New Dose Reduction Techniques in Computed Tomography

MISERICORDIA UNIVERSITY

Student Researcher: Andrew Taylor

Faculty Advisor: Gina Capitano Ed.D., R.T.(R)

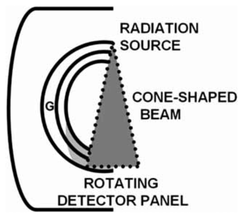
Introduction:

- "Computed Tomography (CT) is the process of creating a cross-sectional tomographic plane of any part of the body" (Long, Rollins, & Smith, 2019, p.206).
- One of the main concerns regarding CT is that it requires the use of larger amounts of harmful ionizing x-rays than other modalities to attain sets of volumetric data.
- To reduce the potential risk of the harmful effects of ionizing radiation, low-dose radiation techniques have been developed for use in CT examinations, such as low-dose chest computed tomography (LDCT).
- The long term effects of LDCT are likely very small in comparison to standard full dose protocol (Parker, Groves & Kusmirek, 2017).
- The purpose of this research is to examine recently developed dose-reduction techniques used in modern CT scanners and to evaluate how CT protocols have improved both in regards to maintaining diagnostic quality and reducing patient dose.

Modern CT Scanner Improvements

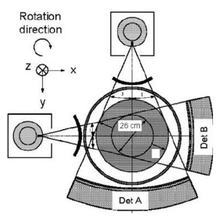
- Modern CT scanners have evolved, and are often dual source (DSCT) or dual energy, which provide several advantages over the traditional single source scanner.
- DSCT has two measurement systems consisting of two x-ray tubes and corresponding detectors. Single source CT has only one x-ray tube and corresponding detector (Lim, Ha, Hwang, & Lee, 2019).
- One major advantage of dual source scanners is the increased pitch rate compared to single source scanners. It can reduce radiation dose, motion artifact, and improve image quality (Lim et al., 2019).

Single Source CT Scanner



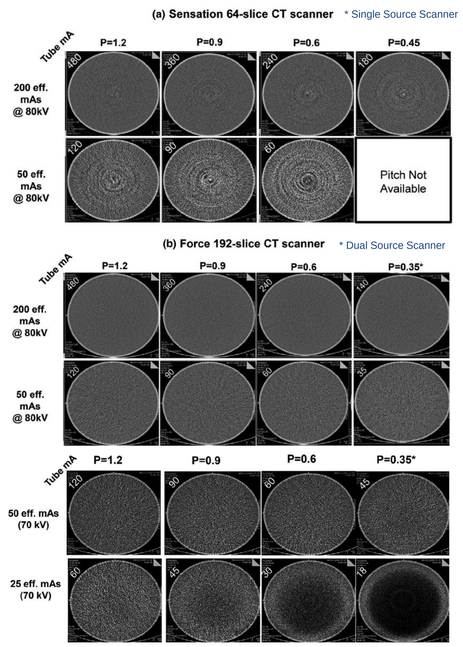
(Bardo, Brown, 2008, p. 234).

Dual Source CT Scanner



(Flohr et al., 2006, p. 259).

- Pitch speed has been found to have a positive impact on the diagnostic quality of images that have utilized ultra-low-dose protocol.
- There is an increased presence of the phenomenon of photon starvation at lower keV ranges, and the data below demonstrate that artifact in full detail (Browne, Bruesewitz, Vrieze, McCollough, & Yu, 2019).
- The data demonstrate that images taken using a lower pitch rate display greater evidence of image artifact. Image artifact is a lesser issue for higher pitch rate systems until keV and mAs ranges are significantly decreased.



(Browne, Bruesewitz, Vrieze, McCollough, & Yu, 2019)

