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Implementation of the ACR Dose Index Registry at a Large Academic Institution: Early Experience

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Abstract A rising conciousness within both the medical community and in the public has been created by the current levels of radiation exposure from increased use of computed tomography. The concern has prompted the need for more data collection and analysis of hospital and imaging center exam doses. This has spurred the American College of Radiology (ACR) to develop the Dose Index Registry (DIR), which will allow participating insitutions to compare the radiation dose from their CT exams to aggregate national CT dose data based on exam type and body part. We outline the steps involved in the process of enrolling in the DIR, the technical requirements, the challenges we encountered, and our solutions to those challenges. A sample of the quaterly report released by the ACR is presented and discussed. Enrolling in the ACR dose registry is a team effort with participation from IT, a site physicist, and a site radiologist. Participation in this registry is a great starting point to initiate a QA process for monitoring CT dose if none has been established at an institution. The ACR has developed an excellent platform for gathering, analyzing, and reporting CT dose data. Even so, each insititutions will have its own unique issues in joining the project.

Keywords Computed tomography · Radiation dose · Quality assurance

Background

The maturation of CT has occurred over the last decade with advances in multidetector systems, isotrophic voxels, and 3D workstations [1]. CT has arguably taken the place of the physical exam with a large percentage of people coming through the emergency department undergoing a CT exam in order to find or confirm suspected diagnoses [2]. The number of CT exams performed in the USA has increased 1,900 % between 1980 and 2005[3]. The large increase in CT use has come at a cost: rapidly increasing radiation dose exposure. Multiple high profile public cases of over-radiation have now brought this concern to the forefront of the public. The amount of radiation exposure attributable to medical imaging has increased 97 % from 1980 to 2005, increasing from 0.5 to 3 mSv, and now makes up almost 50 % of a single person's yearly background radiation exposure and doubling the yearly individual total background radiation exposure from 3.6 to 6.2 mSv [4].

The radiology community has been concerned about radiation exposure for several years including creating the Image Gently/Image Wisely campaigns and the continued evaluation and refining of the American College of Radiology (ACR) Appropriateness Criteria with inclusion of radiation ratings based on exam [5–7]. Manufacturers of CT hardware and software have also supported this endeavor with introduction of multiple new technologies to reduce patient radiation dose exposure over the last few years. These include dose modulation, low-dose protocols, and newer reconstruction algorithms [8–12].

The issue for radiologists with reducing radiation dose is the continuing struggle with physics: decreasing dose increases image noise resulting in decreased diagnostic image quality [13]. Emergence of new reconstruction algorithms, such as GE's Adaptive Statistical Iterative Reconstruction, help address this concern with up to 65 % decrease in dose without loss of image quality [8, 13, 14]. Technologies such as dual radiation sources allow for elimination of the noncontrast component of multiphase studies which reduces the overall radiation dose of certain exams

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[15]. Image quality and radiation dose limitation will continue to be in a perpetual tug of war until an acceptable compromise can be obtained.

Many institutions collect radiation dose levels, by proprietary methods or using recently available commercial or free software, in order to perform in-house quality assurance for evaluation of dose levels of the institution [16, 17]. Although this is helpful for the institution, it does not allow for comparison with other institutions in order to see whether they are in line with expected dose levels for traditional CT exams. A broadly based program collecting radiation dose exposures would allow for identification of outliers with radiation exposure doses well outside the expected range.

Participating in the Dose Index Registry

University of Washington Medicine comprises two large academic hospitals, two community hospitals, a high-end cancer center, almost 200 outpatient clinics, and seven neighborhood clinics. University of Washington Medical Center is a 450-bed tertiary care hospital and currently contains five CTs and one PET-CT scanners, and performed greater than 13,000 exams in 2011. Harborview Medical Center (HMC) is a 413-bed county-owned level I adult and pediatric trauma and burn hospital located in downtown Seattle and currently contains three CT scanners performing greater than 28,000 exams in 2011.

The ACR first considered the idea of the registry in 2004. After a design phase that lasted 7 years, the Dose Index Registry (DIR) was launched as a component of the National Radiology Data Registry in 2010. The ACR opened the registry to all institutions in May 2011[18].

At our university, there were no objections to joining the registry. The only matter for discussion was whether to register as one facility or two, as there are two distinct medical center campuses. The CT sections on the two campuses operate independently, generally overseen by the same faculty radiologists, but separate technical staffs. By registering as one institution, but two facilities, dose data would be segregated by site.

