Real-Time Skin Dose Radiation Monitoring during Coronary Angiography

INTRODUCTION

The collective dose of radiation used in medical investigations and procedures has increased by greater than 700% between 1980 and 2006 [1]. Consequently the use of ionizing radiation has developed into an important, yet potentially avoidable, public health threat [2] that deserves considerable attention. This is particularly the case in adult cardiology patients where coronary angiography represents 12% of all radiological procedures but contributes a disproportionate ≈ 48% of their total collective dose [3]. Therefore, coronary angiography and intervention is becoming an increasingly important lifetime source of radiation exposure for patients [4]. Radiation exposure is also an important issue for the proceduralist with an interventional cardiologist exposed to 2-3 times higher radiation per year than that of a radiologist [5,6].

Exposure to ionizing radiation during diagnostic procedures can have dose-related deterministic (eg. cataracts and skin damage) as well as stochastic effects (eg. malignancy) [7,8]. It is currently agreed, based upon the “linear-no threshold” model, that no safe dose of radiation exists [5]. Therefore it is generally accepted that all efforts should be made to minimize radiation dose to the patient and staff [9]. During coronary angiography there are a number of well-recognized approaches to reduce patient and operator radiation dose. It has been demonstrated that adequate radiation protection training and diligent adherence to these radiation minimization techniques can reduce dose by up to 90% [6]. These techniques include low fluoroscopy frame rates, minimize fluoroscopy time, low image magnification, minimize distance between the patient and image detector, collimation and real-time digital fluoroscopy recording [10,11]. Also important is minimizing operator dose by utilizing all available above and below table shielding in conjunction with wearing personal protective equipment such as aprons, lead eyewear and thyroid collars [10].

Until recently there has been no visual cue notifying the operator of a radiation dose that places the patient at risk of deterministic skin effects. We recently assessed the utility of the Dose Tracking System (DTS) (Toshiba Medical Systems, Otawara-shi, Tochigi-ken, Japan) for reduction in patient peak skin and total dose during coronary angiography [12].

The DTS provides a real-time pictorial displayed adjacent to the image, be it DSA, DA, one Shots, 3D or in this case fluoroscopy [Figure 1]. The display comprises a colour-coded representation of the cumulative skin dose distribution on a patient graphic as well as the real-time peak skin dose and cumulative skin dose values at the current real-time beam projection. The colour pictorial changes to yellow when peak skin dose reaches 2000mGy and then red when greater than 3000mGy. The DTS calculates the skin dose values using a complex algorithm derived from patient BMI, X-ray tube output, entrance dose and beam angulation.

Systems that provide real-time graphic feedback are designed to prompt alterations in operator behavior and therefore reduce radiation dose. This, and similar real-time systems, [13] make it possible for reactive dose reduction changes to occur during the procedure. It is hypothesized that awareness of the peak skin dose prompts working in a different view to avoid an overlapping field of view. When the new position involves less detector angulation there is likely to be less output from the tube therefore reducing dose area product (DAP) and air kerma.
In this study 1011 consecutive patients were prospectively enrolled at a single centre during coronary angiography and/or percutaneous coronary intervention (PCI). Patients were excluded if they underwent structural heart disease interventions, pacemaker implantation or electrophysiology studies. All patients underwent angiography in a Toshiba Infinix-i angiography suite fitted with the DTS. The study design was a before-after non-randomized series. The DTS was recording information on all patients enrolled in the study. Two patient groups were evaluated sequentially for comparison. The control group represented standard clinical practice where the DTS was recording all the procedural variables (including peak skin dose) without the DTS pictorial feedback displayed for the operator. After the requisite sample size in the control group was obtained, a second group, the ‘DTS group’, was studied with the DTS pictorial feedback displayed for the operator. Coronary angiography and intervention was performed at the discretion of the operator.

The primary endpoint of the study was the Peak skin dose, defined as the highest dose at any portion of the patients skin as defined by the DTS. Secondary endpoints were measurements of total dose; reference point air kerma, cumulative dose area product (DAP) and fluoroscopy time. Significant radiation dose level, above which there may be a risk of deterministic complications such as skin injury, was defined as peak skin dose >3000 mGy [4].

RESULTS

From August 2013 to June 2014 a total of 16 operators performed 1077 consecutive procedures on 1011 patients. There were 488 procedures in the control group (45%) and 589 procedures in the DTS group (55%). Of the 1077 procedures, 617 were diagnostic coronary angiography and 460 were coronary angiography and PCI or FFR. Procedures were performed via radial access in 37.6% with the remainder of the procedures performed via femoral access. When accounting for confounding variables, the use of the DTS significantly reduced mean peak skin dose by 22% (p < 0.001) across the entire cohort. There was also a significant reduction in measures of total dose with reference air kerma reduced by 20% (p < 0.001), and DAP reduced by 17% (p < 0.001). The most profound effect due to implementation of the DTS was seen in patients undergoing PCI where the peak skin dose was reduced by 46.3% [Figure 2]. Impressive reductions in other measures of radiation dose were seen in the PCI cohort; fluoroscopy time fell by 14% (p = 0.028), DAP fell by 35% (p < 0.001) and reference air kerma by 41% (p = 0.004).

Lower peak skin dose was consistent across subgroups including radial access procedures (p < 0.003), patients with...
prior bypass surgery (p < 0.001) and procedures in patients with a high BMI (p < 0.001). Use of the DTS reduced the number of patients identified at high risk of skin damage based upon peak skin dose definition of >3000mGy (control 2.7% vs. DTS 0.7%).

SIGNIFICANCE AND FUTURE DIRECTIONS:
Based on our findings it is proposed that the DTS technology may reduce the incidence of deterministic radiation effects and it supports its more widespread use in the setting of invasive cardiac investigation. The effect of the DTS was not only evident on skin dose but also measures of total radiation dose. An explanation for these findings was outlined by Dr Ariel Roguin in an editorial by stating “Seeing radiation is believing, causing our work habits to change” [14] Furthermore, it has been recommended that patients receiving substantial exposures during cardiac procedures be counseled before discharge and the appropriate arrangements be made for follow-up and monitoring [15]. Ideally, the institution of the DTS would be accompanied by education on safe dose thresholds, techniques to reduce overall exposure and quantitative scatter plots representing operator exposure. The complete system of radiation safety in the cardiac catheterization laboratory may include not only the DTS but also real-time monitoring of all health care workers scatter dose.

CONCLUSION
In this large single center study, it has been demonstrated that the DTS is simple to use and results in substantial reductions in important radiation parameters during invasive coronary procedures.

REFERENCES: