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Overhead arm support reduces radiation exposure during complex endovascular aortic repair

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ABSTRACT

Background: Complex endovascular aortic surgery has been associated with increased fluoroscopic radiation exposure. The radiation dosage necessary for visualization is dependent on the amount of tissue penetration required. Elevation of a patient's arms above their head during endovascular surgery could improve visualization by removing the arms from the field of view. Furthermore, it might reduce the radiation dose required. In the present study, we sought to determine the effect of arm elevation on radiation exposure during endovascular treatment of thoracoabdominal aneurysms.

Methods: All patients enrolled in a single-institution, physician-sponsored investigational device exemption study for endovascular treatment of thoracoabdominal aneurysms (fenestrated/branched endovascular aortic repair [F/BEVAR]) from 2012 to 2022 were assessed. The first 30 patients treated were excluded to account for the learning curve required with treatment. Patients treated after December 2020 were positioned with their arms elevated above their head using an overhead arm support (OAS). These patients were compared with those who had undergone F/BEVAR before the practice change. The radiation dose, fluoroscopy time, and contrast volume used were compared. A subgroup analysis was performed to assess the effect for patients with brachial access.

Results: A total of 145 patients were included in the present study, of whom 43 (30%) had undergone F/BEVAR with their arms supported overhead. No differences were identified in age, body mass index, aneurysm size, or prior aortic intervention between the groups with and without the use of the OAS. A history of dissection (23% vs 7.8%; $P = .01$) was more frequent for the patients treated with their arms elevated. Arm elevation was associated with a significant reduction in the mean radiation exposure (2261 vs 3100 mGy; $P = .01$). No differences were observed in the fluoroscopy time or contrast volume used between the two groups. In addition, no patient experienced palsy of the brachial plexus. Of the 145 patients, 55 (38%) had required brachial arterial access, limiting their ability to elevate both arms. In the subgroup analysis, the patients without brachial access continued to show a significant reduction in radiation exposure with arm elevation (2159 vs 3179 mGy; $P < .01$).

Conclusions: Elevation of a patient's arms above their head using an OAS during F/BEVAR offered a low-cost, simple strategy that resulted in a 30% reduction in radiation exposure without added complications. This technique improved visualization and reduced radiation exposure for patients and physicians and should be included in abdominal aortic and visceral procedures work to improve patient and surgeon safety. (J Vasc Surg 2023;77:991-6.)

Keywords: F/BEVAR; Overhead arm support; Radiation

Advances in endovascular technology have been constantly expanding the scope of vascular pathologies that can be treated with minimally invasive techniques. Complex endovascular aortic aneurysm repair now permits the treatment of juxtarenal abdominal aortic aneurysms (JRAAAs) and thoracoabdominal aortic aneurysms (TAAAs) using branched and fenestrated stent grafts (fenestrated-branched endovascular aortic repair [F/BEVAR]). These interventions, however, have been associated with a concomitant increase in the radiation exposure incurred by both patients and providers.[1]

The radiation exposure required for sufficient visibility during angiographic procedures is dependent on the density and length of tissue penetration required.[2] A critical step in F/BEVAR is the selection of visceral vessels, which will often require extended fluoroscopic

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visualization of the abdominal aorta. Elevation of a patient's arms above their head during F/BEVAR will reduce the amount of tissue in the fluoroscopic field and could improve visualization during these key steps.[3] The use of arm elevation has, thus, been considered to reduce the radiation burden during complex endovascular aortic procedures and allow for improved visualization without increasing the fluoroscopy dose. However, the effect in this practice has not been characterized. Therefore, in the present study, we sought to determine the effect of arm elevation on radiation dose exposure.