After registration, each site needed to build a server to run TRIAD, the data capture and forwarding software developed by ACR. TRIAD requires a PC with minimal capabilities, running Windows XP. Once the server was on the network, the ACR's technical support team worked with the local IT group remotely and installed and configured the software.

TRIAD can be configured to receive data directly from scanners or from PACS (Fig. 1). As it required less effort to install and maintain, the TRIAD server was connected to the PACS archive at each campus. This required the PACS field engineer to configure each enterprise archive to allow its connection to TRIAD. As is often the case, coordinating the efforts of the technical support personnel from three organizations (radiology IT, the PACS vendor, and the DIR) proved to be the greatest challenge of the installation. The final layout is shown in Fig. 2.

The TRIAD software is designed to accept an incoming DICOM exam and forward the following data elements to ACR: AE title of scanner, date and time of exam, exam name, dose information, and an anonymized exam identifier. Dose information can be provided either from a Radiation Structured Dose Report (RSDR) or from optical character recognition of the dose report series from the exam, which is a vendor-specific standard series number (for example, GE: 999, Siemens: 501, Philips: 103e). As a consequence, https is used for data transport without the need for a VPN to comply with HIPAA.

Two of the three CTs at HMC do not support RSDR, so the dose report series method was necessary. The third does send RSDR data to the archive, however, the PACS is not able to interpret the RSDR data, but rather stored it as a text note, and cannot export the report to TRIAD. This required us to export the dose report series to TRIAD even for scanners that support RSDR. We await a patch for our PACS to address this shortcoming.

With the software installed and running, several minor problems arose. Initially, the server's hard drive was filling up in less than a day, when according to specifications it should have the capacity of more than 2 weeks of data before autopurging. This was due to the fact that the PACS archive had been configured to send the entire exam to TRIAD rather than only the DICOM header and dose report series. The issue was resolved by changing the sending instructions in the PACS.

The server is currently monitored daily, and encounters a repeated error several times per day. This software bug is known by DIR IT support service and occurs when data is forwarded from the TRIAD server to the central server. Additionally, the DIR has a trigger mechanism to e-mail or phone the site administrator if it does not receive any dose data over a specified time interval (48–96 h).

In summary, the installation, configuration and maintenance of the TRIAD server is a simple matter. The greatest challenge, as usual, is getting the technical personnel from different vendors to communicate directly with each other.

Exam Code Mapping

The Dose Index Registry is predicated on comparing similar exams from different institutions, but it is often difficult or even impossible to identify similar exams from the exam names associated with them. The exam names are

