

# Impact of vascular resident involvement on operative variables and outcomes in endovascular aneurysm repair

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## ABSTRACT

**Objective:** Our objective was to determine how operative variables and patient outcomes differ for endovascular aneurysm repair (EVAR) done with and without trainees.

**Methods:** A retrospective review of patients who underwent elective infrarenal EVARs with bifurcated endograft between October 1, 2017, and September 30, 2022, was carried out. The presence of vascular residents, patient demographics and comorbidities, intraoperative variables, and postoperative clinical outcomes were tabulated. Operative variables and patient outcomes were compared between cases with and without trainees using the Student *t* test. A multivariate analysis of fluoroscopic measures was also carried out using body mass index (BMI) as a covariate.

**Results:** A total of 148 patients were included in the study with 53 cases taking place with trainees and 95 without. There were no statistically significant differences in patient demographics or comorbidities between the groups. Cases with trainees had significantly longer surgical time ( $84 \pm 5$  minutes vs  $71 \pm 3$  minutes;  $P < .01$ ), fluoroscopy time ( $19 \pm 1$  minutes vs  $14 \pm 1$  minutes;  $P < .001$ ), and higher volumes of contrast ( $86 \pm 6$  mL vs  $72 \pm 3$  mL,  $P = .02$ ). When correcting for body mass index, cases with trainees still had longer fluoroscopy times ( $P < .01$ ). There was also a trend toward greater radiation doses with trainees ( $531 \pm 74$  mGy vs  $381 \pm 53$  mGy;  $P = .10$ ). The presence of trainees did not significantly impact patient outcomes such as mortality, length of stay, or postoperative complications.

**Conclusions:** The presence of vascular residents at EVARs increased surgical and fluoroscopy time despite the presence of two attending surgeons. This finding should be considered when optimizing trainee education while minimizing radiation exposure and its impact on patient care. (JVS-Vascular Insights 2025;3:100230.)

**Keywords:** Operative time; Radiation exposure; Internship and residency

Surgical education relies strongly on the progressive involvement of surgical residents, enabling them to build competence under the guidance and safety of an experienced surgeon. This approach has been studied widely across numerous surgical subspecialties to understand its effect on patient outcomes. Although prior research did not show a correlation with perioperative mortality, resident involvement has been associated with longer operative times and, in some cases, increased complication rates within vascular surgery and other surgical subspecialties.<sup>1–6</sup> Despite this finding, there remains no

clear consensus regarding the impact of trainees on postoperative outcomes.

Studies investigating the impact of trainee involvement within vascular surgery also lack consensus. For instance, although trainee participation increases operative time for carotid endarterectomies, it was not linked to a significant increase in major or minor adverse events.<sup>7</sup> Conversely, resident participation in lower extremity amputations and infrainguinal bypasses may be associated with increased morbidity and graft failure.<sup>6,8</sup> Although prior studies in orthopedic surgery have suggested an inverse relationship between radiation exposure and surgeon experience, similar findings in vascular surgery are lacking.<sup>9</sup>

Endovascular aneurysm repair (EVAR) is a fundamental yet technically demanding procedure within modern vascular surgery. It requires skill, precision, and patience for successful execution. Given the potential implications of trainee involvement for patient outcomes, further research in this area is essential. Therefore, our study aimed to assess the impact of resident participation during EVAR on intraoperative variables and patient outcomes.

## METHODS

A single-center retrospective review was completed of all elective EVARs at Kelowna General Hospital (KGH) between October 1, 2017, and September 30, 2022. Ethical

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approval from the health authority and the university's institutional review board was granted. Since 2017, it has served as one of the distributed sites for the University of British Columbia's (UBC) integrated vascular surgery residency program. It is a unique setting that functions as a residency training site for part of the year and a traditional community hospital for the remainder.

The KGH rotation is designed to provide integrated vascular surgery residents with opportunities to function independently and acquire greater operative autonomy. Typically completed during the third year of training, this required rotation builds on prior experience, equipping residents with a strong foundation in the processes and steps involved in deploying various devices. EVAR procedures are performed at each UBC training site in specialized hybrid operating rooms, although the devices used may vary in manufacturer.

