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Temporal Trends in Radiation Exposure and Utilization of Coronary CT Angiography, SPECT, and Invasive Coronary Angiography

Ronald L. Jones[1*], Richard A. Clark[1], Bernard J. Rubal[1], Ryan J. McDonough[1], Kenneth Stone[1], Edward A. Hulten[2], Todd C. Villines[2], Ahmad M. Slim[1*] and Kevin E. Steel[1*]

[1]Cardiology Service, Brooke Army Medical Center, 3551 Roger Brooke Dr, Fort Sam Houston, TX 78234, USA.
[2]Cardiology Service, Walter Reed National Military Medical Center, 8901 Wisconsin Avenue. Bethesda, MD 20850, USA.

Authors' contributions

This work was carried out in collaboration between all authors. Author SKE designed the study, and assisted in data collection, analysis and first draft write up. Authors RAC, RJMD,KES performed data collection and study segment verification as well as input on data collection. The statistical analysis was performed by authors BJR and EAH with valuable input on final manuscript write up. Author RLJ, collected data and assisted in analysis, wrote the first draft of the manuscript. Author AMS, designed the radiation reduction process, assisted in data analysis and wrote the final manuscript.

Original Research Article

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ABSTRACT

Background: The use of noninvasive medical imaging has increased over the past decade at a cost of significant lifetime radiation exposure to study subjects. We report the implementation of radiation dose reduction methods and associated reduction in ionizing radiation exposure with Coronary Computed Tomography Angiography (CCTA) over time.
Methods: Radiation doses and total number of studies performed were evaluated

**Corresponding author: Email: ahmad.m.slim.mil@mail.mil; ronald.l.jones244.mil@mail.mil; kevin.e.steel.mil@mail.mil;*

constantly from January 2010 to September 2012 for CCTA (N=2613), as well as Single photon emission computed tomography (SPECT, N=8060) part of an ongoing effort to minimize radiation exposure. Analysis of variance was used to evaluate the radiation exposure reduction among modalities. We compared CCTA radiation doses in the era of retrospective protocols coupled with dose modulation (40%-80%phase) using Siemens® 64-slice Dual Source technology, with prospective scanning on the same equipment, as well as radiation doses on the newer Siemens® Flash Equipment and the implementation of nursing/technologist aggressively driven protocol for heart rate control and image acquisition independent of imaging provider presence during acquisition.

Results: The radiation dose reduction with implementation of multiple measures of radiation reduction to include physician independent-technician driven CCTA protocol resulted in a reduction from mean of 9.85±5.96 (median 8.8mSv) to mean of 3.00±2.53(median 2.1mSv) ($p<0.0001$). CCTA radiation dose has decreased by 69.2% since January of 2010 while SPECT radiation dose remained constant at 14mSv ($p<0.0001$).

Conclusion: Continued advances in software and hardware technology, combined with “physician independent-technician driven” CCTA protocol have drastically reduced radiation dosing in CCTA to annual background radiation exposure, while maximizing the benefit of the study and without sacrificing patient safety.

Keywords: CCTA; radiation dose reduction; physician independent CCTA; ICA.

ABBREVIATION

CCTA: Cardiac Computed Tomography Angiography; ICA: Invasive Coronary Angiography; SPECT: Single Photon Emission Computed Tomography.

1. BACKGROUND

Imaging techniques for the diagnosis of coronary artery disease are increasingly utilized as chest pain is a common complaint. With increased use of imaging for chest pain, there is an increase in exposure to radiation potential long term side effects of radiation exposure. [1]Recently, rapid advances in hardware and software have significantly reduced the radiation exposure from coronary CTA [2,3].

At our institution, the impact of advances in CCTA technology and standardization of protocols on patient radiation exposure were evaluated. Utilization was also evaluated and compared to other imaging modalities used in the evaluation of chest pain to include SPECT and cardiac catheterization.