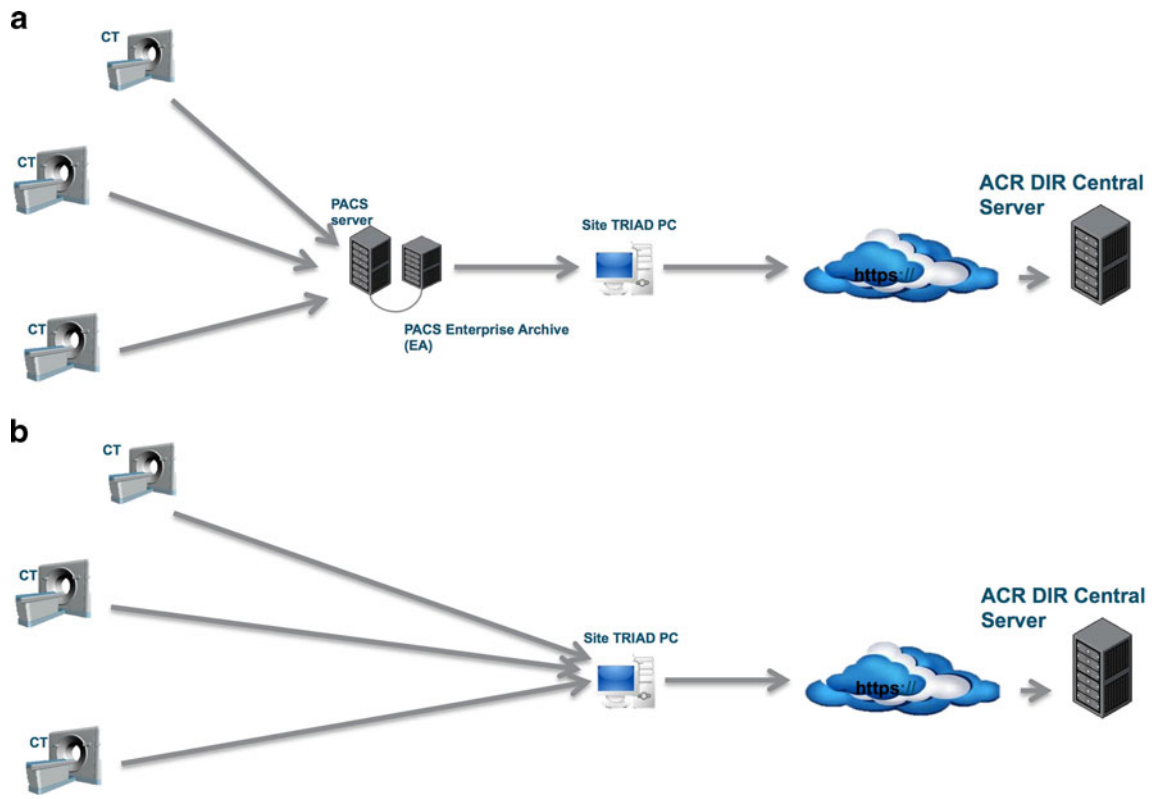

Fig. 1 Diagram of the connection possibilities to the TRIAD server. **a** Connection of PACS servers from each location to the TRIAD server. **b** Connection of each individual modality directly to the TRIAD server

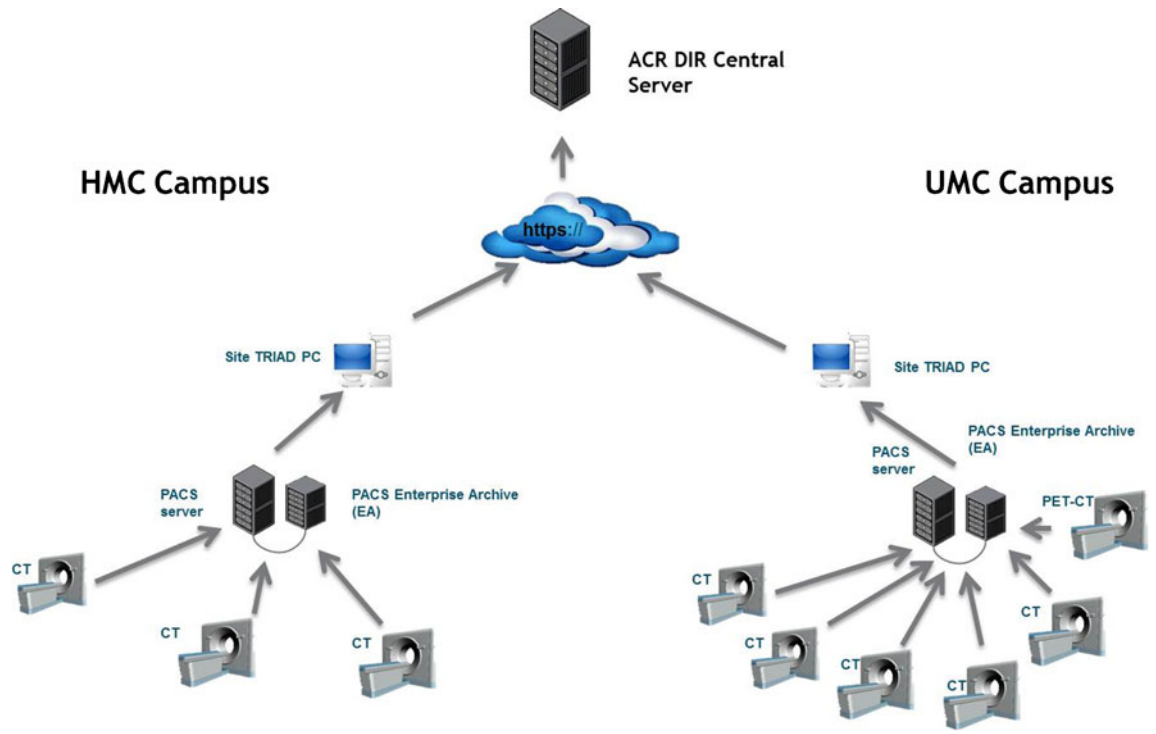

Fig. 2 Schematic diagram of the current connection set-up at our facilities

FacilityId	StudyDescription	Short_Name	RPID
100556	CT HEAD SURGICAL PLANNING WO CONTRAST	CT HEAD WO IVCON	RPID22
100556	CT HEAD W/O	CT HEAD WO IVCON	RPID22
100556	CT HEAD WO CONT	CT HEAD WO IVCON	RPID22
100556	CT HEAD WO CONTRAST	CT HEAD WO IVCON	RPID22
100556	CT Head Scan wo Contrast	CT HEAD WO IVCON	RPID22
100556	CT Head w/o Con	CT HEAD WO IVCON	RPID22
100556	CT Head w/o Con/Mag/Al	CT HEAD WO IVCON	RPID22
100556	CT NEEDLE GUIDE BIOPSY NEURO	CT HEAD WO IVCON	RPID22
100556	CT ORBIT EAR WO CONTRAST	CT HEAD WO IVCON	RPID22
100556	CT ORBITS,SCREEN FOR MRI	CT HEAD WO IVCON	RPID22
100556	CT Orb/Ear w/o	CT HEAD WO IVCON	RPID22
100556	CT Orbit/Sinus MR Screen	CT HEAD WO IVCON	RPID22
100556	CT Orbits or Ear wo Contrast	CT HEAD WO IVCON	RPID22
100556	HEAD CT	CT HEAD WO IVCON	RPID22
100556	HEAD WO	CT HEAD WO IVCON	RPID22
100556	TCT HEAD	CT HEAD WO IVCON	RPID22
100556	TCT HEAD W/O	CT HEAD WO IVCON	RPID22
100556	TCT HEAD WO CONTRAST	CT HEAD WO IVCON	RPID22
100556	TCT Head Scan wo Contrast	CT HEAD WO IVCON	RPID22
100556	TCT Head wo Con	CT HEAD WO IVCON	RPID22
100556	TCT Head wo Con/Mag/Al	CT HEAD WO IVCON	RPID22
100556	TCT Orbits or Ear wo Contrast	CT HEAD WO IVCON	RPID22

Fig. 3 List of the 19 exam names used at HMC for noncontrast head CT

idiosyncratic, no standard rules exist, and institutions can change their exam naming convention at will. The ACR chose to use the RadLex Playbook as its standard, and required all participants to map their local exam codes to that standard lexicon. ACR provided a mapping tool that was functional, but somewhat cumbersome in its first release[1]. Since exam-naming conventions tend to evolve over the years, and hospitals rarely apply new names to old exams, a PACS archive has many names for the same exam, each of which must be coded for the DIR separately. For example HMC has 19 distinct exam names for a noncontrast head CT (Fig. 3). Most of these are not used anymore, but are retained by PACS for use in identifying historical comparisons. The mapping task is time consuming and difficult, requiring someone involved in CT scanning, either tech or radiologist, to perform. There is no practical error-checking mechanism, and the inevitable ambiguities degrade the overall precision of the mapping process. Once done, however, the mapping only has to be updated if new exam names are introduced. The ACR has plans to make the mapping tool more user friendly to ease the mapping task.

Initial Report

The first report from the Dose Index Registry for the period July to December 2011 was issued in January 2012 comparing our facilities to peer institutions as well as the dose data in the entire registry.

Criteria for patient exams to be included in report were:

1. age of patient, >18
2. name of exam was tagged using DIR Exam Mapping Tool
3. at least 100 exams from at least 10 different facilities were mapped to the same DIR procedure heading

CT Dose Index ($CTDI_{vol}$) and dose length product (DLP) were compared to peer institutions and the entire dose registry [19]. Peer institutions are selected based on facility type, census region, and community size and separate comparisons made for each category. For example, HMC is compared to other academic facilities, facilities located on the west coast and facilities located in metropolitan areas as well as the entire DIR database.

The report provides $CTDI_{vol}$ and DLP dose measurements totaled both by exam and by scan. Per-exam doses are determined by summing the dose for all series within an exam. Per-scan doses are defined as the maximum dose value of any individual series within the exam.