During the procedure, resident physicians are given monitored autonomy, with attending physicians providing guidance and stepping in as needed during more complex stages. This process generally includes gaining access, navigating to the target lesion, performing fluoroscopy, graft deployment, cannulation, and closure. UBC vascular surgery uses a competency-by-design framework, facilitating progressive skill development and training residents to perform these tasks confidently before starting at KGH. The group structure at KGH allows two attending physicians per case, who assist with fluoroscopy and surgical tasks when no resident is present.

A total of 148 patients were included. Patients were selected exclusively based on their compliance with the inclusion and exclusion criteria because a formal power calculation was not conducted. Cases were identified using the electronic medical record, with selection based on billing codes specific to EVAR. Cases miscoded for billing were excluded, along with procedures performed for ruptured aneurysms, those with prior open or endovascular aortic surgery, and advanced cases involving fenestrated grafts, iliac branched endoprosthesis, or planned internal iliac artery embolization.

The primary outcome measure was intraoperative radiation dose. Secondary outcomes included fluoroscopy time, the number of digital subtraction angiography (DSA) runs, the volume of contrast used, and intraoperative complications. Intraoperative complications were defined as unplanned conversion to groin cutdown from percutaneous access, renal artery coverage, postoperative acute limb ischemia, and hematoma requiring drainage. Postoperative outcomes at 30 days, such as mortality, morbidity, and reintervention rates, were also included in our secondary outcomes.

The independent variable in our analysis was the presence of integrated vascular surgery trainees in the operating room. Age, sex, body mass index (BMI), smoking status, and medical comorbidities were documented. A

## ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center, retrospective, non-randomized review
- **Key Findings:** Resident involvement in 53 of 148 endovascular aneurysm repairs resulted in increased operative time ( $84 \pm 5$  minutes vs  $71 \pm 3$  minutes;  $P < .01$ ) and fluoroscopy time ( $19 \pm 1$  minutes vs  $14 \pm 1$  minutes;  $P < .001$ ).
- **Take Home Message:** Resident involvement in vascular surgery is important and is associated with intraoperative differences despite the lack of differences in postoperative outcomes.

diagnosis of hypertension, coronary artery disease, arrhythmia, chronic obstructive pulmonary disease, obstructive sleep apnea, liver disease, end-stage renal disease, diabetes, and stroke were also reported.