METHODS

Patients. All patients who had undergone F/BEVAR at the University of Washington Medical Center had provided written informed consent, and the institutional review board approved the present study. A retrospective review of the medical records was conducted for all patients enrolled in a single-institution, physician-sponsored independent device exemption (IDE) study for endovascular treatment of TAAAs from 2012 to 2022. Patient data were abstracted from the clinical medical records, including operative reports, inpatient progress notes, laboratory results, and outpatient clinic documentation. The first 30 patients treated under the IDE were excluded to account for the expected learning curve required for this novel treatment modality.

Patient positioning. Patients treated after December 2020 were positioned with their arms elevated above their head using an overhead arm support (OAS; Fig). Before the practice change, the patients' arms had been tucked by their side with adequate protection of all pressure points. Before the advent of the Gore VBX bridging stent graft technology (W. L. Gore & Associates, Flagstaff, AZ), which allowed deployment of stents into downward going branches via entirely femoral access, brachial artery access was commonplace during F/BEVAR in our practice. After Food and Drug Administration approval of the VBX stent graft in 2017, a significant reduction had occurred in the usage of brachial artery access during F/BEVAR. Arm access in our practice has since been reserved exclusively for patients for whom we expect significant aortic tortuosity or anatomically complex target vessels that would prevent successful repair using entirely femoral artery access. To reduce the potential for confounding from this practice change, a subgroup analysis was performed to account for brachial artery access, which had prevented placement of both arms above the head. In all cases for which upper extremity access was required, the brachial artery had been accessed in the proximal-to-mid upper arm by direct cutdown to allow for primary repair of the arteriotomy. The accessed arm was positioned directly laterally at 90°, with the contralateral arm tucked at the patient's side before the practice change. After implementation of the OAS, the patients who had required brachial artery access were positioned with the contralateral arm elevated using the OAS.

ARTICLE HIGHLIGHTS

- **Type of Research:** A single-center, retrospective analysis of prospectively collected data from an institutional independent device exemption study
- **Key Findings:** Overhead arm support positioning during complex fenestrated/branched endovascular aortic repair for patients with thoracoabdominal aortic aneurysms for 145 patients resulted in a 30% reduction in radiation exposure with no cases of brachial plexus palsy.
- **Take Home Message:** Our study showed that overhead arm support positioning is safe and should be considered the standard of care for aortic and visceral surgery to improve patient and surgeon safety.

Equipment. The patients' arms were elevated using an OAS manufactured by Adept Medical, Ltd (Auckland, New Zealand), purchased new for <$500, and designed to secure a patient's arms in compatible C-arm, magnetic resonance imaging or computed tomography systems. All procedures were performed in the same hybrid operating room, using the Allura Xper FD20 Cath/Angio system (Philips Healthcare, Amsterdam, Netherlands). After installation of the AlluraClarity imaging processing software, no major modifications or firmware updates had occurred to the imaging equipment during the study period. Three-dimensional image fusion technology was not used for any patients in the present study. Intravascular ultrasound (IVUS) was used to treat aneurysms secondary to chronic dissection and confirm wire location within the true lumen and was not used to aid in the cannulation of target vessels.

Variables assessed. The baseline cohort information, including age, weight, body mass index, aneurysm size and extent, treatment indication, and history of vascular surgery, was recorded. The operative details were also compared, including the use of additional proximal thoracic endovascular aortic repair or distal aortic graft deployment, use of IVUS, number of target vessels treated, and use of upper extremity access. The primary outcomes, including radiation dose as measured in cumulative air kerma, fluoroscopy time, contrast volume used, and incidence of brachial plexus palsy, were compared.

Statistical analysis. The outcomes were compared between groups before and after the introduction of arm elevation using univariate analysis. A subgroup analysis was performed of the patients who had not required

Fig. Positioning of patients undergoing complex endovascular aortic surgery using overhead arm support (OAS) with arms secured in position and pressure points protected. Photographs published with subject permission.

