Circulation: Cardiovascular Interventions

ORIGINAL ARTICLE

Patient Body Mass Index and Physician Radiation Dose During Coronary Angiography

Is the Obesity Epidemic Impacting the Occupational Risk of Physicians in the Catheterization Laboratory?

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BACKGROUND: Consistent with the increasing prevalence of obesity in the general population, obesity has become more prevalent among patients undergoing cardiac catheterization. This study evaluated the association between patient body mass index (BMI) and physician radiation dose during coronary angiography.

METHODS AND RESULTS: Real-time radiation exposure data were collected during consecutive coronary angiography procedures. Patient radiation dose was estimated using dose area product. Physician radiation dose in each case was recorded by a dosimeter worn by the physician and is reported as the personal dose equivalent (H_p10). Patient BMI was categorized as <25.0, 25.0 to 29.9, 30.0 to 34.9, 35.0 to 39.9, and ≥40. Among 1119 coronary angiography procedures, significant increases in dose area product and physician radiation dose were observed across increasing patient BMI categories (*P*<0.001). Compared with a BMI <25, a patient BMI ≥40 was associated with a 2.1-fold increase in patient radiation dose (dose area product, 91.8 [59.6–149.2] versus 44.5 [25.7–70.3] Gy×cm^2; *P*<0.001) and a 7.0-fold increase in physician radiation dose (1.4 [0.2–7.1] versus 0.2 [0.0–2.9] μSv; *P*<0.001). By multiple regression analysis, patient BMI remained independently associated with physician radiation dose (dose increase, 5.2% per unit increase in BMI; 95% CI, 3.0%–7.5%; *P*<0.0001).

CONCLUSIONS: Among coronary angiography procedures, increasing patient BMI was associated with a significant increase in physician radiation dose. Additional studies are needed to determine whether patient obesity might have adverse effects on physicians, in the form of increased radiation doses during coronary angiography.

Key Words: body mass index ■ cardiac catheterization ■ humans ■ obesity ■ prevalence

https://www.ahajournals.org/journal/circinterventions

WHAT IS KNOWN

- Consistent with the increasing prevalence of obesity in the general population, obesity has become more prevalent among patients undergoing cardiac catheterization.
- Increasing patient body mass index results in higher patient radiation doses during coronary angiography.
- The greatest source of physician radiation exposure during cardiac catheterization comes from scatter radiation emitted from the patient, which itself is proportional to patient radiation dose.

WHAT THE STUDY ADDS

- Among patients undergoing coronary angiography, increasing patient body mass index was observed to be associated with a significant increase in physician radiation dose.
- Whereas prior studies have documented the adverse health consequences of obesity on the patient, additional studies are needed to determine whether patient obesity may have adverse health effects on physicians as well, in the form of increased radiation doses during coronary angiography.

Based on recent estimates, greater than one-third of all adults in the United States are now obese.[1] Consistent with the high prevalence of obesity in the general population, obesity has become more prevalent among patients undergoing cardiac catheterization.[2] This rise in obesity has likely impacted radiation usage in the catheterization laboratory because obese patients undergoing fluoroscopic procedures receive greater radiation doses than nonobese patients.[3–5] This increase in radiation dose is attributable to the increased energy required to overcome tissue attenuation and facilitate a sufficient number of photons reaching the image intensifier to generate adequate images.[3–5]

The greatest source of physician radiation exposure during cardiac catheterization comes from scatter radiation emitted from the patient, which itself is proportional to patient radiation dose.[6] Because greater radiation doses are required to produce adequate images in obese patients, greater amounts of scatter radiation are emitted,[3–5] and consequently, the obesity epidemic has the potential to alter the occupational risks of physicians performing cardiac catheterization. Patient body mass index (BMI) has been clearly shown to impact patient radiation dose during fluoroscopic procedures,[3–5] yet the impact of patient BMI on the radiation doses received by operating physicians is less well understood. The present study was performed to evaluate the association of patient BMI and physician radiation dose during coronary angiography.

METHODS

Study Population

The SHIELD study (Combining Robotic-Stenting and Proactive Shielding Techniques in the Catheterization Laboratory to Achieve Lowest Possible Radiation Exposure to Physicians and Staff) was a single-center prospective observational study, designed to investigate radiation exposure to physicians and staff members in the cardiac catheterization laboratory.[7] The study was conceived, designed, and conducted by investigators of the Frederik Meijer Heart and Vascular Institute of Spectrum Health (Grand Rapids, MI). The local institutional review board approved the protocol, and all participants provided informed consent. On reasonable request, the data, analytic methods, and materials for this study will be made available to other researchers for purposes of reproducing the results.

Data were prospectively collected on consecutive cases in 2 fluoroscopy suites having identical fluoroscopy systems (Allura Xper FD10 X-ray system; Philips, Amsterdam, the Netherlands). All cases having a start time between ≈8 AM and 5 PM, Monday through Friday, were included in the study. Cases that did not utilize any radiation were excluded as specified in the study protocol. For the purposes of this analysis, only those procedures in which coronary angiography was performed were included. Procedures not involving coronary angiography, including stand-alone right heart catheterizations and pacemaker implantations, were excluded from this analysis.

Radiation Monitoring

Real-time radiation exposure data were collected using a commercially available dosimetry system that contains a bedside monitor capable of displaying real-time radiation doses (RaySafe i2; Unfors RaySafe, Billdal, Sweden). Physicians and staff members were blinded to the monitor display and to the radiation data collected by the dosimeters for the duration of the study. During the study, each physician wore a dosimeter located on either the left anterior side of the glasses or on the left anterior side of the thyroid collar. According to standard operating procedure at the study institution, 2 shields were positioned between the patient and operating physician in all cases: a ceiling-mounted upper body lead shield with a patient contour cutout and a lower body lead shield attached to the side of the operating table extending from table to floor.[6] A radiation-absorbing disposable pad (RadPad; Worldwide Innovations & Technologies, Kansas City, MO) was utilized at the discretion of the operating physician and staff members.

Patient and Physician Radiation Doses

Radiation metrics recorded for each case included the fluoroscopy time, air kerma, and dose area product (DAP), which were automatically calculated by the fluoroscopy imaging system. Consistent with prior methodology, the patient radiation dose per case was estimated by the DAP.[4,8,9] Physician radiation dose per case was the personal dose equivalent (H_p10), as recorded and reported directly by the dosimetry system.

Statistical Analysis

For the purposes of this analysis, patients were categorized into the following subgroups based on BMI: <25.0, lean; 25.0 to 29.9, overweight; 30.0 to 34.9, class I obesity; 35.0 to 39.9, class II obesity; and ≥40, morbid obesity. Descriptive statistics were used to summarize baseline characteristics and outcome measures. Normally distributed continuous variables are shown as mean±SD. Non-normally distributed continuous variables are shown as median (25th–75th percentile). Categorical variables are shown as count (%frequency). *P* values for comparison of continuous variables were derived from 2 sample independent *t* tests if data were normally distributed or from Wilcoxon rank-sum tests if data were not normally distributed. Levene test was used to assess for homogeneity of variance among any numerical comparisons. *P* values for comparison of categorical variables were generated with a χ^2 analysis or a Fisher exact test if the expected cell counts were <5 in >20% of the cells. *P* values for numeric relationship comparisons were produced using a Pearson correlation, and normality assumptions were checked. *P* values for the comparison of the 5 BMI categories were derived from an ANOVA analysis when data were normally distributed and from a Kruskal-Wallis analysis when the data were non-normally distributed. To determine where the differences occurred between the 5 groups, Bonferroni correction was used on Wilcoxon rank-sum *P* values. A multiple regression analysis was completed using physician radiation dose as the response and testing BMI, age, radiation-absorbing pad, right heart catheterization, fractional flow reserve (FFR), percutaneous coronary intervention (PCI), and radial access as the predictors. The multiple regression model needed to be log transformed for normality of residuals to be met. Then, a backward selection was completed to ensure all variables left in the model were significant at the *P*=0.05 level. All statistical analyses were generated using SAS (SAS Enterprise Guide software, version 7.1; SAS Institute, Inc, Cary, NC).