2. METHOD

2.1 Cardiac Computed Tomography Angiography

This study was a retrospective review of patients who obtained a CCTA scan during the period of January 2010 through September of 2012. Patients were identified through case logs and the current radiology client service IMPAX used at our facility. Patients were included in this review if they were older than 18 years of age and had a CCTA performed. Patients were excluded if only CAC imaging was performed. There were no patients who had more than one CCTA during the study period. Patient demographics were not collected during the data collection and analysis phase.

Radiation doses were evaluated regularly from January 2010 through September of 2012 as part of an ongoing process improvement measure. The radiology tracking system (IMPAX) recorded radiation dose as dose length product (DLP). This was converted to millisieverts (mSv) by multiplying the DLP by a conversion coefficient of 0.014 [4].

From January of 2010 to March of 2011, a retrospective helical protocol with a 64 slice CT scanner (Somatom Definition CT®, Siemens, Erlagen, Germany) was utilized. From March of 2011 to March of 2012, studies were obtained utilizing a prospective sequential protocol. During this protocol, instead of using radiation through the entire cardiac cycle, the CT scan and software would only obtain images during select phases in diastole, typical 60-80% of the R-R interval. B-Blockers are used to slow the heart rate and thus prolong diastole to optimize image acquisition.

In March of 2012, 128-slice dual head scanner with a single heart beat image acquisition of the complete coronary when a heart rate of less than 60 was achieved (Somatom Definition Flash CT®, Siemens, Erlagen, Germany).In June of 2012, there was implementation of a physician independent-technician driven CCTA protocol see Appendix A with aggressive heart rate control. A standing order set using beta-blockers to achieve the intended heart rates was used in an attempt to minimize radiation exposure by minimizing variability driven by each imager's approach to heart control. Previous to this, physicians were usually present with the technologist at the time of acquisition of the CCTA. This protocol was primarily technician driven without the need for the presence of the physician during scanning. Previously physicians were usually present during scanning or were called prior to scanning to help optimize HR and CT parameters to obtain optimal images.

2.2 Invasive Coronary Angiography

Diagnostic coronary artery angiogram radiation doses were obtained from the catheter laboratory database where radiation exposure doses were reported as air kerma levels. These were not converted to comparable doses for CCTA or SPECT as the conversion required patient characteristics such as height and weight which were not collected for this study. Cases that went on to intervention were excluded. All diagnostic catheterizations were included. Many of these patients also had left ventriculograms performed and were also included in this review.

2.3 Single Photon Emission Computed Tomography

SPECT imaging protocols have not changed at our institution over the time frame evaluated. Same day EKG-gated technetium-99m protocol with 10mCi at rest and 30mCi at peak exercise as per American Society of Nuclear Cardiology guidelines was used [5].All SPECT imaging evaluated during this study period were single day studies. As every patient underwent the same protocol over the study period, it was assumed that the radiation dose to each individual who underwent SPECT imaging was equivalent. Our institutional average for radiation exposure during SPECT imaging is calculated to be 14.6mSv for single day technetium myocardial perfusion studies.

2.4 Statistical Analysis

Continuous variables are presented as means±standard deviations (SD) or median (inter-quartile range) where appropriate. Proportions are presented as counts and percentages. An ANOVA (IBM SPSS Version 19.0) was employed assess difference among CT protocols. Bonferroni correction was applied for multiple group comparisons. Linear regression was used to assess the change in procedural volume over time. All statistical test were two-tailed with P values considered significant if <0.05.

3. RESULT

In the SPECT group, there were a total of 5095 cases. As the current protocol has not changed in our institution, it was assumed per package labeling that the amount of radiation each patient received was the same.

In the ICA group, there were a total of 1796 cases, and a total of 1565 cases in the CCTA group. Table 1 shows the mean effective dose for CCTA between the four groups. Fig. 1 demonstrates the median and inter-quartile ranges over the course of two years with each protocol change in CCTA at our facility. There is a statistically significant reduction in mean effective dose with comparison of the four groups ($p<0.0001$). There was not a statistically significant change in radiation dose between the 64 slice CT scanner to the 128 slice dual head scanner. Once the physician independent protocol was adopted, the mean effective dose was decreased in a statistically significant manner compared to the three previous protocols ($p<0.0001$).