Table I. Baseline patient demographics and characteristics stratified by arm position

Variable	Arm elevation: No (n = 102)	Arm elevation: Yes (n = 43)	*P* value
Age, years	72 ± 7.5	75 ± 7.4	**.04**
BMI, kg/m^2	27 ± 4.8	26 (3.8)	.33
Male gender	69 (68)	36 (84)	.05
Urgent indication	13 (13)	9 (21)	.21

BMI, Body mass index.
Data presented as mean ± standard deviation or number (%).
Boldface *P* values represent statistical significance.

arm access to undergo F/BEVAR. Continuous variables were assessed using the Student *t* test and Mann-Whitney *U* test according to the normalcy of distribution. All other variables were compared using χ^2 tests. Statistical analysis was performed using SPSS, version 27 (IBM Corp, Armonk, NY).

RESULTS

Baseline, anatomy, and operative characteristics. A total of 145 patients with TAAAs were included in the present study, of whom 43 (30%) had undergone F/BEVAR with their arms supported overhead. No differences were identified in age, body mass index, aneurysm size and extent, urgent indication, or prior aortic intervention between the two groups with and without the use of OAS (Table I). A presentation with aneurysmal degeneration of a chronic dissection (23% vs 7.8%; $P = .01$) and the use of IVUS (21% vs 4.9%; $P = .01$) was more frequent for patients treated with their arms supported overhead (Table II). Of the 145 patients, 55 (38%) had required brachial arterial access. This approach was more common for the group treated without the use of the OAS (50% vs 9.3%; $P = .01$), which primarily reflected the change in practice at our institution. No difference was found in the use of additional aortic grafts, including proximal thoracic endovascular aortic repair and distal bifurcated devices. Additionally, the aneurysm extent and mean number of target vessels treated (3.9) was similar.

Outcomes. The use of OAS was associated with a 27% reduction in mean radiation exposure (2261 vs 3100 mGy; $P = .01$; Table III). No difference was observed in the fluoroscopy time or contrast volume used between the two groups. No patient had experienced palsy of the brachial plexus postoperatively, and no time limit was in place for maintaining the overhead arm position. Also, none of the first 30 patients treated in the IDE study, who had been excluded from the present analysis, had developed palsy of the brachial plexus. In the subgroup analysis of the 82 patients who had not required brachial access, the improvement in radiation exposure with OAS remained significant (2159 vs 3179 mGy; $P < .01$; Table IV) without any significant differences in the baseline characteristics (Table V).

DISCUSSION

Elevation of the patient arms above the head during F/BEVAR resulted in a 27% reduction in the mean radiation exposure, with no significant changes in the contrast volume or fluoroscopy time. This reduction was achieved with no increased risk incurred to the patient or disruption of procedural flow. The reduction in radiation exposure persisted in the subgroup analysis of only those patients without brachial access, with a 32% reduction despite no significant differences in baseline anatomic complexity or operative difficulty.

To the best of our knowledge, the present study represents the first to evaluate the effect of OAS on radiation dose administration. However, the concept of OAS for

Table II. Operative and anatomic characteristics of patients stratified by arm position

	Arm elevation		
Variable	**No (n = 102)**	**Yes (n = 43)**	***P* value**
Maximum diameter, mm	68 ± 13	72 ± 12	**.03**
Size at celiac artery, mm	42 ± 13	42 ± 11	.91
Size at SMA, mm	42 ± 13	38 ± 9.0	.32
Extent of TAAA[a]			.74
Extent 4	42 (41)	19 (44)	
Extent 1-3	60 (59)	24 (56)	
Prior aortic intervention	55 (54)	23 (54)	.96
Brachial access	51 (50)	4 (9.3)	**<.01**
Dissection	8 (7.8)	10 (23)	**<.01**
Intravascular ultrasound	5 (5.0)	9 (21)	**<.01**
Target vessels	3.9 ± 0.5	3.9 ± 0.4	.82
Additional aortic grafts	87 (85)	40 (93)	.20
Proximal TEVAR	47 (46)	16 (37)	.33
Distal aortic device	73 (72)	36 (84)	.12

SMA, Superior mesenteric artery; *TAAA*, thoracoabdominal aortic aneurysm; *TEVAR*, thoracic endovascular aortic repair.
Data presented as mean ± standard deviation or number (%).
Boldface *P* values represent statistical significance.
[a]Classified as Crawford extent 4 and included pararenal abdominal aortic aneurysms.