Figure 4 shows an example of the DIR report showing $CTDI_{vol}$ per exam and per scan and Fig. 5 shows DLP per exam and per scan for one exam code—CT abdomen at HMC. Data is shown in boxplots and histograms. On the top left of each page is displayed a summary of median values per exam for our facility compared with our three different peer groups (facility type, location, and census region) and the entire dose registry. Boxplots display the minimum, maximum, interquartile range (25–75th percentile), mean and median values. On

[1] An updated release is much more user friendly.

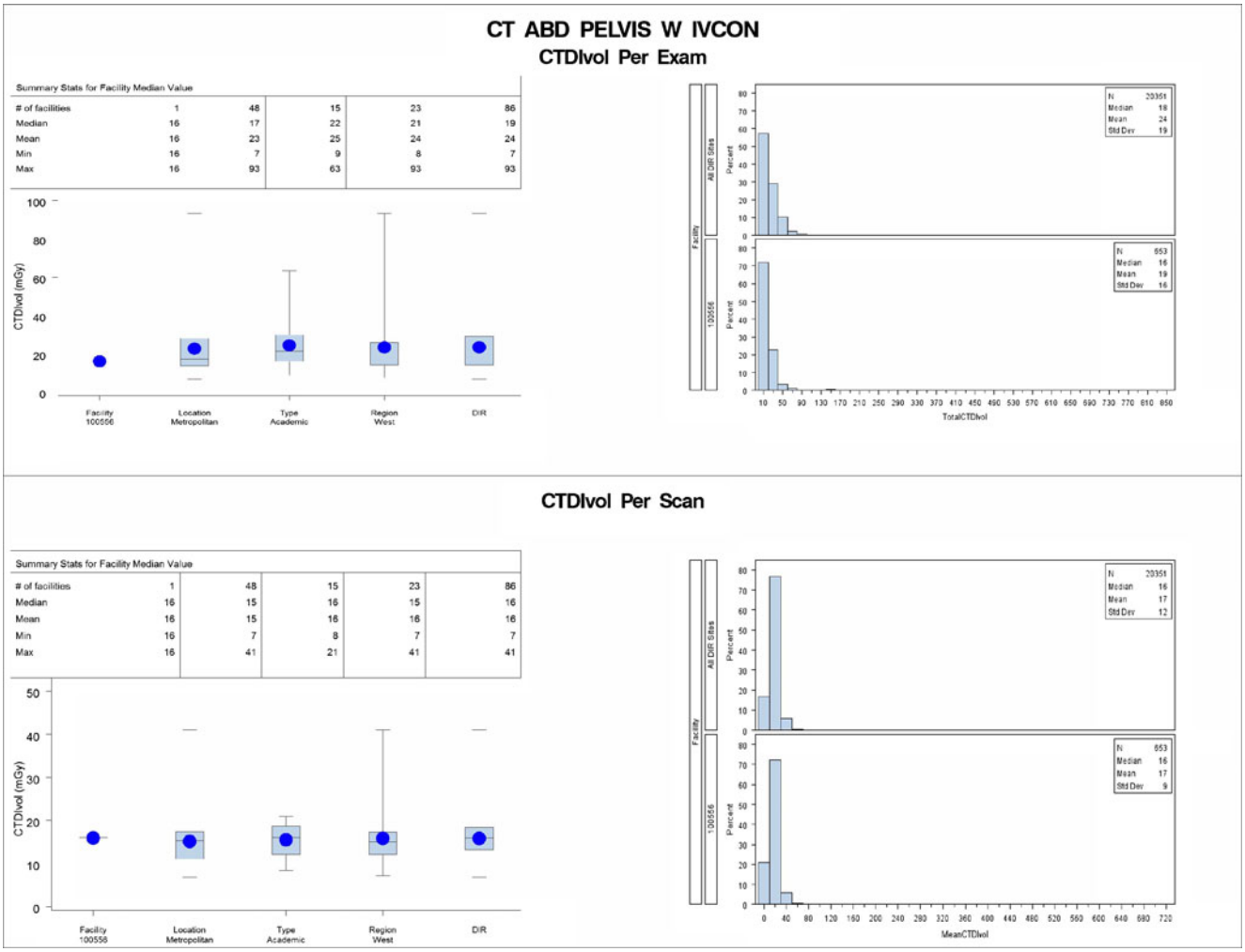

Fig. 4 Example of the DIR report showing $CTDI_{vol}$ per exam and per scan

the top right, histograms compare all DIR facilities (top) to HMC (bottom) for the dose per exam. Likewise, data per scan is shown on the bottom of each page. [2]

