ORIGINAL RESEARCH

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Impact of trainee involvement on patient radiation exposure and contrast volumes during invasive cardiac procedures

Abstract

Purpose: The impact of cardiology fellows (CFs) and interventional cardiology fellows (ICFs) on patient radiation and contrast exposure during diagnostic coronary angiography and percutaneous coronary intervention is unknown.

Methods: Between 2011 and 2014, 16,175 cases were retrospectively assessed involving 27 CFs, 22 ICFs and 24 staff as primary operators.

Results: During diagnostic coronary angiography, ICFs administered the lowest radiation dose ($5,648 \pm 5,523$ cGy*cm²; 1.30 ± 1.27 mSv)—achieving 22% less radiation than the staff ($6,889 \pm 4,294$ cGy*cm²; 1.58 ± 0.99 mSv) and 36% less than CFs ($7,700 \pm 6,751$ cGy*cm²; 1.77 ± 1.55 mSv) ($p < 0.01$). When adjusted for access site, CFs administered more radiation than either the ICFs or staff. However, differences between ICFs and staff were exclusively observed during transradial procedures ($p < 0.01$). With regards to contrast administration, ICFs administered less contrast (126.3 ± 57.6 mL) than either CFs (130 ± 52.4 mL) or staff (132.7 ± 47.6 mL) ($p < 0.01$)—again, a finding isolated to the transradial cohort. Of the 6,751 percutaneous coronary intervention cases, no significant differences existed between the ICFs or staff cardiologists in patient radiation exposure—but a CF as the primary operator resulted in an 18% increase in radiation exposure. Notably, contrast use was not different amongst the types of operators ($p > 0.05$).

Conclusion: In conclusion, having a cardiology fellow as primary operator during invasive cardiac procedures increases patient radiation exposure and minimally increases contrast administration. Strategies to minimize patient radiation exposure while maintaining trainee involvement should be evaluated.

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Introduction

Diagnostic cardiac angiography (dCA) and percutaneous coronary intervention (PCI) are performed via the transradial or transfemoral approach [1]. Increasingly, the impact of cumulative ionizing radiation exposure from diagnostic testing and intervention is being recognized [2]. While the impact of access site selection and center experience has been well established [2] the impact of trainee involvement in procedures—namely cardiology fellows (CFs) and interventional cardiology fellows (ICFs)—is unknown.

Materials and methods

Accordingly, we conducted a retrospective observational study of the CAPITAL revascularization registry between January 2011 and June 2014 [3]. Exclusions included a history of coronary artery bypass grafting (CABG), structural heart interventions and right heart catheterizations. All procedures were performed using either Philips Allura FD10 fluoroscopy device (Phillips Medical Systems, Andover, MA) equipped with MRC-G5-200-0508 x-ray tubes, or Philips Allura FD20 fluoroscopy device (Phillips Medical Systems, Andover, MA) equipped with MRC-G5-200-0407 x-ray tubes. Our center employs standard angiography angles along with 15 frames-per-second for coronary views and 30 frames-per-second for left ventriculogram assessments, which are maintained by dedicated radiation technologists present in every case. Our center has both dedicated radial curves and traditional femoral catheters, which were used at the discretion of the operator. Patient's presentation, baseline demographics, dose area product, contrast volume, access site, procedure type and operator characteristics were analyzed. To determine the patient radiation exposure, dose-area product (DAP) ($\text{cGy} \cdot \text{cm}^2$) was converted to millisieverts (mSv) using a conversion factor of 0.00023 [4]. Specifically, operator groups were classified by the primary operator: attending cardiologist (staff), CF or ICF. Cardiology fellows are in the process of completing their core adult cardiology residency training, which includes rotations in the cardiac catheterization laboratory with a focus on obtaining vascular access and basic angiographic views. Conversely, interventional cardiology fellows are licenced cardiologists who are undertaking additional training in interventional cardiology, typically having completed hundreds of diagnostic coronary angiograms prior to the start of their fellowship. In our center, their case volume is extremely high, with the ICFs performing more cases than staff during their training period.

Data are expressed as mean $\pm$ standard deviation. Comparisons were made using one-way analysis of variance with Holm-Sidak *post hoc* testing to compare between groups. Stratified analyses by procedure type, access type and operator type were performed. All analyses were performed using Sigmaplot.

Results

In total, 16,175 cases (mean 65.6 ± 12.0 years of age, 68.7% male) were included in the final analysis. During the study period, there were 27 CFs, 22 ICFs and 24 staff performing procedures as primary operators. No differences in patient baseline characteristics existed when stratified by operator type. Transradial access was preferentially employed, being the primary access site in 8,888 cases (54.9%) with 9,425 being dCA (58.2%). The primary operator was a CF in 1,992 cases (12.3%), an ICF in 9,923 cases (61.4%) and staff in 4,260 cases (26.3%). During dCA, ICFs administered the lowest radiation dose ($5,648 \pm 5,523 \text{ cGy} \cdot \text{cm}^2$, $1.30 \pm 1.27 \text{ mSv}$)—achieving 22% less radiation than the staff ($6,889 \pm 4,294 \text{ cGy} \cdot \text{cm}^2$; $1.58 \pm 0.99 \text{ mSv}$) and 36% less than CFs ($7,700 \pm 6,751 \text{ cGy} \cdot \text{cm}^2$; $1.77 \pm 1.55 \text{ mSv}$) ($p < 0.01$ for both comparisons, Figure 1). When adjusted for access site, CFs consistently administered more radiation than either the ICFs or staff. However, differences between ICFs and staff were exclusively observed during transradial procedures ($5,664 \pm 5,731 \text{ cGy} \cdot \text{cm}^2$; $1.30 \pm 1.32 \text{ mSv}$ vs. $7,505 \pm 4,380 \text{ cGy} \cdot \text{cm}^2$; $1.72 \pm 1.01 \text{ mSv}$, respectively, $p < 0.01$). With regards to contrast administration, ICFs administered less contrast ($126.3 \pm 57.6 \text{ mL}$) than either CFs ($130 \pm 52.4 \text{ mL}$) or staff ($132.7 \pm 47.6 \text{ mL}$) ($p < 0.01$; Figure 1)—again, a finding isolated to the transradial cohort.