Table III. Patient outcomes stratified by arm position

	Arm elevation		
Variable	**No (n = 102)**	**Yes (n = 43)**	***P* value**
Radiation, mGy	3100 ± 1810	2261 ± 987	**.01**
Fluoroscopy time, minutes	56 ± 23	56 ± 19	.64
Contrast used, mL	155 ± 38	149 ± 42	.43
Brachial plexus palsy	0 (0)	0 (0)	1.00

Data presented as mean ± standard deviation or number (%).
Boldface *P* values represent statistical significance.

Table IV. Patient outcomes stratified by arm position in subgroup analysis of patients without brachial artery access

	Arm elevation		
Variable	**No (n = 51)**	**Yes (n = 39)**	***P* value**
Radiation, mGy	3179 ± 1729	2159 ± 931	**<.01**
Fluoroscopy time, minutes	50.3 ± 18	56.1 ± 20	.18
Contrast used, mL	157 ± 41	146 ± 41	.20
Brachial plexus palsy	0 (0)	0 (0)	1.00

Data presented as mean ± standard deviation or number (%).
Boldface *P* values represent statistical significance.

use during F/BEVAR has been previously described.[4] A study by Marcondes et al[4] reported in 2021 identified 44 consecutive patients who had been treated for TAAAs with F/BEVAR using overhead upper extremity positioning and found it to be safe with no neurologic injuries sustained. However, that previous study had not assessed the effects on the radiation dose.

Our retrospective study has provided quantitative evidence that OAS results in a 30% reduction in the total radiation dose during complex endovascular aortic repair. The use of OAS is low cost, easy to implement, and has the potential to result in a substantial reduction in radiation exposure. Given the described effects of long-term radiation exposure, this provides the potential

Table V. Anatomic and baseline patient characteristics stratified by arm position in subgroup analysis for patients without brachial artery access

Variable	Arm elevation		*P* value
	No (n = 51)	Yes (n = 39)	
Age, years	73 ± 7.8	76 ± 7.3	.08
Aneurysm size, mm	69 ± 12	71 ± 11	.33
Size at celiac axis, mm	41 ± 14	42 ± 11	.37
Size at SMA, mm	41 ± 13	38 ± 9	.44
Extent of TAAA[a]			.49
Extent 4	26 (51)	17 (44)	
Extent 1-3	25 (49)	22 (56)	
Prior aortic intervention	20 (57)	20 (51)	.6
Urgent indication	6 (12)	8 (21)	.26
Dissection	7 (14)	5 (13)	.39
Intravascular ultrasound	5 (9.8)	7 (18)	.39
Additional aortic grafts	44 (86)	36 (92)	.37
Proximal TEVAR	24 (47)	15 (39)	.42
Distal aortic device	36 (71)	32 (82)	.21

SMA, Superior mesenteric artery; *TAAA*, thoracoabdominal aortic aneurysm; *TEVAR*, thoracic endovascular aortic repair.
Data presented as mean ± standard deviation or number (%).
[a]Classified as Crawford extent 4 and included pararenal abdominal aortic aneurysms.

opportunity to reduce the dose-related risks of cancer and cardiovascular disease to both patients and providers.[5,6] We theorized that the reduction in radiation observed had resulted primarily from the increased dose required for penetrance through a patient's arms in the lateral views. By eliminating the need for increased penetrance, lower radiation doses were sufficient to allow for adequate imaging. Although the present study had only assessed the effect for patients undergoing F/BEVAR, the benefit of OAS positioning will likely extend to all interventions in the abdomen for which oblique gantry angles are required for sufficient visualization, including treatment of the aorta, iliac, and visceral vessels. The implications for this reduction in radiation exposure could also be extended to other endovascular procedures that involve visualization of the abdomen, including procedures performed by specialists outside of vascular surgery.