RESULTS

Study Population

Between August 3, 2015, and February 26, 2016, radiation data were collected in 1119 consecutive cases in which coronary angiography was performed. Of these, patient radiation doses were available in 1116 (99.7%) cases, and physician radiation doses were available in 1114 (99.6%) cases. The characteristics of these procedures are summarized in Table 1. The distribution of patient BMI in the study population is presented in Figure 1. Overall, 17.0% of patients had a BMI <25.0, and 83.0% of patients were either overweight or obese. Obesity was present in 50.1% of patients, and morbid obesity was present in 9.6% of patients.

Patient and procedural characteristics according to BMI category are shown in Table 2. Across BMI categories, procedural characteristics were not significantly different for the frequency of right heart catheterization (*P*=0.78), FFR (*P*=0.49), PCI (*P*=0.63), robotic PCI (*P*=0.97), radial access (*P*=0.10), or fluoroscopy time per case (*P*=0.26). The frequency of radiation-absorbing

Table 1. Patient and Procedural Characteristics

	Total (N=1119)
Age, y	66.1±11.8
Height, cm	172.4±10.1
Weight, kg	91.7±21.3
BMI	30.8±6.6
Arterial access	
Femoral access	479 (42.9)
Radial access	636 (56.9)
Brachial access	2 (0.2)
FFR	130 (11.6)
PCI	338 (30.2)
RHC	242 (21.6)
Radiation-absorbing pad	655 (59.0)
Fluoroscopy time, min	5.9 (3.2–11.1)
Air kerma, mGy	781 (527–1261)
DAP, Gy×cm²	63.8 (41.8–97.6)

Normally distributed values are shown as mean±SD. Non-normally distributed variables are shown as median (25th–75th percentile). Categorical values are shown as n (%frequency). BMI indicates body mass index; DAP, dose area product; FFR, fractional flow reserve; PCI, percutaneous coronary intervention; and RHC, right heart catheterization.

pad use increased significantly across increasing BMI categories (*P*=0.007; Table 2). When treating BMI as continuous variable, no significant differences were observed for patient BMI among cases with and without right heart catheterization (*P*=0.86), FFR (*P*=0.78), PCI (*P*=0.25), or robotic PCI (*P*=0.86). Patient BMI was significantly higher among cases with (31.4±6.9) compared with those without (30.0±6.2) use of a radiation-absorbing pad (*P*=0.0003). Similarly, patient BMI was higher for cases with (31.3±6.8) compared with those without (30.2±6.3) use of radial access (*P*=0.01). A weak, negative correlation was observed between age and BMI (r=–0.17; *P*<0.0001).

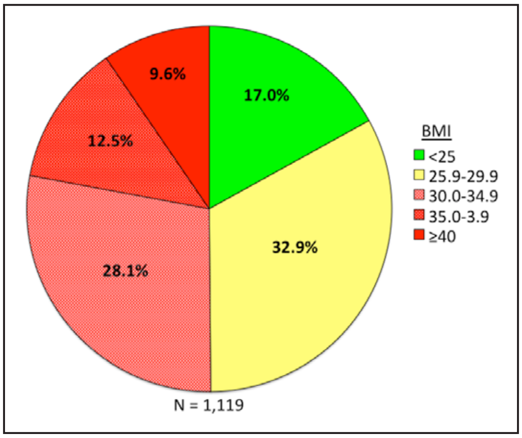

Figure 1. Distribution of body mass index (BMI) among the study population.
Shown is the distribution of patient BMI in the study population, which consisted of 1119 consecutive patients undergoing coronary angiography who met inclusion criteria.