CCTA mean effective dose has been decreased over the course of two years while the dose for SPECT has remained constant. Fig. 2 demonstrates this relationship with the increasing difference in dose between the two modalities. A reduction in CCTA dose was noted after implementation of the independent physician protocol, which was significant compared to SPECT ($p<0.0001$). Similarly the average dose of radiation in ICA has remained constant in our system over the past two years Fig. 3.

Over the past two years the monthly procedural volume for ICA, SPECT, and CCTA has changed Fig. 4. From two years prior the caseload for SPECT has decreased by 47.1% ($p<0.001$). The caseload for ICA over this timeframe has decreased as well by 10.8% ($p=0.036$). However, during this time CCTA caseload has increased by 52.1% ($p=0.001$).

Table 1. Mean and median effective dose with CCTA

Group	N	Mean (mSv)	Standard Deviation	IQ_{25}	Median	IQ_{75}
1	745	9.9	5.96	5.3	8.8	13.1
2	318	7.0	6.45	2.4	4.3	10.7
3	169	6.5	6.00	2.4	4.1	8.5
4	277	3.0	2.53	1.4	2.1	4.2

Group 1- Initial retrospective helical protocol, Group 2 - Prospective sequential protocol, Group 3 – Flash protocol, Group 4 – Flash, physician independent protocol. IQ indicates inter-quartile (25^{th} versus 75^{th}). Reduction in both mean and median radiation doses seen over the time period evaluated

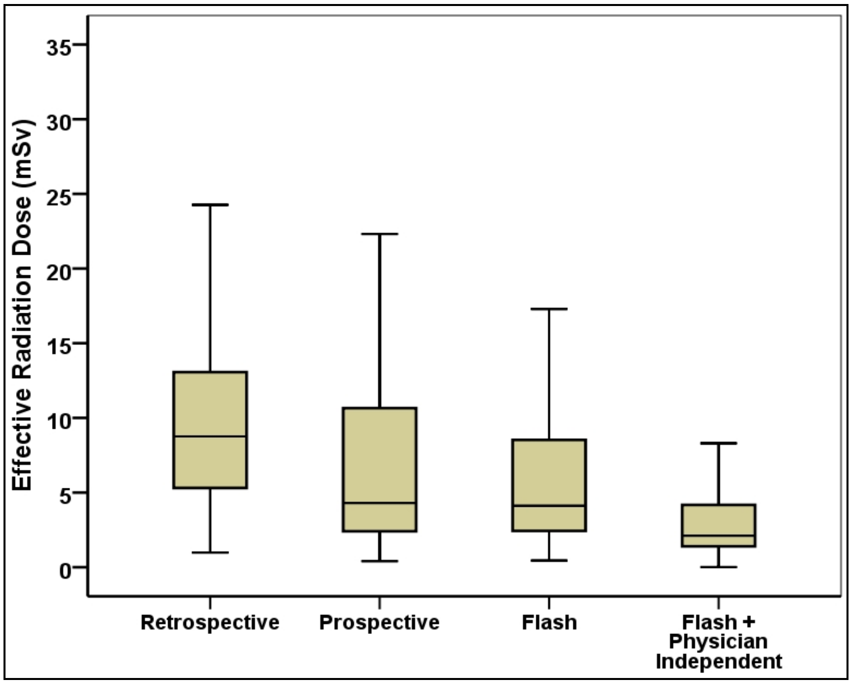


Fig. 1. Tabular data represented as box-and-whisker plot demonstrating the dispersion of data around the mean. The whiskers of the box plot represent 1.5x the lower and upper inner quartiles. There is a decrease in the radiation dose with less variability in radiation during the evaluated time period