Discussion

National benchmark data in radiology has been very difficult to come by, especially in areas pertaining to radiation. The ACR Dose Index Registry represents a significant step in the direction of being able to set national standards for CT radiation exposure. A participating institution can use group data to establish quality targets and can use the regular reports to evaluate its performance against those targets, as well as compare its performance against peer institutions across the country. HMC has been monitoring CT dose by a partially manual system for more than 5 years in which technologists record the total DLP values into the RIS. In spite of this effort, we have only our own historical performance to gauge our current practices and as technology changes, comparison to past performance becomes decreasingly relevant. This process will stay in place until the DIR reports have been validated against our own data collection. At that point, the manual process of dose entry can be phased out.

Limitations of Dose Measurements

Although $CTDI_{vol}$ and DLP are the current standard methods for expressing radiation exposure, both models are somewhat limited as they are determined using phantoms. $CTDI_{vol}$ is an estimate of the total amount of radiation received in a standard volume. The dose length product is $CTDI_{vol}$ multiplied by the length of the scan. Patient dose is

[2] The second report, issued in September 2012, tracks SSDE for selected exam codes, $CTDI_{vol}$ and DLP on a per scan basis, but not per exam. This has the effect of underestimating the dose received by the patient in multi-phase exams, but making the report more coherent. Further evolution of the reporting format is expected.