Table 2. Patient and Procedural Characteristics According to Patient BMI

	BMI <25.0 (n=190)	BMI, 25.0–29.9 (n=368)	BMI, 30.0–34.9 (n=314)	BMI, 35.0–39.9 (n=140)	BMI ≥40 (n=107)	*P* Value
Age, y	67.6±12.4	67.2±11.8	65.9±11.3	65.0±10.8	61.6±11.6	<0.001
Radial access*	99 (52.4)	197 (53.5)	193 (61.5)	82 (58.6)	67 (63.2)	0.10
FFR	19 (10.0)	48 (13.0)	34 (10.8)	20 (14.3)	9 (8.4)	0.49
PCI	63 (33.2)	112 (30.4)	94 (29.9)	43 (30.7)	26 (24.3)	0.63
RHC	42 (22.1)	73 (19.8)	73 (23.2)	33 (23.6)	21 (19.6)	0.78
Radiation-absorbing pad	101 (53.2)	196 (53.8)	193 (62.3)	93 (66.4)	72 (67.3)	0.007

Normally distributed values are shown as mean±SD. Categorical values are shown as n (%frequency). BMI indicates body mass index; FFR, fractional flow reserve; PCI, percutaneous coronary intervention; and RHC, right heart catheterization.

*The 2 brachial access cases were included and analyzed under this category.

Impact of BMI on Patient Radiation Dose

A significant increase in both air kerma and DAP was observed across increasing patient BMI categories (*P*<0.001 for both; Table 3; Figure 2). Compared with a patient BMI <25, a patient BMI ≥40 was associated with a 2.1-fold increase in DAP (91.8 [59.6–149.2] versus 44.5 [25.7–70.3] Gy×cm^2; *P*<0.001) and a 1.9-fold increase in air kerma (1097 [795–2008] versus 571 [343–830] mGy; *P*<0.001).

Patient radiation doses as determined by DAP and as stratified by diagnostic coronary angiography procedures and procedures involving PCI are provided in Table 3. Compared with diagnostic coronary angiography procedures, those procedures involving PCI were associated with a 1.9-fold increase in DAP (101.7 [67.9–156.1] versus 54.4 [36.9–76.7] Gy×cm^2; *P*<0.001). Among diagnostic coronary angiography procedures, a BMI ≥40 was associated with a 2.2-fold increase in DAP compared with a BMI <25 (81.4 [58.7–120.0] versus 36.2 [23.9–51.7] Gy×cm^2; *P*<0.001). Among PCI procedures, a BMI ≥40 was associated with a 2.6-fold increase in DAP compared with a BMI <25 (184.7 [114.8–249.1] versus 70.0 [45.0–103.2] Gy×cm^2; *P*<0.001).

Impact of Patient BMI on Physician Radiation Dose

The median radiation dose per case for physicians was 0.6 (0.1–5.2) µSv. A significant increase in physician radiation dose was observed across increasing patient BMI categories (Table 3; Figure 2). A patient BMI ≥40 was associated with a 7.0-fold increase in physician radiation dose compared with a patient BMI <25 (1.4 [0.2–7.1] versus 0.2 [0.0–2.9] µSv; *P*<0.001).

Physician radiation doses stratified by diagnostic coronary angiography procedures and those procedures involving PCI are provided in Table 2. Compared with diagnostic coronary angiography, PCI procedures were associated with a 2.4-fold increase in physician radiation dose (1.2 [0.1–11.2] versus 0.5 [0.1–2.9] µSv; *P*<0.001). Among diagnostic coronary angiography procedures, a patient BMI ≥40 was associated with a 5.0-fold increase in physician radiation dose compared with a patient BMI <25 (1.0 [0.1–4.6] versus 0.2 [0.0–2.8] µSv; *P*=0.008). Among PCI procedures, a patient BMI ≥40 was associated with a 23.5-fold increase in physician radiation dose compared with a patient BMI <25 (4.7 [0.3–10.8] versus 0.2 [0.0–4.7] µSv; *P*=0.01).

By log-transformed multiple regression analysis, right heart catheterization (*P*=0.41) and radial access (*P*=0.34) were not significantly associated with physician radiation dose. The final log-transformed model showed that BMI (dose increase, 5.2% per unit increase in BMI; 95% CI, 3.0%–7.5%; *P*<0.0001), age (dose increase, 1.3% per year of age; 95% CI, 0.1%–2.5%; *P*=0.04), PCI (dose increase, 166.7%; 95% CI, 98.0%–259.3%; *P*<0.0001), and FFR (dose increase, 103.7%; 95% CI, 32.0%–214.2%; *P*=0.0013) were independently associated with an increase in physician radiation dose, and that use of a radiation-absorbing pad was independently associated with a decrease in physician radiation dose (dose reduction, 69.4%; 95% CI, 59.4%–76.9%; *P*<0.0001; Table 4). Because of the observational nature of the study and the variability among the data, the r-squared value of the model is low (0.13) and indicates low precision among the predictors.