Of the 6,751 PCI cases, only 323 (4.8%) were performed with CFs as primary operator, 5,663 (83.9%) by ICFs and 765 (11.3%) by staff alone. No significant differences existed between the ICFs or staff cardiologists in patient radiation exposure ($11,579 \pm 11,036 \text{ cGy} \cdot \text{cm}^2$; $2.66 \pm 2.54 \text{ mSv}$ vs. $11,771 \pm 10,008 \text{ cGy} \cdot \text{cm}^2$; $2.71 \pm 2.30 \text{ mSv}$, $p > 0.05$; Figure 1)—but a CF as the primary operator resulted in an 18% increased radiation exposure ($13,696 \pm 15,577 \text{ cGy} \cdot \text{cm}^2$; $3.15 \pm 3.58 \text{ mSv}$, $p < 0.01$ for both comparisons). When stratifying by elective or emergent PCI, there was no difference between ICFs and staff with respect to radiation exposure. Notably, contrast use was not different amongst the types of operators ($p > 0.05$).

FIGURE 1. Patient radiation dose and contrast volume administered during invasive cardiac procedures.

Radiation dose (in dose-area product; cGy-cm²) and contrast volume administered during diagnostic coronary angiography (A, B) and percutaneous coronary intervention (C, D). Abbreviations: CF, cardiology fellow; DAP, dose-area product; ICF, interventional cardiology fellow; PCI, percutaneous coronary intervention

Discussion

Radiation exposure during cardiac procedures poses cumulative risks to both patients and health care providers. Thus, understanding modifiable factors that impact patient exposure remains relevant. Our study is the first to examine the influence of involving cardiology trainees during different phases of education on patient radiation exposure and contrast administration. Of note, we observed a marked increase in patient radiation exposure during involvement of a CF, during both dCA and PCI. Interestingly, by the time

the trainees progress to ICFs, these differences dissipate—with ICFs outperforming staff in patient radiation exposure albeit primarily during transradial procedures. By understanding the importance of trainee involvement in invasive cardiac procedures, this study may provide the impetus to training centers to adjust their case selection, supervision and monitoring during this critical phase of learning, while enabling more efficient radiation protection practices.

Only one other study to date has evaluated the impact of CFs on patient radiation exposure; similarly identifying a 45% increase in DAP compared with staff during dCA [5]. Our study confirms those findings, and also reports that, as CFs progress to ICFs, administered radiation is lower during dCA and comparable to staff during PCI. These findings corroborate the data on learning curves, which point to relatively rapid reductions in radiation dose over the course of a learner's training [2,6]. While elimination of the learning phase for CFs is not possible, awareness of the marked increased dose in patient radiation has implications for case selection and supervision of trainees early in their training.

Improved radiation exposure outcomes in dCA performed by ICFs compared with staff is a unique observation that likely reflects multiple factors. First, the extremely high volume of primary operator cases during the training period likely marginally enhances proficiency, which may wane during lower volume periods later in an operator's career. Second, stratified analysis demonstrating this difference existed only in the transradial cohort of patients and likely reflects a greater proficiency in transradial technique in newly trained operators. Future studies examining predominantly transradial-trained operators may better evaluate if this reflects a temporal bias in our study or if this difference reflects de-skilling as operating volumes diminish.

Finally, a secondary endpoint in our analysis was contrast administration. Contrast media is associated with contrast-induced nephropathy and acute kidney injury with numerous studies linking dose with adverse outcomes [7]. Interestingly, while CFs administered significantly more contrast than either ICFs or staff, this difference was small (4 mL) and likely clinically insignificant. Moreover, although the numbers of PCIs performed with CFs as primary operator were small, no differences were seen in contrast use among operator type.

Certainly our study was not without limitations. First, it was retrospective and observational and, thus, unmeasured factors may influence case selection or trainee involvement. Second, the use of DAP, while widely accepted [2], remains the subject of debate regarding the optimal measurement and reporting of patient radiation. Third, we were unable to robustly control for the procedural complexity of either cohort, though there was no overt difference demonstrated based on the surrogate data available (number of stents and catheters). Fourth, we were unable to perform subgroup analyses on operators who transitioned from CF to ICF or ICF to staff due to a small number of individuals in these respective categories. Finally, for both our primary and secondary outcome we used surrogate markers—radiation

exposure and contrast administration—as a quality indicator. Although our sample size was very large, this study was still underpowered and did not have long term follow-up to evaluate clinical outcomes.

Conclusion

Having a cardiology fellow as primary operator during invasive cardiac procedures increases patient radiation exposure and minimally increases contrast administration. Strategies to minimize patient radiation exposure while maintaining trainee involvement should be evaluated.

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