Rationale and methods of radiation dose optimization; validation of SSDE, importance of patient centering, and factors influencing paediatric radiation exposure at CT.

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The aim of this paper is:

1. To discuss the rationale for careful monitoring of radiation exposures in a diagnostic imaging and interventional radiology department.
2. To share University College Cork's (UCC) experience with investigating lifetime cumulative effective doses in groups of patients who are "at risk" for high lifetime exposures
3. To briefly discuss strategies adopted at UCC to optimize radiation exposure in these patient groups.
4. To share our experience with "radiation dose management software" (RDMS) in our department.
5. To discuss the enormous potential of this technology and challenges which implementation of these systems pose.
6. Share Cork University Hospital experience with application of RDMS system

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1. Rationale

Total radiation from all sources is approximately 3.6 mSv. The vast majority of exposure to the Irish population (86%) is from background radiation-radon. Approximately 14% of the total exposure is from medical imaging 14% from Medical Imaging. Recent data from US suggest that 50% of total radiation exposure to population may now be attributable to medical imaging.

CT utilization increased by 300% from 1996 and 2010. In the same period CT contribution to dose increased from 30% to 67%. There are several important factors associated with the increase:

- Rapidly proliferating new indications- CT colonography, CT angiography, CT perfusion, CT coronary angiography
- Increased speed and ease of CT imaging –larger anatomic areas can be scanned
- Multi-phase scanning protocols
- Developments to reduce radiation exposure are being implemented in a non-standardized fashion
- Different departments focus radiation optimization efforts on different anatomical regions and individual protocols e.g. abdominal CT, brain CT's etc.
- Differences between generations of CT scanners, manufacturers and models of CT scanners and how these technologies are used at different institutions

The net effect is a huge variability in radiation exposures in clinical practice and in the literature. A department may have very low CT brain exposures but unacceptably high abdominal CT exposures. Dose reduction now a major focus of industry and CT manufacturers now see capability for low dose imaging as major selling point for new CT equipment.

2. UCC Experience with "At Risk Patients"

Of special interest is cumulative effective dose (CED) in patient groups "at risk" for high CED:

- Crohn's Disease
- Organic and functional GI disorder
- Cystic fibrosis patients
- Testicular cancer

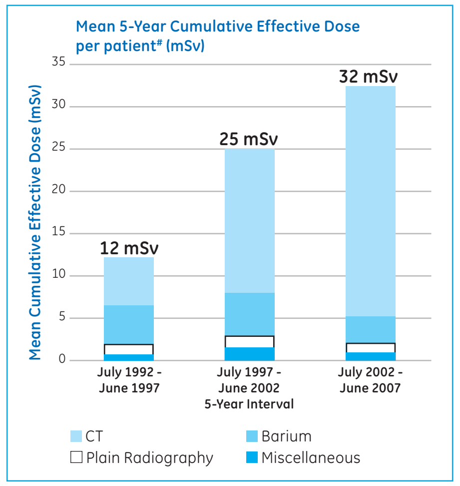
Patients with the above diagnosis are considered at risk because:

- Young age at presentation and initial imaging
- Chronic relapsing condition
- Emerging concerns of "young cancer survivors"

Study 1

Crohn's Disease: factors associated with exposure to high levels of ionizing radiation

AN Desmond, K O'Regan, C Curran, S McWilliams, T Fitzgerald, MM Maher, F Shanahan



The increased utilization of CT in the final 5 years of the study is evident from the graphic above. CT accounted for 16.2% of studies and 84.7% of diagnostic radiation. 15.5% of patients received high CED (>75 mSv). It is interesting to note the increase in CT utilization corresponded with a decrease in barium studies.