The present study had several limitations that must be addressed. First, it was possible that additional procedural differences existed and had contributed to the decrease in radiation safety, including the addition of a second surgeon to the practice during the study period. However, the major markers of complexity, including the number of aortic components and target vessels treated, had remained consistent, and the mean fluoroscopy time did not differ between the two groups. Increased operator experience resulting in improved collimation and positioning presented an additional potential confounder. However, we specifically attempted to account for this by excluding the first 30 patients treated in the present study, with a 4-year period. The use of the ALARA (as low as reasonably achievable) principles has been considered standard for all F/BEVAR cases and had not changed during the study period. No significant upgrades had occurred in the imaging software, and the total fluoroscopy time had remained stable between the two groups, suggesting that the reduction in radiation was not a result of fewer digital subtraction angiography runs. Deployment of the main body and bridging stents was standardized to require both an anteroposterior and a lateral view for safe deployment, which also had not changed in our practice. Subtle changes in practice such as these listed previously were potential confounders to our results. However, decreasing radiation exposure has been universally accepted as a beneficial outcome and should be the goal of every endovascular intervention.[7]

CONCLUSIONS

Elevation of a patient's arms above their head using an OAS during F/BEVAR offers a low-cost, easy to implement intervention that resulted in a 30% reduction in radiation exposure without added risk to the patient. This technique improved visualization and reduced radiation exposure for patients and physicians and should be included in aortic and visceral procedures to improve patient and surgeon safety.

AUTHOR CONTRIBUTIONS

Conception and design: AP, MS, SZ
Analysis and interpretation: AP, MA, MS, SZ
Data collection: AP, MA
Writing the article: AP, MS, SZ
Critical revision of the article: AP, MA, MS, SZ
Final approval of the article: AP, MA, MS, SZ
Statistical analysis: AP, MA
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Overall responsibility: SZ

REFERENCES

1. Thakor AS, Winterbottom A, Mercuri M, Cousins C, Gaunt ME. The radiation burden from increasingly complex endovascular aortic aneurysm repair. Insights Imaging 2011;2:699-704.
2. Vano E, Gonzalez L, Fernandez JM, Prieto C, Guibelalde E. Influence of patient thickness and operation modes on occupational and patient radiation doses in interventional cardiology. Radiat Prot Dosimetry 2006;118:325-30.
3. Sen I, Tenorio ER, Pitcher G, Mix D, Marcondes GB, Lima GBB, et al. Effect of obesity on radiation exposure, quality of life scores, and outcomes of fenestrated-branched endovascular aortic repair of pararenal and thoracoabdominal aortic aneurysms. J Vasc Surg 2021;73:1156-66.e2.
4. Marcondes GB, Tenorio ER, Baumgardt G, Mendes B, Oderich GS. Evaluation of safety of overhead upper extremity positioning during fenestrated-branched endovascular repair of thoracoabdominal aortic aneurysms. Cardiovasc Intervent Radiol 2021;44:1895-902.
5. Kamiya K, Ozasa K, Akiba S, Niwa O, Kodama K, Takamura N, et al. Long-term effects of radiation exposure on health. Lancet 2015;386:469-78.
6. Kirkwood ML, Guild JB, Arbique GM, Anderson JA, Valentine RJ, Timaran C. Surgeon radiation dose during complex endovascular procedures. J Vasc Surg 2015;62:457-63.
7. Kirkwood ML, Arbique GM, Guild JB, Timaran C, Chung J, Anderson JA, et al. Surgeon education decreases radiation dose in complex endovascular procedures and improves patient safety. J Vasc Surg 2013;58:715-21.

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