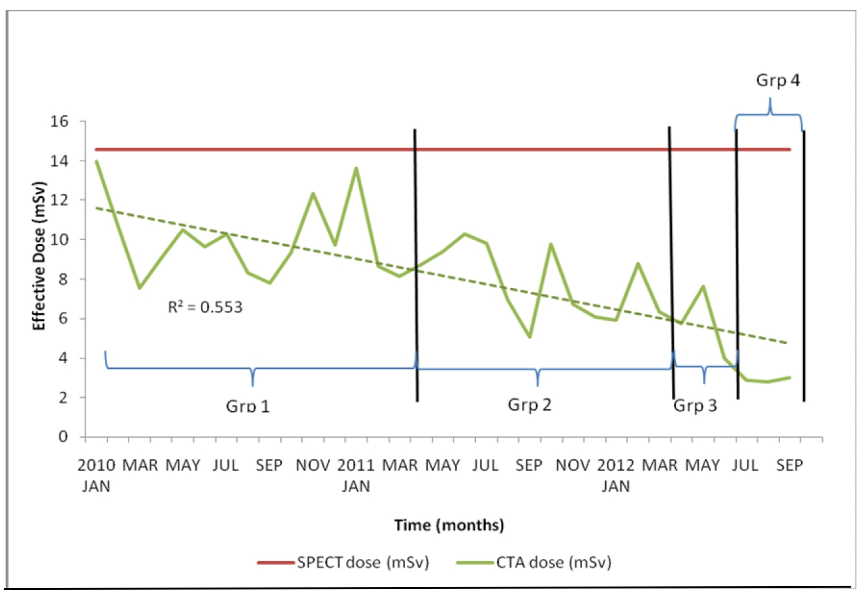


Fig. 2. Average radiation dose over the time period studied for Single photon emission computed tomography with technetium (SPECT) and cardiac computed tomography (CCTA)

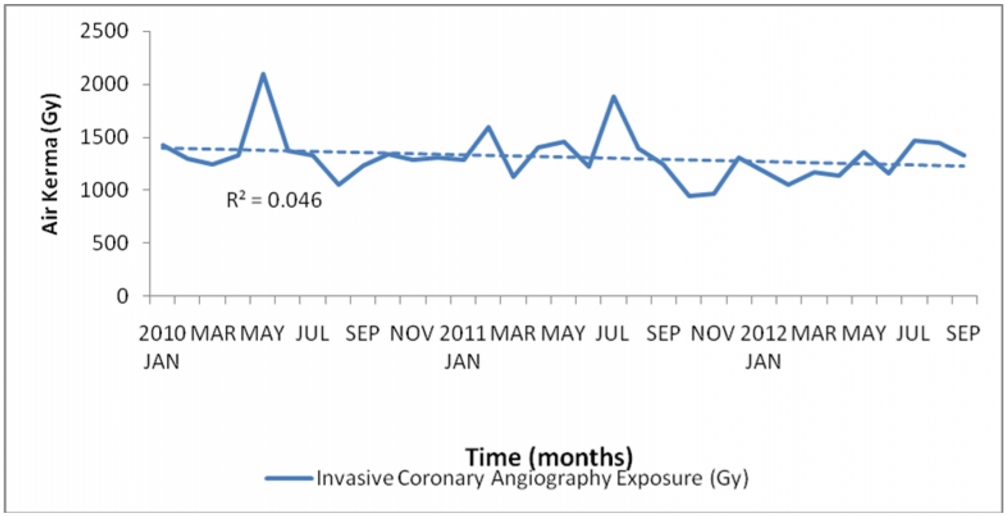


Fig. 3. Radiation exposure measured in air kerma levels as measured in the cardiac catheter lab over the duration of time reviewed