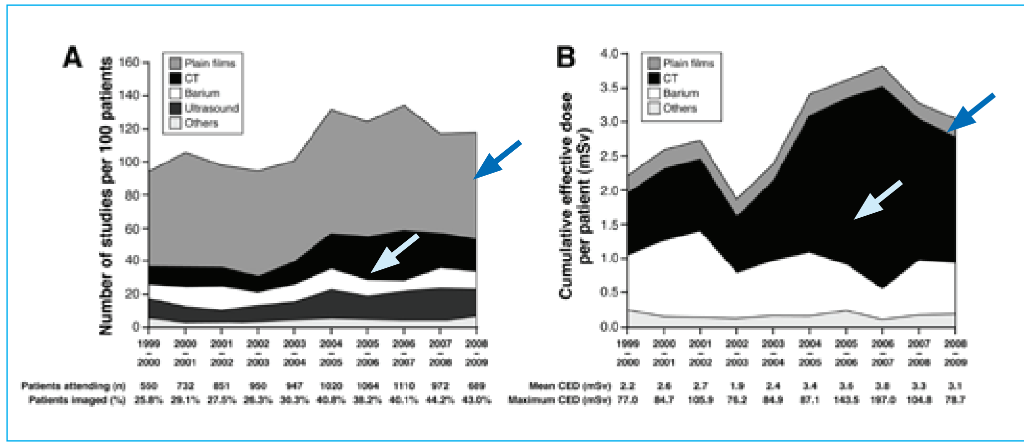
Study 2

Radiation Exposure From Diagnostic Imaging Among Patients With Gastrointestinal Disorders

Alan N. Desmond, Sebastian McWilliams, Michael M. Maher, Fergus Shanahan and Eamonn M. Quigley. Clinical Gastroenterology and Hepatology Volume 10, Pages 259-265 (March 2012)

Study findings included the following:

- Increase in number of imaging studies/ annum
- Increase in Use of CT
- Stable use of plain radiography
- Reduced use of barium studies
- Increase in CED is disproportionately due to increased use of CT

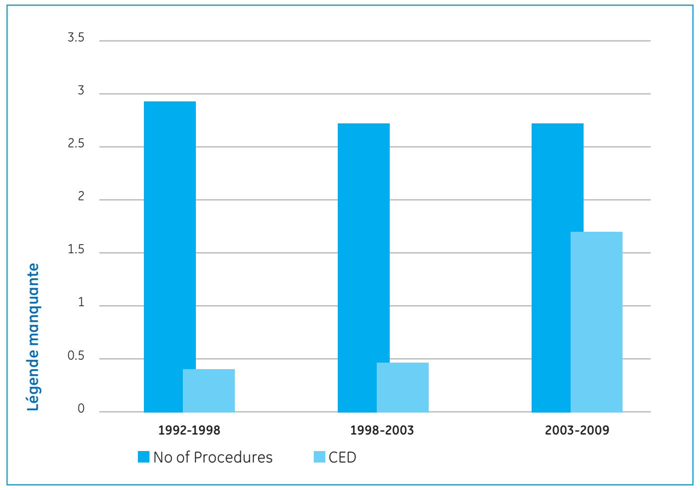


Study 3

Radiologic Imaging in Cystic Fibrosis

O'Connell OJ, Chest 2012 Jun;141(6):1575-83
Mettler F et al Radiology 2008;248:254-63.

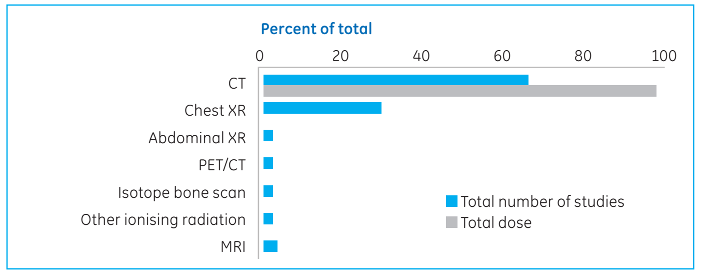
232 Cystic Fibrosis patients at CUH participated in the study between 1992 and 2009 (divided into three 5-year study periods). The mean age of patients was 21.5 years (SD 11.6 years). The mean FEV1 % predicted - 66% (SD 27.3%). Seven patients received lung transplants during study period and 42 patients died (Hepatocellular Ca n=1)
The study found a slight decrease in number of annual procedures but a 5.9 fold increase in annual CED between period 1 and period 3.



Study 4

CED in Testicular Carcinoma

The project sought to compare testicular carcinoma patients to other "at risk groups". The study found CT comprised 64% of imaging studies and CT is responsible for 98% of CED.



Conclusions

- There is Increased performance of CT scanning across all study groups in recent years with continued high utilization of plain radiographs.
- Small subgroups of patients (especially Testicular cancer patients and Crohn's patients) receive high radiation doses.
- Computed Tomography is the biggest contributor to CED in all groups studied.
- If we want to reduce CED in groups "at risk for high CED" we must reduce exposure from CT.
- Monitoring dose within a radiology is extremely labour intensive and haphazard
- Sporadic "red flag cases" very difficult to identify and investigate
- Potential for failure to recognize protocols imparting excessive radiation exposures

3. Strategies for Radiation Dose Optimization

The purpose of radiation dose optimization is achieving a diagnostic quality image at lowest possible radiation dose. Reducing radiation dose can increase image noise – increasing the possibility of a missed diagnoses. There is a fine balance between radiation exposure and image quality.

