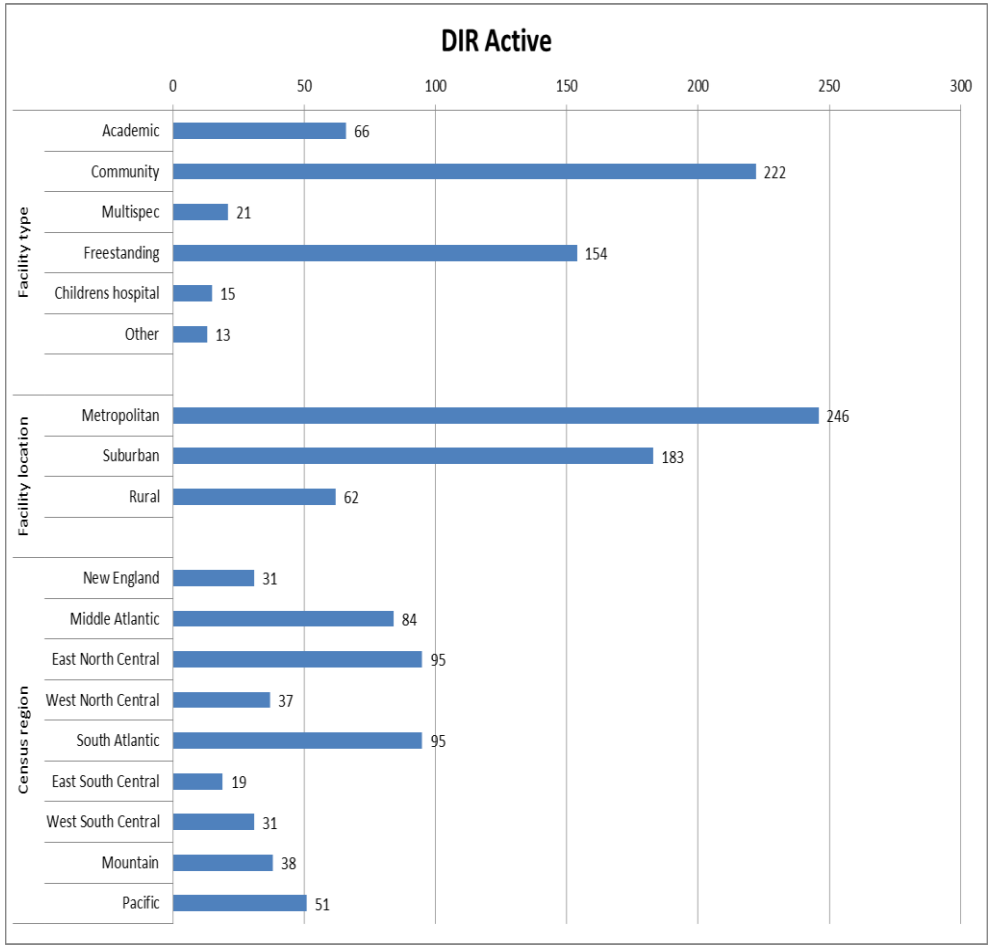


Participation from a Variety of Practice Types Across the US



Black dots indicate DIR facilities that contributed data for this report.

Some facilities outside of the US



January – June 2014

- 585 facilities received feedback reports on adult exams, and 564 on pediatric
- Reports on over 2 million adult CT exams and 194,000 pediatric CT exams with standardized names
- Results reported on Size-Specific Dose Estimate (SSDE), CTDIvol, and DLP

Additional Benefits of DIR

- Meets the recent Joint Commission requirements for CT radiation dose monitoring
- Meets reporting requirements
  - Certified as PQI (Practice Quality Improvement) project for ABR MOC (Maintenance of Certification)
  - Supports CMS's PQRS (Practice Quality Reporting System) requirements for 2014
- Free webinars led by ACR DIR staff and committee to answer questions related to radiation dose monitoring

How accurate are the data?

- There are several sources of inaccuracies
  - Errors in data processing, for example, inaccurate parsing, misidentification of timing runs
  - Incomplete data submission, particularly on localizers
  - Vendor issues in parsing dose screen
  - Ability to standardize procedure names

Data accuracy – mitigation and issues

- Over the past two years, facilities have helped us identify errors and correct them. As a result, data quality improves with use of the registry.
- As more scanners generate RDSRs, errors in the data decrease.
- There are persistent issues with some vendors in processing dose screens and we continue to identify and correct these.

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Data accuracy – mitigation and issues

- Exam name standardization has improved greatly as facilities have become more comfortable with the process and helped us adapt our processes.
- Persistent issues related to procedure names
  - The scanner fields that are available to us sometimes contain truncated names of procedures
  - Protocol names with more complete information are not always available
  - Hand entered procedure names continually introduce new names that may be unmapped
  - Actual procedure may change after protocol was picked and may not be reflected anywhere in the procedure name

Future plans

- Establish Diagnostic Reference Levels for high-volume CT exams
- Include additional modalities in the registry in the near future
  - Interventional fluoroscopy: in design stages for combining data from scanners and RIS to support appropriate exam name standardization
  - Computed and digital radiography: in pilot but waiting for scanner manufacturers to make some DICOM modifications to generate compliant radiation dose structured reports
  - Nuclear medicine: proposed

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