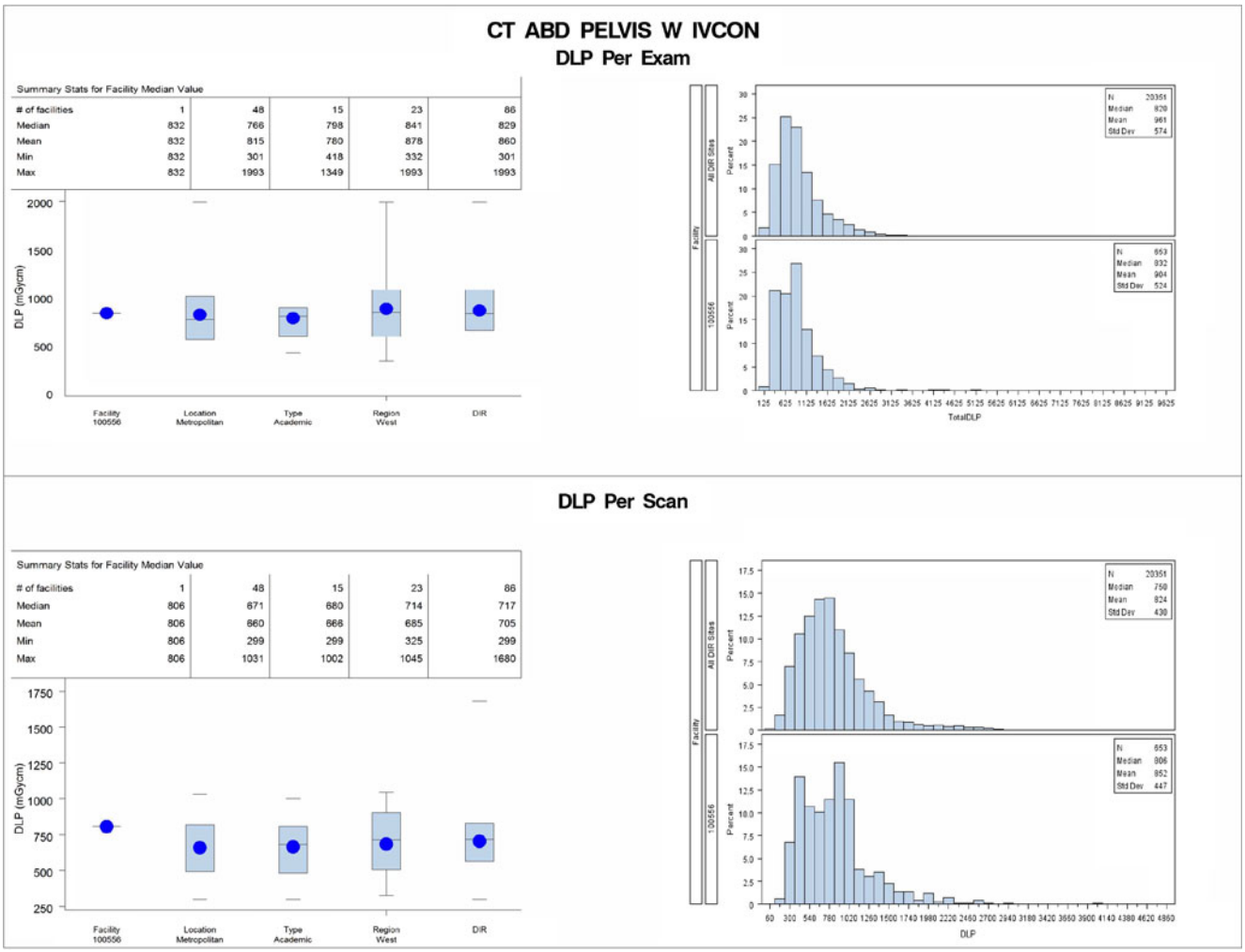

Fig. 5 Example of the DIR report showing DLP per exam and per scan for one example code—CT abdomen at HMC

determined by way of a conversion factor that is patient size dependent. The conversion factor can be based on any one of the following patient-dependent factors: AP dimension, lateral dimension, sum of the AP and lateral dimension or the effective diameter of the patient. The updated TRIAD application captures scout images of each patient, and transfers them to the central location, where the patient's size is estimated and a conversion factor assigned based on one of the above measurements. This allows reporting of size-specific dose estimates in the second and subsequent DIR reports.

Being a phantom measurement, $CTDI_{vol}$ is useful when comparing one scan protocol to another, since the calculation is patient independent. However, since it does not account for the length of the scan, it does not address total dose received by the patient.

DLP better approximates the dose actually received by the patient in a particular scan. It suffers from the same limitation as $CTDI_{vol}$ in that it is based on phantom measurements, and also does not account for patient size in reporting. It is less useful in comparing scan parameters from one protocol or scanner to another, since scan range, which varies from patient to patient, is part of the calculation.

Limitations of the Dose Index Registry

The ACR DIR makes use of the best dose measurements available today. While reproducible and relevant, the ACR itself notes several limitations of their reporting methods. The $CTDI_{vol}$ per exam can overestimate the actual $CTDI_{vol}$ in situations where an extra series is taken to capture a small section that was initially missed or to repeat a portion of a scan marred by artifact. The $CTDI_{vol}$ per scan will underestimate the actual $CTDI_{vol}$ in situations where more scans are obtained of the same body region than called for by a particular protocol [20].

The RadLex Playbook allows only one tag for contrast enhancement. Therefore if one assigns both oral (or rectal)

contrast and IV contrast, then the exam is tagged as exam with IV contrast. While RadLex allows noncontrast, contrast and three-phase contrast studies, it does not allow for four phase (i.e., noncontrast, arterial phase, venous phase, and delayed) exams.

We also encountered issues that limited the reliability of the data contained in the report. Multipart exams that are segmented after acquisition have only one dose report series, and the total administered dose is reported as having been received by the patient in each of the segmented parts of the exam. This markedly inflates the reported dose administered in each portion of the exam and to the patient in aggregate.

Exam code mapping is a manual process undertaken at widely distributed sites, resulting in unavoidable inconsistencies. Exams not tagged accurately by the sending facility cause problems both by skewing the benchmark data, and by being compared to inappropriate benchmark data itself.

In spite of the difficulties in mapping, the RadLex method is superior to an alternative approach using CPT codes to group exams, as the CPT system is insufficiently granular. Additionally, CPT codes are only finalized at the time of billing, whereas the dose data is sent at the time of scanning. The additional reconciliation step would be prohibitively complex.

Conclusion

The ACR Dose Index Registry is well designed to capture meaningful data in an automated fashion. In our experience, it is straightforward to join and implement, with the major technical challenges being the typical intervendor communication issues. The greatest challenge that remains is that exam code mapping is very difficult to do in a consistent fashion and affects the quality of the data in the report. When these challenges have been surmounted, the real value of the index will be in discovery of those institutions that are over-radiating patients under their current standard protocols and assisting them in maximizing their dose reduction potential and reduce the overall patient radiation dose levels.

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