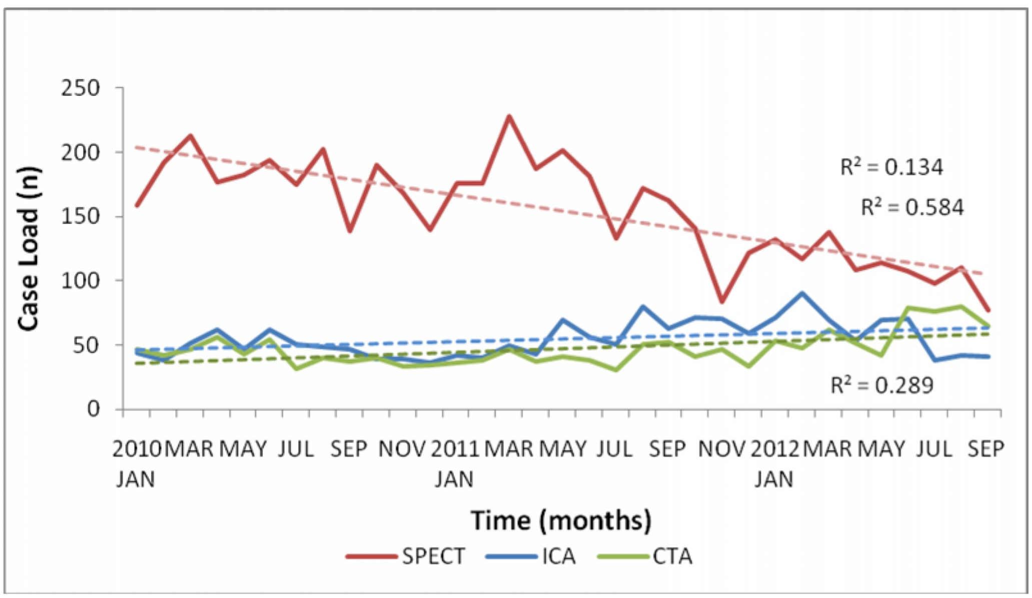


Fig. 4. Imaging caseload for Single photon emission computed tomography (SPECT), diagnostic cardiac catheterization (ICA), and cardiac computed tomography (CCTA) over the time period reviewed

4. DISCUSSION

There have been significant advances in CT technology. At our institution, which is a tertiary referral center, we have implemented successive generations of CT scanner technology and subsequently implemented a formal CT acquisition dose-reduction protocol. We observed the following findings in this retrospective analysis. First, CT radiation was sequentially reduced with the implementation of modern CCTA technology, mainly related to lower kV and increased use of prospective ECG triggered acquisition. The decrease in radiation dose is consistent with what has been reported at other institutions [6]. Secondly, the implementation of a radiation reduction protocol further reduced dose. Thirdly, there has been a significant increase in CTA utilization and a decrease in the utilization of SPECT imaging. It is unclear as to the cause for this decrease in SPECT imaging. This comparison is somewhat limited as our institution has not pursued dose reduction techniques for SPECT. Also, our institution trains cardiology fellows who perform ICA. There is a learning curve for fellows as they learn how to limit fluoroscopy time and adjust frame rate which can affect radiation exposure for patients.

We have also noticed that by performing a physician independent protocol, giving more responsibility to technicians to perform scans by following specific criteria, physicians no longer need to be present for scans and are asked fewer questions. This allows them to perform other duties while still being available for questions when they arise.

The case volume for ICA has remained relatively stable at our institution. The caseload for CT over the last few months is beginning to increase. SPECT scans have drastically decreased over the time period which is not accounted for in the volume of cases of ICA or CTA. This may be related to other modalities available at our institution to include stress MRI and stress echo which are not represented here. An informal poll of the cardiology staff suggested this decline was related to availability of other imaging modalities with results that seemed more consistent with clinical findings.

There are a number of limitations to our institutions process improvement review. The exact dosing per patient for SPECT scans is not known but is given as a running average which is the reason for the lack of variability seen with respect to radiation dosing. Also, our institution does not have a method to convert air kerma to mSv which makes comparison of radiation dosing between ICA and CCTA limited. This is a retrospective review of process improvement and not a randomized controlled trial with the inherent flaws of reviewing retrospective data. There is always a concern that image quality may suffer due to reduced radiation and this was not assessed in our review.