DISCUSSION

The principal observation of the present study, which evaluated the association between patient BMI and the radiation dose of physicians performing coronary angiography, was that increasing patient BMI was associated with an increase in physician radiation dose. This observation is consistent with the concept that higher patient radiation doses, which were also observed to increase in a stepwise fashion with patient BMI, result in higher amounts of scatter radiation, the primary source of radiation exposure to physicians performing cardiac catheterization.[3–6] The observations made in

Table 3. Patient and Physician Radiation Doses During Coronary Angiography Procedures According to Patient BMI

	BMI <25.0	BMI, 25.0–29.9	BMI, 30.0–34.9	BMI, 35.0–39.9	BMI ≥40	*P* Value
Fluoroscopy time, min	5.9 (2.9–11.4)	5.6 (2.9–10.5)	5.9 (3.5–10.8)	6.1 (3.3–13.0)	7.0 (3.5–11.8)	0.26
Air kerma, mGy	571 (343–830)	701 (476–1022)	851 (583–1357)	1014 (732–1606)	1097 (795–2008)	<0.001
Patient radiation dose per case according to DAP						
All procedures	n=189	n=367	n=314	n=140	n=106	
DAP, Gy×cm^2	44.5 (25.7–70.3)	56.0 (36.6–86.6)	69.1 (49.1–102.7)	77.8 (56.3–137.7)	91.8 (59.6–149.2)	<0.001
Diagnostic angiography	n=126	n=255	n=220	n=97	n=80	
DAP, Gy×cm^2	36.2 (23.9–51.7)	46.0 (33.3–65.4)	62.0 (44.2–78.9)	70.2 (52.6–94.9)	81.4 (58.7–120.0)	<0.001
PCI	n=63	n=112	n=94	n=43	n=26	
DAP, Gy×cm^2	70.0 (45.0–103.2)	90.6 (65.7–144.7)	116.7 (84.7–170.4)	142.2 (75.5–203.3)	184.7 (114.8–249.1)	<0.001
Physician radiation dose per case						
All procedures	n=189	n=367	n=312	n=139	n=107	
Personal dose equivalent, μSv	0.2 (0.0–2.9)	0.5 (0.1–4.8)	0.8 (0.1–6.3)	1.0 (0.1–6.6)	1.4 (0.2–7.1)	<0.001
$H_p(10)$/DAP (μSv/[mGy×cm^2]×10^{-5})	0.5 (0.0–5.7)	0.9 (0.2–7.1)	1.0 (0.2–9.1)	1.0 (0.1–8.1)	1.3 (0.2–10.0)	0.12
Diagnostic angiography	n=126	n=255	n=219	n=97	n=81	
Personal dose equivalent, μSv	0.2 (0.0–2.8)	0.4 (0.1–2.6)	0.6 (0.1–3.6)	0.9 (0.1–2.9)	1.0 (0.1–4.6)	0.051
$H_p(10)$/DAP (μSv/[mGy×cm^2]×10^{-5})	0.5 (0.0–5.5)	0.8 (0.3–5.5)	0.8 (0.2–5.5)	1.0 (0.2–5.0)	1.0 (0.2–9.7)	0.62
PCI	n=63	n=112	n=93	n=42	n=26	
Personal dose equivalent, μSv	0.2 (0.0–4.7)	1.0 (0.1–11.1)	2.0 (0.3–12.8)	1.8 (0.1–16.7)	4.7 (0.3–10.8)	0.020
$H_p(10)$/DAP (μSv/[mGy×cm^2]×10^{-5})	0.4 (0.0–5.9)	0.9 (0.1–8.1)	1.4 (0.3–16.8)	1.2 (0.1–16.6)	3.2 (0.2–11.2)	0.12

Values shown are median (25th–75th percentile). BMI indicates body mass index; DAP, dose area product; $H_p(10)$, personal dose equivalent; and PCI, percutaneous coronary intervention.

this study are concerning considering that long-term radiation exposure among interventional cardiologists has been linked to multiple adverse health effects[10–14] and that the prevalence of obesity in the cardiac catheterization laboratory has been increasing over time.[2] Whereas obesity has been convincingly associated with health problems in patients,[15] the present observations support the need for additional studies to determine whether patient obesity might have an adverse impact on the health of treating physicians by exposing them to greater amounts of radiation during coronary angiography.