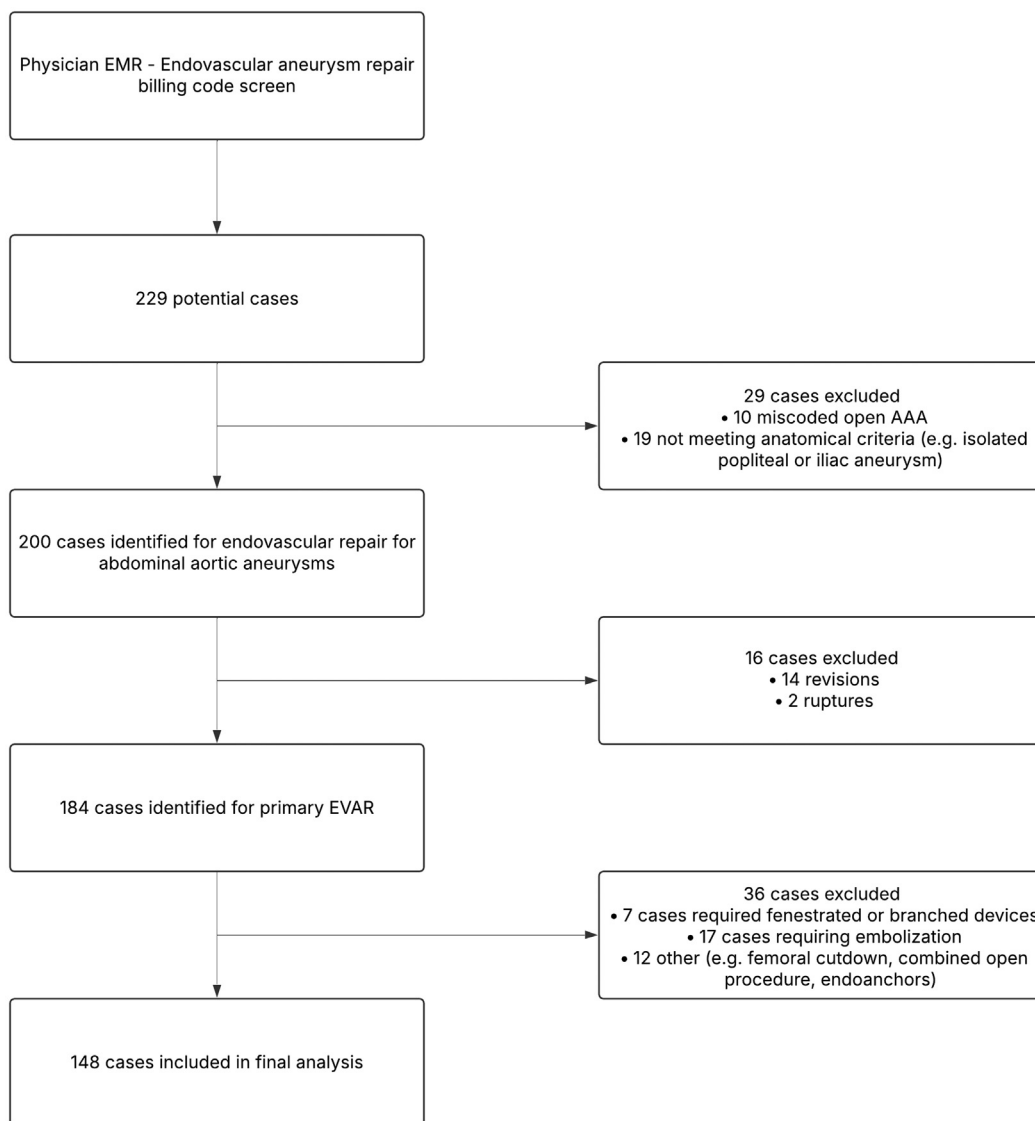
Patient demographics were compared using univariate analysis. Continuous variables were compared using unpaired, two-tailed *t* tests. Categorical variables were evaluated using odds ratios (ORs) with 95% confidence intervals (CIs). The impact of resident presence during cases was assessed using the Student *t* test. Multivariate analysis with BMI as a covariate was also completed for outcomes such as total fluoroscopy time, total radiation dose, fluoroscopy dose, and DSA dose.

BMI was selected as a covariate in the analysis owing to its known influence on radiation exposure and fluoroscopy time during endovascular procedures. A larger body habitus necessitates higher radiation doses and may prolong procedure times to achieve adequate imaging quality.<sup>10–12</sup> A linear regression was performed with BMI as a covariate to account for this confounding factor. This approach enabled a more accurate comparison of contrast volume, radiation exposure, and duration between groups, independent of the influence of body size.

## RESULTS

A total of 148 patients met the inclusion criteria for the study. The participant recruitment and exclusion process is detailed in the Fig. Patient demographics and comorbidities, stratified by trainee involvement, are detailed in Table I. There was no statistically significant difference in patient demographics between groups. In total, 92 patients (91.8%) were male, with an average age of  $76 \pm 1$  years. Residents were involved in 53 cases (36.8%), and attending surgeons operated independently in 95 cases (63.2%). The distribution of resident cases was 2 cases with PGY-2 (3.8%), 44 with PGY-3 (83.0%), 3 with PGY-4 (5.7%), and 5 with PGY-5 (7.5%) residents.

