RADIATION ACCUMULATION DATABASE (RAD): AN AUTOMATED METHOD FOR SUMMATION OF PATIENTS' RADIATION DOSES

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INTRODUCTION

In recent years, medical imaging has surpassed environmental exposure as the largest source of radiation exposure to the US population. The US Department of Health and Human services has classified ionizing radiation as a carcinogen since 2004, and with increasing utilization of medical imaging, radiation's potential deleterious has received significant attention. In recent years, the media have paid significant attention to the subject, and numerous news agencies regularly report on the subject.

With many organizations calling for responsible imaging, the need for permanent recording of patient radiation dose from medical imaging is apparent. As Computed Tomography (CT) accounts for the largest percentage of radiation exposure from diagnostic imaging, with an enlarging percentage each year, recording of CT dose in a format that can be easily accessed and analyzed is clearly of primary importance. While the newer DICOM-SR format fulfills this need, many institutions currently use the conventional DICOM format, which records the dose to patients as a DICOM image as part of the patient's study.

Cook and colleagues have recently described the use of Optical Character Recognition (OCR) in a "pipeline for extracting and archiving CT radiation dose information." While we have employed a similar method to archive the CT radiation dose for current studies that have screen-captured dose reports, similar reports are not available for many older studies, primarily those obtained by less modern scanners. With the use of OCR alone, the true cumulative dose to the patient from prior exams is not available to the radiologist or ordering clinician at our institution. In order to accurately measure the cumulative dose to the patient, we have developed a technique to mine patients' doses from information in the DICOM headers when the dose report is not available.

METHODS

If available, screen-captured CT dose reports are translated into a database using GOCR, an open-source OCR package, in a manner similar to that described by Cook and colleagues, with specific interest paid to the CT Dose Index (CTDI, in mGy) and Dose Length Product (DLP, in mGy-cm). This produces a fairly reliable capture of dose (Figure 1), however with each scanner come systematic errors that are addressed in our algorithm.

When a dose report is not available, the CTDI and DLP estimates are calculated through scan parameter mining. CT scanners use a large CTDI look-up table incorporated in the scanner software to calculate dose prior to scanning. To generalize dose measurements, an abbreviated look-up table was generated by recording projected dose in key protocols with varying technique settings. This provided the standard weighted CTDI (CTDIw, in mGy) for each scanner and study type by technique (Figure 2). These values would then be referred to based on the kVp, mAs, scan range, and body part scanned, which are all mined from the DICOM header. Because many scanners vary mAs based on tissue thickness, a weighted mAs average is generated to simplify dose calculation. The CTDI is multiplied by the length of the scanning range to generate the DLP. For studies acquired spirally and not axially, the CTDIw is converted into the volumetric CTDI (CTDIvol, in mGy) by multiplying the CTDIw by the spiral pitch factor.

The OCR and calculated CTDI and DLP values are recorded in the database, along with demographic information about the patient and scan type available from the Radiology Information System (RIS).

Figure 1. Schematic for conversion of screen-captured dose report to text file using the GOCR utility. Name is obscured for privacy.

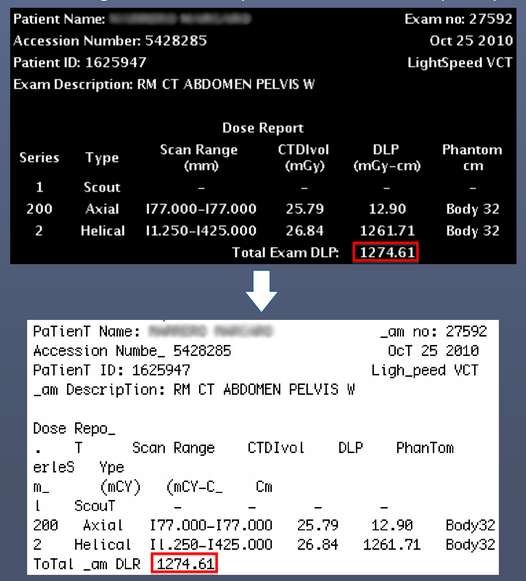

Figure 2. Sample Body CTDI Look-up Table

kVp	CTDIw per 100 mAs
80	2.4
120	7.6
140	10.9

RESULTS

Prior to the implementation of this system, the only available means of recording patient radiation exposure was by examining the screen-saved dose report in each exam, detailing the CTDI and DLP for each particular CT study. The values obtained using our data-mining technique are not significantly different from those reported on the CT generated dose report, so this technique allows us to gather cumulative information from a considerably longer time frame. Small variances between supplied and calculated doses were attributed to differences in the calculation of scan length and the phantoms used.

DISCUSSION

This accurate and automated means of recording the DLP of our CT studies in a format that is easily accessed and analyzed provides us with a valuable Quality Assurance (QA) tool. The utility of such a tool in comparing the same type of CT study between scanners, as well as between institutions, has been previously described by Cook and colleagues. This tool can also be used to provide near real-time alert messaging, as was described by Wang and colleagues, so that when studies that exceed a pre-determined DLP limit a QA officer can be immediately notified by email or text message to allow for prompt investigation of the cause of the abnormal dose. If such a dose is due to technologist or protocol error, the technique for future scans can be corrected before more patients are inappropriately exposed.

Since the DLP is unique to CT, the DLP must be converted into an effective dose (ED) in order to calculate the cumulative patient dose across all modalities utilizing ionizing radiation (i.e., radiography, fluoroscopy, PET, and nuclear medicine studies). By cross-referencing with the ImPACT CT Patient Dosimetry Calculator, the ED will be calculated from the DLP and other values such as sex and type of study (i.e., irradiated body part), which are also available in the image DICOM header. Since the conversion factors used to calculate ED are estimates and may change, any future changes can be applied to past DLP values to provide the most accurate value of patient effective dose. This cumulative effective dose could, in theory, be provided to the clinician at the time of order entry along with a translation of the ED value into an estimated increased risk of carcinogenesis, reinforcing the principal of ALARA.

An additional benefit to our method for DICOM header-based dose calculation is the ability to check the accuracy of our OCR generated, dose report DLP values. The optical character misrecognition of a decimal point or numeric value may alter the recorded DLP by a significant degree, even an order of magnitude. By using two methods to calculate patient dose, we decrease the likelihood of error.

LIMITATIONS

The stochastic effects of ionizing radiation are inferred estimations largely based on the increased cancer incidence in survivors of Hiroshima and Nagasaki. However, the direct carcinogenic effect of ionizing radiation used in medical imaging has been observed in certain populations. Further, studies have shown that dose estimation based on phantoms, which we use in both the OCR and calculation methods for assessing patient dose, are in fact poor estimations of the actual patient dose. While the value of the information provided by our tool is limited by estimations, it is nevertheless helpful in assessing relative exposure to a given patient, radiation output for a given scanner, and ultimately in minimizing radiation exposure.

CONCLUSION

This tool allows our department to calculate both the prior radiation dose to patients as well as maintain and update those records as patients undergo further imaging. Ultimately, this tool could be expanded to encompass other radiography, fluoroscopy, and nuclear medicine studies. Further, since patients obtain imaging at multiple sites, it is the hope of the authors that similar techniques could be used to populate a national radiation dose database.

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