Impact of Obesity on Patient Radiation Dose

Consistent with prior observations indicating a high prevalence of obesity among patients undergoing cardiac catheterization,[2] >50% of the current study population was obese, and ≈10% of the study population was morbidly obese. Between 1998 and 2009, Buschur et al[2] demonstrated that morbid obesity increased by 91% among patients undergoing PCI. Supporting the concept that the increasing prevalence of obesity may exert a negative impact on patient radiation safety, the present study demonstrated a significant increase in patient radiation dose across increasing BMI categories. Comparable with the doubling of patient radiation dose we observed among morbidly obese patients, Ector et al[4] demonstrated a 2.2-fold increase in patient radiation dose in obese patients undergoing pulmonary vein isolation. Also similar to our findings, Shah et al[5] found obese patients undergoing coronary angiography to have a radiation dose that was 2.5-fold higher than lean patients.

Patient Obesity and Physician Radiation Dose

Whereas morbid obesity was associated with a doubling of the patient radiation dose compared with lean patients, we observed morbid obesity to be associated with a 7-fold increase in the physician radiation dose during coronary angiography procedures. Although the impact of patient BMI on the relative increase in physician radiation dose was seemingly greater than the impact on patient dose, particularly in the PCI subgroup, this observation should be interpreted with caution owing to the small number of patients with a BMI ≥40. When considering this finding, it should be noted that the literature supports the concept that scatter radiation at a fixed point is proportional to the DAP.[8,9] This concept likely accounts for the observation that when physician radiation doses were normalized to DAP, no differences in the normalized radiation doses were observed across patient BMI categories. However, physician radiation dose is not solely dependent on DAP but rather depends on other factors as well, including the