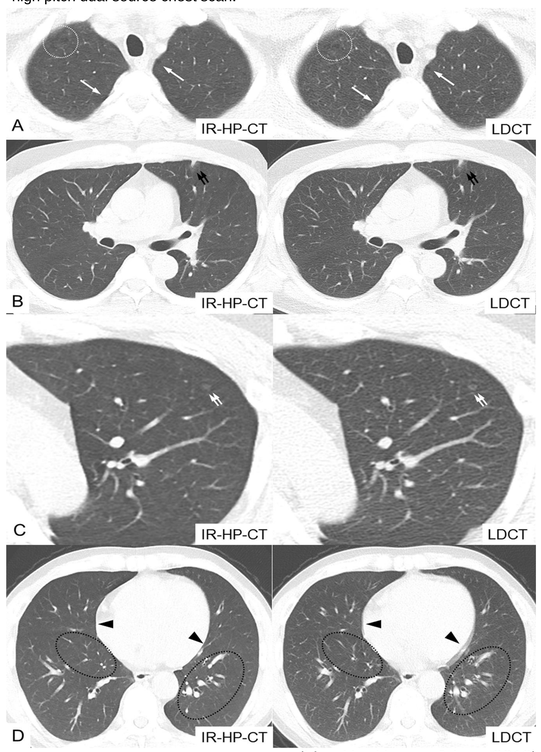
New Dose Reduction Techniques

- Several new dose reduction techniques have been developed that can significantly reduce the total dose in studies when compared to older low-dose techniques. In some cases, these new techniques can even increase the diagnostic quality of images.
- The advantage of having two sources of x-rays over one, allows modern scanners to utilize an algorithmic process known as iterative reconstruction to be able to reconstruct data gathered from multiple tube sources (Solomon, Marin, Choudhury, Patel & Samei, 2017).

- When looking for liver lesions, iterative reconstruction techniques were found to "increases detectability at a given radiation dose (approximately 2% increase in detection accuracy) and allows for imaging at reduced radiation dose (16% ± 13), while maintaining low-contrast detectability of subtle hypoattenuating focal liver lesions" (Solomon et al., 2017, p. 777).
- By combining the use of both dual source scanners and iterative reconstruction techniques, technologists found that 120 kVp/30 mAs iterative reconstruction high pitch dual source chest scan(IR-HP-CT) reduced not only the dose by 40% but also the cardiac pulsation evident on both lung and mediastinal images, and it afforded an image quality comparable to or superior to that afforded by 120 kVp/40 mAs LDCT (Lim et al., 2019).
- When testing low dose protocol for maxillofacial bones, there was an approximate 70% dose reduction used in the technique for the CT axial images, and 74% of observers still preferred CT images over DR for the diagnosis of fractures (Meijer, Rozema, Hartman, Duim, Minnen, Krijnen & Groot, 2016).

* IR-HP-CT: Iterative Reconstruction high pitch dual source chest scan.

* LDCT: Low dose chest scan



(Lim, Ha, Hwang & Lee, 2019)

	LDCT	IR-HP-CT
Pitch	0.8	3.2
Gantry Rotation time (ms)	0.5	0.28
Reconstruction algorithm (kernel)	Filtered back projection (B50f)	Iterative reconstruction (i50f, SAFIRE, S3)
Tube current (mAs)	40	30
Tube voltage (kVp)	Fixed 120 kVp	
Automatic tube current modulation	Not applied	

LDCT, low-dose chest CT; IR-HP-CT, iterative reconstruction of high-pitch dual source chest CT; SAFIRE, Sinogram Affirmed Iterative Reconstruction.
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	IR-HP-CT	LDCT	P-value*
Scan length (cm)	44.2 ∓ 2.8 (43.2, 45.3)	40.8 ∓ 2.7 (39.8,41.9)	<.0001
DLP (mGy-cm)	73.1 ∓ 4.6 (71.4, 74.8)	109.5 ∓ 7.3 (106.8, 112.2)	<.0001
SSDE (mGy)	2.1 ∓ 0.2 (2.1, 2.2)	3.5 ∓ 0.3 (3.4, 2.6)	<.0001
Effective radiation dose (mSv)	1.0 ∓ 0.1, (1.00, 1.05)	1.5 ∓ 0.1 (1.49, 1.57)	<.0001
Summation of anteroposterior and lateral diameter (cm)	58.5∓4.5, (57.0, 60.5)		

Data are means ∓ standard deviation, and the values in parentheses are the 95% confidence intervals. IP-HR-CT, iterative reconstruction of highpitch dual-source chest CT; LDCT, low-dose chest CT; DLP, dose-length product; SSDE, size-specific dose estimates. *P-values were calculated using the paired t-test.
https://doi.org/10.1371/journal.pone.0211097.t003

Conclusion

- Advancements in the modern CT scanner have resulted in the design of low dose protocols which utilize significantly less radiation than typical protocols.
- While radiation dose has reduced dramatically for many different studies, CT should still not be considered a low dose modality.
- Despite the pivotal role of CT inclusive of dose reduction strategies, some argue "that the concept of 'low dose' itself is flawed and that such statements only increase unjustified fear by patients, causing some patients to decline CT examinations that might better manage their disease or even save their lives" (Rehani, Szczykutowicz & Zaidi, 2020, p. 293).
- CT technologists need to educate patients regarding the risks of ionizing radiation and the diagnostic benefits of examinations, and as always, should try to reduce dose and image gently!

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