5. CONCLUSION

We report a significant reduction in CCTA estimated effective radiation dose after implementation of advances in software and hardware technology in addition to changes in the clinical scanning protocol designed to reduce dose.

CONSENT

Not applicable.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. This project was a process improvement project and the published data has been cleared for publication by the department of clinical investigation, Brooke Army Medical Center.

COMPETING INTERESTS

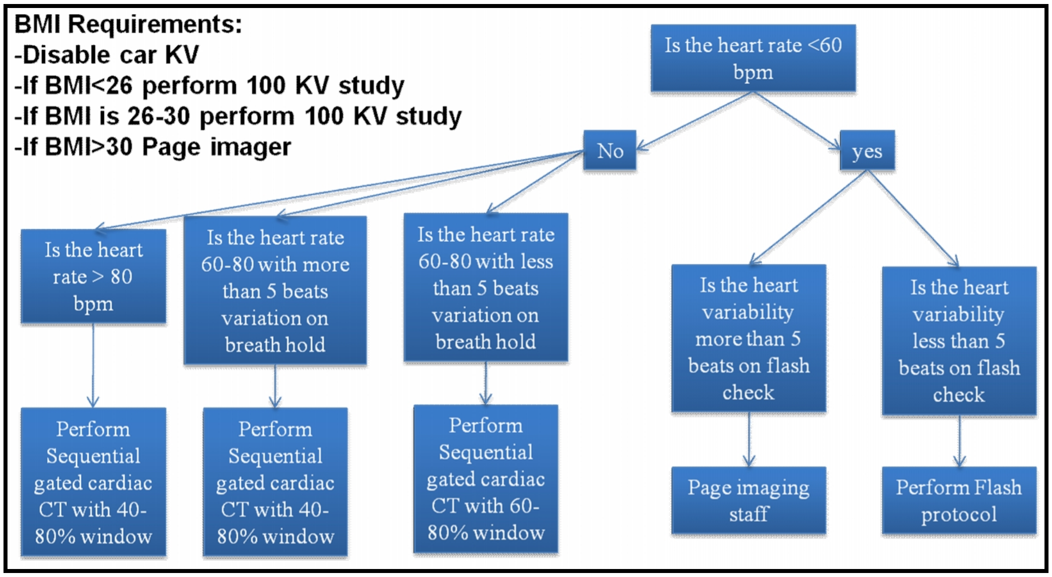
Authors have declared that no competing interests exist.

REFERENCES

1. Hall EJ, Brenner DJ. Cancer risks from diagnostic radiology. Br J Radiol. 2008;81(965):362-78.
2. Achenbach S, Marwan M, Ropers D, Schepis T, Pflederer T, Anders K, et al. Coronary computed tomography angiography with a consistent dose below 1 mSv using prospectively electrocardiogram-triggered high-pitch spiral acquisition. Eur Heart J. 2010;31(3):340-6.
3. Einstein AJ, Moser KW, Thompson RC, Cerqueira MD, Henzlova MJ. Radiation dose to patients from cardiac diagnostic imaging. Circulation. 2007;116(11):1290-305.
4. McCollough C CD, Edyvean S, Geise R, Gould B, Keat N, Huda W, et al. The Measurement, Reporting, and Managment of Radiation Dose in CT; College Park, MD; 2008.
5. Henzlova MJ CM, Hansen CL, Taillefer R, Yao S. Imaging guidelines for nuclear cardiology procedures: stress protocols and tracers. J Nucl Cardiol. 2006;13(6):80-90.
6. Ghoshhajra BB, Engel LC, Major GP, Goehler A, Techasith T, Verdini D, et al. Evolution of coronary computed tomography radiation dose reduction at a tertiary referral center. Am J Med. 2012;125(8):764-72.

APPENDIX

Appendix A. Physician independent protocol for performing CCTA for optimization and standardization of scanning patients



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