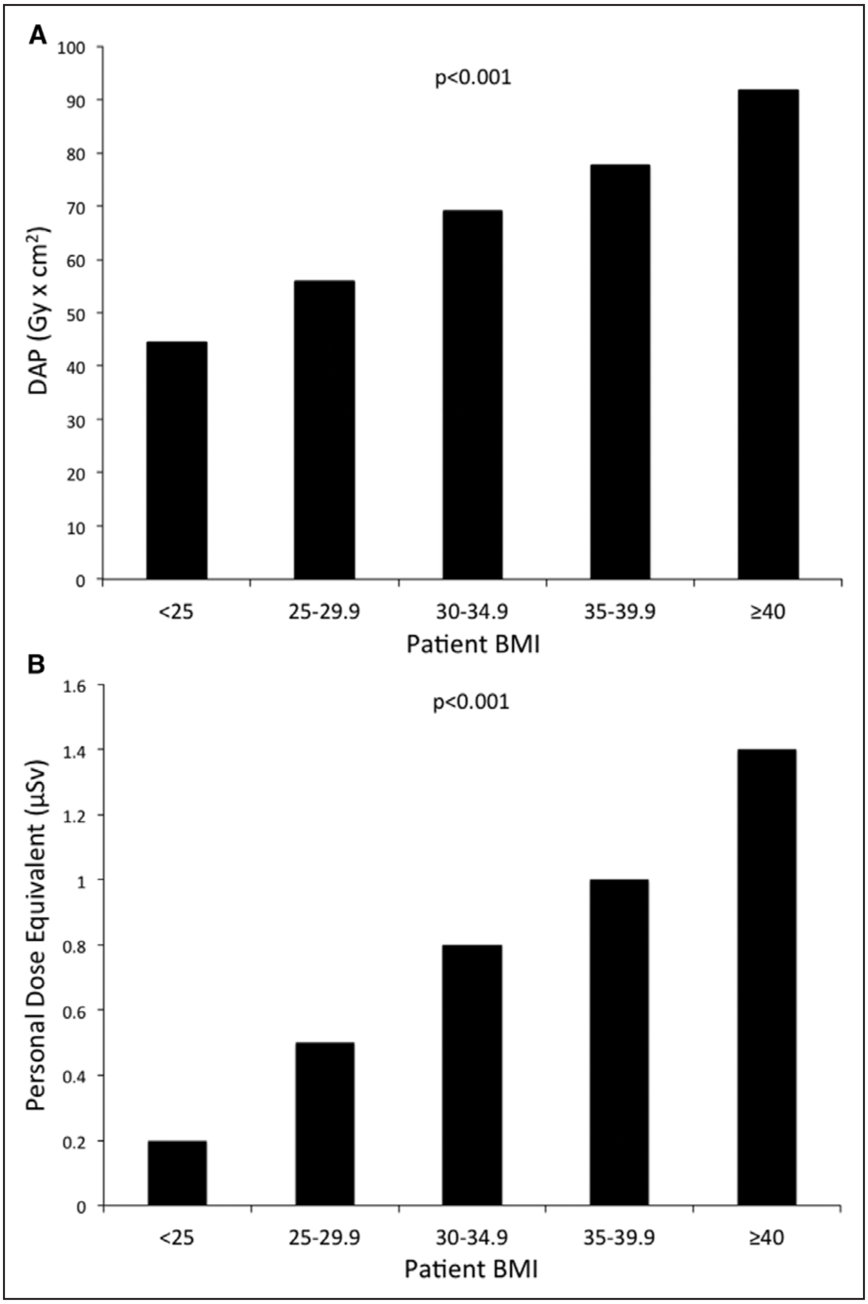

Figure 2. Patient and physician radiation doses per case during coronary angiography according to patient body mass index (BMI).
There was a stepwise increase in patient radiation dose (**A**) and physician radiation dose (**B**) across increasing patient BMI categories. *P* values shown are for the trend. DAP indicates dose area product.

distance between the physician and the patient, the degree of lead shielding, and the time the physician spends in the zone of scatter radiation. Thus, it is conceivable that if any of these other factors is unfavorably impacted by increasing patient BMI, then physician radiation dose may increase out of proportion to the DAP alone. For instance, it is possible that patient body habitus, particularly among morbidly obese patients, may prevent optimal positioning of accessory lead shields in some cases. Clearly, additional studies are needed to better understand the impact of morbid obesity on physician radiation doses and to determine whether morbid obesity has a disproportionate impact on physician radiation dose compared with patient radiation dose.

Radiation Safety in the Obesity Epidemic

We observed large relative increases in physician radiation doses across increasing patient BMI categories, yet the absolute increases in physician radiation dose per case across BMI categories were smaller. The results of the multiple regression analysis performed in this study also help to place the association between patient BMI and physician radiation dose into context, particularly with respect to other clinical factors associated with physician radiation doses. For instance, whereas each 1-unit increase in patient BMI was associated with a ≈5% increase in physician radiation dose, the performance of FFR and PCI was each associated with >100% increases in physician radiation dose. When interpreting these findings, it

Table 4. Variables Independently Associated With Log of Physician Radiation Dose by Multiple Regression Analysis

	Δ%Exposure	β	*P* Value
PCI	166.7 (98.0 to 259.3)	0.98 (0.68 to 1.28)	<0.0001
FFR	103.7 (32.0 to 214.2)	0.71 (0.28 to 1.15)	0.0013
BMI	5.2 (3.0 to 7.5)	0.05 (0.03 to 0.07)	<0.0001
Age, y	1.3 (0.1 to 2.5)	0.01 (0.0 to 0.02)	0.0409
Radiation-absorbing pad	−69.4 (−76.9 to −59.4)	−1.18 (−1.47 to −0.90)	<0.0001

