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MINI-FOCUS ISSUE: RADIATION DOSE REDUCTION
Clinical Research

Radiation Dose Reduction in the Cardiac Catheterization Laboratory Utilizing a Novel Protocol

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Objectives This study reports the results a novel radiation reduction protocol (RRP) system for coronary angiography and interventional procedures and the determinants of radiation dose.

Background The cardiac catheterization laboratory is an important source of radiation and should be kept in good working order with dose-reduction and monitoring capabilities.

Methods All diagnostic coronary angiograms and percutaneous coronary interventions from a single catheterization laboratory were analyzed 2 months before and after RRP implementation. The primary outcome was the relative dose reduction at the interventional reference point. Separate analyses were done for conventional 15 frames/s (FPS) and at reduced 7.5 FPS post-RRP groups.

Results A total of 605 patients underwent coronary angiography (309 before RRP and 296 after RRP), with 129 (42%) and 122 (41%) undergoing percutaneous coronary interventions before and after RRP, respectively. With RRP, a 48% dose reduction (1.07 $\pm$ 0.05 Gy vs. 0.56 $\pm$ 0.03 Gy, $p < 0.0001$) was obtained, 35% with 15 FPS RRP (0.70 $\pm$ 0.05 Gy, $p < 0.0001$) and 62% with 7.5 FPS RRP (0.41 $\pm$ 0.03 Gy, $p < 0.001$). Similar dose reductions for diagnostic angiograms and percutaneous coronary interventions were noted. There was no change in the number of stents placed or vessels intervened on. Increased dose was associated with male sex, radial approach, increasing body mass index, cine runs, and frame rates. Using a multivariable model, a 48% relative risk with RRP ($p < 0.001$), 44% with 15 FPS RRP and 68% with 7.5 FPS RRP was obtained.

Conclusions We demonstrate a highly significant 48.5% adjusted radiation dose reduction using a novel algorithm, which needs strong consideration among interventional cardiology practice.
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Ionizing radiation makes invasive cardiology procedures such as coronary angiography, percutaneous coronary intervention (PCI), and electrophysiologic diagnostics and therapeutics possible (1). The cardiac catheterization laboratory is an important source of medical radiation (2). Radiation risks can be thought of as deterministic (effects after exceeding certain threshold, e.g., skin burns) or stochastic (a risk of an outcome is proportional to the dose received, e.g., malignancy or teratogenicity) (3). Reducing the radiation exposure in the cardiac catheterization laboratory is important, especially as procedures are becoming more complex (2). Unfortunately, once all confounding factors are accounted for, decreasing the radiation dose generally results in lower image quality as there is decreased signal-to-noise ratio (1). The purpose of our study was to assess the radiation dose reduction associated with a new radiation reduction protocol (RRP), and to quantify any changes in the throughput of cases through the catheterization laboratory after the dose reduction protocol was implemented.

Methods

Intervention. In the first 2 weeks of May 2012, at our institution we upgraded the cardiac catheterization laboratories (Philips Allura Xper, Royal Philips Electronics, Amsterdam, the Netherlands) with the novel ECO protocol (Fig. 1). The ECO settings are technical changes in the EPX (or examination programmed x-ray parameters) of the Allura Xper systems where X-ray parameters (e.g., the peak tube voltage, the cathode current, spectral filter) are fine-tuned to the specific examination type and patient size. The technical changes involved increasing the thickness of x-ray beam spectral filters for acquisition imaging, reducing the frame rates (7.5 frames/s [FPS]), reducing detector dose rate in acquisition imaging, and setting the default fluoroscopy dose rate mode from normal to low or a combination of these changes.

Data collection. We reviewed data of consecutive patients who underwent cardiac catheterization procedures at 1 of our institution's 3 cardiac catheterization laboratories 2 months prior to RRP implementation and 2 months after implementation. A single laboratory was chosen to maintain consistency and remove potential machine-related differences. There was no change in operators or seasonal differences during the investigation period. Institutional ethics board approval was obtained. Patient demographic information and biometric data (height, weight, body mass index [BMI]), which may affect radiation exposure, was obtained from the catheterization laboratory database. Arterial access (radial vs. femoral) was documented. Procedural details including total fluoroscopic time and cine angiographic acquisition runs were recorded. The number of vessels intervened upon and number of stents placed was also recorded. The pre-RRP fluoroscopic and cineangiographic images were all acquired in 15 FPS. However, once the RRP was established, the option of 7.5 FPS or 15 FPS acquisition was available at the operator's discretion (Fig. 2A).

Data analysis. The primary outcome of this study was air kerma—radiation dose reduction as measured at the interventional reference point ($K_{A,R}$) 15 cm from the isocenter of the beam. Mean radiation exposure before and after RRP implementation was recorded. Subgroup analysis was done for patients undergoing only diagnostic angiography as well as those undergoing PCI (Fig. 2A). Furthermore, separate analyses were done for RRP performed at conventional frame rates (15 FPS) and reduced frame rates (7.5 FPS). The chi-square test was used to test for statistical significance for categorical variables. Continuous variables were expressed as mean ± SD or mean ± SE and analyzed with *t* test or Mann-Whitney *U* test for statistical significance. Univariate analysis was performed using SAS (version 9.2, SAS, Cary, North Carolina) to assess for predictors of increased $K_{A,R}$ (sex, BMI, access approach, fluoroscopy time, number of cine runs, PCI (yes/no), RRP use, and frame rate) for all studies, angiography alone, PCI alone, and the previously listed studies done at 15 FPS and 7.5 FPS. Beta coefficients of variance with standard errors were calculated. A multivariate linear regression analysis was performed with the preceding variables and an adjusted $K_{A,R}$ (mean ± SE) was reported with percentage of reduction after RRP.

Abbreviations and Acronyms

BMI = body mass index

FPS = frames per second

$K_{A,R}$ = air kerma at the interventional reference point

PCI = percutaneous coronary intervention

RRP = radiation reduction protocol

Results

Patient characteristics. A total of 605 consecutive patients underwent diagnostic angiography and/or PCI at a single cardiac catheterization laboratory at St. Boniface Hospital, Winnipeg, Manitoba, Canada, a major tertiary cardiac care referral center. A total of 309 patients were included prior to RRP implementation (March 1, 2012, to April 30, 2012). Of these, 180 underwent diagnostic angiography and 129 underwent PCI (Fig. 2A). A 2-week implementation period was undertaken. There were 296 patients in the post-RRP group (May 18, 2012, to July 22, 2012); of those, 174 underwent diagnostic angiograms and 122 underwent PCI. Of the post-RRP cohort, 160 patients had their studies completed at traditional 15 FPS and 136 patients underwent studies at 7.5 FPS (Fig. 2B). The choice of frame rate was at the discretion of the operator. Of the 67 diagnostic angiograms done at 7.5 FPS in the post-RRP group, only 2 studies required more than one-third of the cineangiograms at 15 FPS to improve visualization. For PCI in the post-