Dose optimization activity requires attention to following acquisition parameters:

- Automatic Exposure Control (AEC) techniques
- Reducing dose without automA (i.e. fixed tube current technique)
- Scanning beyond the anatomical limits-Importance of Radiographer
- Iterative Reconstruction techniques

Summary

Reducing dose requires team approach. Radiologists, radiographers, medical physicians and referring physicians must all have a role. Individualizing protocols to specific patients and disease entities will yield significant dose reductions.

Newer generations of CT scanners incorporating newer technologies (e.g. Iterative reconstruction) will result in significant dose reductions. These need to be used optimally and we need to be aware of potential for over-exposure when staff are inexperienced with new technology.

Very difficult to optimize dose for all anatomic areas throughout a hospital. To identify areas at risk, it is vital to have capability to monitor radiation exposures associated with every protocol, at every CT scanner, at all times of day and night. Easily accessible online software systems to facilitate regular monitoring of dose associated with CT studies necessary.

4. Radiation Dose Management Systems

Radiation Dose Management Systems (RDMS) are web-based patient radiation dose monitoring software products used to capture, track and report radiation dose directly from any imaging device or PACS.

The RDMS can monitor and archive dosimetric data in a multi-modality and vendor-agnostic environment. The RDMS can track patients' cumulative dose over time and steps can be taken to prevent excessive medical radiation exposure.

The RDMS can assess factors within radiology department/system which may affect dose. For example, sporadic excessive exposures can be recognized immediately. Large volumes of data pertaining to radiation are readily available and easily accessible. Daily/weekly reports, customized to the needs of a department are easily generated from the RDMS.

Individual hospital performances can be assessed and compared to national or international guidelines/best practices. The RDMS is a valuable tool for driving awareness across modalities & devices with cumulative dose tracking. RDMS systems analyze radiation dose delivered to patients undergoing a variety of imaging procedures.

Hospitals can optimize performance with analytics tools to find the right balance between image quality and dose. The RDMS can also provide feedback to staff on team initiatives to reduce dose can be appreciated and analzsed critically.

RDMS also enable compliance with reporting capabilities for radiation safety personnel , internal stakeholders, patients, external governing bodies, and regulatory authorities.

The functionality of an RDMS system fits well with the mission of newly formed Hospital Dose Optimization Teams. Dose teams can set protocol-specific alert levels to draw attention to opportunities for dose conservation. With knowledge of alerts, the team can focus on personnel, equipment, techniques and other valuable patterns highlighted by dose analytics.

5. Challenges of RDMS Systems

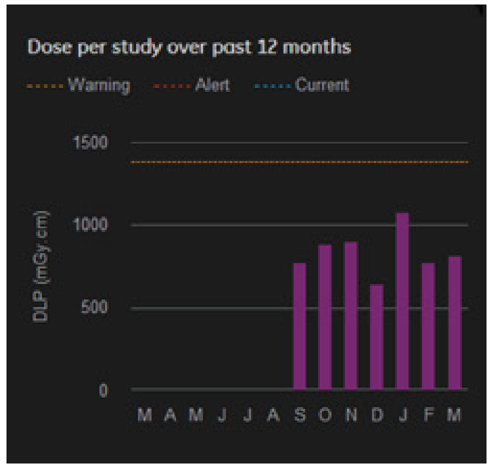
Radiographers were anxious initially at installation of RDTS at CUH. Radiographers felt there was a new "watchdog" in their midst. Radiographers were particularly resistant to monitoring individual radiographer doses (feature still not enabled on the system).

After first few meetings, most radiographers saw benefits of RDMS e.g. highlighting good practices and excellence in the workplace. Lead radiographer in CT now finds RDMS an "invaluable tool" and would feel "vulnerable without it".

6. Cork University Hospital with GE Healthcare RDMS Systems

Study 1

Audit of Imparted doses to Paediatric Patients using RDMS



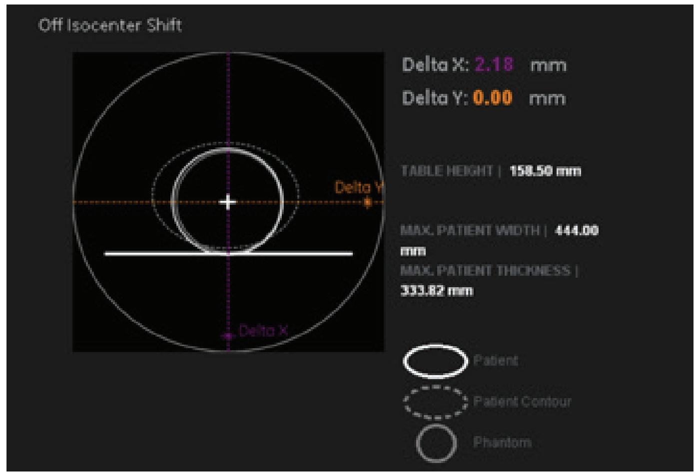
Conclusion

Use of RDMS highlighted the vast array of protocols available to the radiographers. 214 locally coded protocols. Identified need to reduce the number/streamline the protocols to enable appropriate selection especially in paediatric population (i.e. "routine brain" vs. "on call brain")

RDMS facilitates assessment of dose associated with individual CT protocols and comparison with DRLs. RDMS enables identification of those protocols where risk for over-exposure occurs.

Study 2

Using Isocentre Tool in RTDS to assess patient positioning on CT table.
121 consecutive adult abdominal CTs were evaluated for delta X & Y from isocenter and prone vs supine scanning

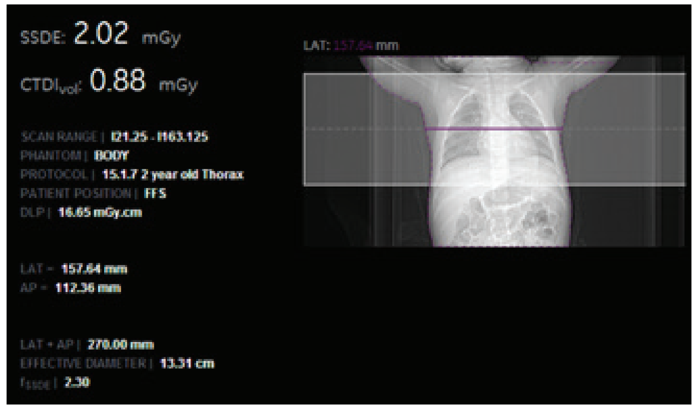


Conclusion

Accurate patient centering is a simple dose reduction strategy often neglected in the literature. Positioning was generally good in this study. Inaccurate positioning more likely in prone than supine positions. Resultant mean dose increase ~14.74% (range 2.5-46.0%). Automated centering tool would be of benefit.

Study 3

Accuracy of SSDE estimation with RDMS.



Size Specific Dose Estimates (SSDE) is a correction factor developed by AAPM Task Group 204 to better estimate patient dose during CT scan. SSDE (product of correction factor and CTDIvol) estimates the peak dose at the center of the scan length of the irradiated patient. Accuracy of SSDE within 20%.

The Quality Improvement Registry in CT Scans in Children (QuIRCC) is already using SSDE in dose recording. SSDE is automatically generated by dose-tracking software

Conclusion

RDMS is a major advance in monitoring radiation exposures delivered to patients; delivered by hospitals; and delivered by imaging facilities.

For the first time, data relating to radiation exposures are available instantaneously online.

If data are closely monitored and systems are put in place to monitor and investigate "red-alerts" , accidental large exposures should be reduced and repeated accidental high exposures should be eliminated.

Once initial resistance is overcome, RDMS creates a focus on dose optimization in a radiology department. Opportunities for national and international dose registries to be established and for systems for coding studies in a standardized fashion to be handled centrally.

Facility for staff to access RDMS individually in their work environment (i.e in CT scanning suite) is a major advantage. Radiographers and radiologists can monitor their own performance.

If large percentage of staff buy-in to looking at their own performance, incidences of "red alerts" will decrease. Decreased "red-alerts" good for patient safety and reduces work of RDMS team.

Important, however, that reducing dose is not over-prioritized at the expense of image quality and reduced diagnostic integrity.

Areas of concern include:

- RDMS provides huge volumes of data, which requires close monitoring and analysis on a daily basis.
- If systems are not in place to deal with BIG DATA, hospitals will be vulnerable if important data pertaining to patient safety is ignored
- Staff currently employed with responsibility for Radiation Safety need to become proficient with RDTS
- Implementation of RDTS will undoubtedly require hiring of additional staff.
- National and International standardization of Coding of studies needs to be carefully addressed.
- At a basic level, radiographers now need be vigilant in coding CT studies carefully
- Systems should allow radiographers to highlight studies requiring modification, additional imaging phases etc., or studies with technical difficulties etc.

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