For the categorical variables PCI, FFR, and radiation-absorbing pad, the Δ% exposure values represent the percentage change in exposure when the variable was present. For the continuous variables BMI and age, the Δ% exposure values represent the percentage change in exposure per 1-unit increase in BMI or year of age, respectively. β values were obtained from the regression model. BMI indicates body mass index; FFR, fractional flow reserve; and PCI, percutaneous coronary intervention.

is important to remember that the adverse health risks associated with occupational radiation exposure are likely related to the cumulative impact of small radiation doses obtained during the course of a physician's career. Hence, it is the chronic repeated exposure to low doses of ionizing radiation that is thought to account for the increased incidence of premature cataract formation,[10–12] early carotid atherosclerosis,[13] and possibly left-sided brain malignancies[14] among interventional cardiologists. Furthermore, evidence of a detectable acute DNA damage response in operators performing fluoroscopic procedures has recently been demonstrated.[16]

Considering the increasing recognition of the health risks faced by interventional cardiologists, combined with the growing prevalence of obesity in the catheterization laboratory, the observations of the present study perhaps call for more aggressive radiation safety practices in the era of the obesity epidemic. The observation that radiation-absorbing pads were used significantly more frequently across increasing BMI categories might indicate that operators were aware of the potentially higher rates of radiation exposure from obese patients and implemented additional protective strategies to reduce the exposure. Notably, use of a radiation-absorbing pad was associated with a ≈70% reduction in physician radiation dose in the multiple regression analysis. As another means to reduce exposure, continued improvements in fluoroscopy equipment should be encouraged. It is notable that novel fluoroscopy systems, such as those that utilize real-time image noise-reduction technology, have been demonstrated to reduce radiation doses by ≈50% or more.[17–20] Additional studies will be required to determine the impact of noise-reduction technology in the catheterization of obese patients.

Limitations

The single-center, retrospective design of this analysis represents a significant limitation. That the distribution of body fat was not recorded among patients also represents a limitation because body fat distribution has been shown to influence radiation doses.[3] Importantly, only adipose tissue located between the photon source and image intensifier will attenuate photons and thereby influence the patient radiation dose. Hence, for the same BMI, a patient with central obesity would be expected to have a greater dose and generate more scatter radiation than a patient whose body fat is peripherally distributed. The present study was limited in that it did not account for tube angulation, which is an important determinant of radiation dose to the patient and operator.[4,5] Another limitation is that dosimeters could be worn by physicians on either the left anterior side of the glasses or on the left anterior side of the thyroid collar. This variable placement of dosimeters may have impacted the study results. The study is also limited considering that use of radiation-absorbing pads differed significantly across BMI categories. The lack of control in the study design regarding radiation-absorbing pad use may have introduced bias into the results. It should be noted, however, that large increases in physician radiation doses were observed, despite more frequent use of radiation-absorbing pads across increasing patient BMI categories. There are additional limitations to consider in regard to the radiation dosimeters worn by physicians in this study. These dosimeters, which are not intended to be legal dosimeters of record, have been shown to have directional dependence and large relative changes between doses recorded in the low region. These factors may have influenced the study results. Finally, the use of DAP to estimate patient dose rather than calculating effective doses for patients may be considered a limitation. However, the calculation of effective dose for patients is performed using a conversion coefficient that does not account for patient BMI.[5] Furthermore, it was previously demonstrated that increases in the calculated effective doses for patients were smaller than the corresponding increases in DAP values across increasing BMI categories.[4] Based on this prior finding, the relative increase in patient radiation dose across BMI categories reported in the present study would have been smaller if patient dose was estimated using effective dose rather than DAP.

Conclusions

Among patients undergoing coronary angiography, increasing patient BMI was observed to be associated with a significant increase in physician radiation dose. Whereas prior studies have documented the adverse health consequences of obesity on the patient, additional studies are needed to determine whether patient obesity may have adverse health effects on physicians as well, in the form of increased radiation doses during coronary angiography.

ARTICLE INFORMATION

Received April 19, 2018; accepted November 28, 2018.

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Sources of Funding

This work was partially funded by a research grant from Corindus Vascular Robotics (Waltham, MA).

Disclosures

Dr Madder has received research grants (significant) and served on the advisory board (significant) of Corindus Vascular Robotics. The other authors report no conflicts.

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