Operative and outcome variables are presented in Table II. Cases with trainees had significantly longer surgical time ( $84 \pm 5$  minutes vs  $71 \pm 3$  minutes;  $P < .01$ ),



**Fig.** Patient exclusion flowsheet. AAA, abdominal aortic aneurysm; EMR, electronic medical record; EVAR, endovascular aneurysm repair.

increased fluoroscopy time ( $19 \pm 1$  minutes vs  $14 \pm 1$  minutes;  $P < .001$ ), and higher contrast volumes ( $86 \pm 6$  mL vs  $72 \pm 3$  mL,  $P = .02$ ). Although cases with trainees demonstrated a trend toward higher total radiation doses ( $531 \pm 74$  mGy vs  $381 \pm 53$  mGy;  $P = .10$ ), this difference did not attain statistical significance. Similarly, radiation dose during fluoroscopy ( $274 \pm 49$  mGy vs  $178 \pm 37$  mGy;  $P = .12$ ) and DSA ( $257 \pm 31$  mGy vs  $203 \pm 24$  mGy;  $P = .18$ ) specifically showed no significant differences. After adjusting for BMI, cases with trainees still had longer fluoroscopy times ( $P < .01$ ).

Trainee presence did not impact patient outcomes significantly, including mortality, length of stay, and postoperative complications. The mean length of stay was  $3.2 \pm 1.2$  days for cases with trainees and  $2.9 \pm 0.6$  ( $P = .83$ ) for those without. There was a single 30-day mortality in the no-trainee group secondary to a

pulmonary embolism identified on autopsy (1%), and short-term postoperative complication rates were not significantly different between trainee and nontrainee cases (11% vs 12%,  $P = .97$ ).

Table II also displays the frequency with which each type of endograft was used. There were no statistically significant differences in the distribution of endograft types between groups, with Cook grafts (Cook Medical, Bloomington, IN) used in 51% vs 59%, Gore (W. L. Gore & Associates, Flagstaff, AZ) in 47% vs 39%, and Medtronic (Medtronic, Dublin, Ireland) in 2% vs 2% for the trainee and no-trainee cases, respectively.

## DISCUSSION

In this study, resident involvement was associated with a statistically significant increase in operative time, fluoroscopy time, and contrast volume and a trend toward

**Table I.** Patient demographics and comorbidities

	Trainees (n = 53)	No trainees (n = 95)	P value/OR	95% CI
Male	46 (85)	90 (95)	2.74	0.82-9.11
Age, years	76 ± 1	76 ± 1	0.54	
BMI, kg/m <sup>2</sup>	27 ± 1	27 ± 1	0.39	
Hypertension	34 (62)	55 (58)	0.83	0.41-1.66
Coronary disease	16 (30)	33 (35)	1.25	0.61-2.58
Arrhythmia	11 (20)	18 (19)	0.98	0.42-2.32
COPD	8 (15)	19 (20)	1.51	0.58-3.91
OSA	8 (15)	25 (26)	2.30	0.92-5.75
Liver disease	2 (4)	5 (5)	1.39	0.26-7.42
ESRD	3 (6)	7 (7)	1.30	0.32-5.25
Diabetes	7 (13)	16 (17)	1.30	0.50-3.40
Stroke	5 (9)	4 (4)	0.41	0.11-1.61
Smoker			NS	
Current	7 (13)	22 (23)		
Ex	40 (75)	57 (60)		
Never	6 (11)	16 (17)		

BMI, Body mass index; CI, confidence interval; COPD, chronic obstructive pulmonary disease; ESRD, end-stage renal disease; OSA, obstructive sleep apnea; NS, not significant.  
Continuous variables are presented as mean ± standard error of the mean and analyzed using the Student *t* test. Categorical variables were analyzed using ORs.

increased total radiation dose. However, resident involvement did not significantly affect mortality, length of stay, or postoperative complications.

Despite the lack of significant difference in radiation dose between groups, there was a trend toward increased radiation with trainees. This trend persisted despite correcting for BMI. Recent publications have found that

vascular surgery trainees are regularly exposed to significant radiation doses, often inadvertently over institutional policies.<sup>13</sup> The risks associated with radiation exposure, including cataracts, skin burns, and cancer, are directly proportional to the amount of exposure and make adherence to the as low as reasonably achievable principle essential for both residents and attending physicians.

**Table II.** Differences in operative variables and patient outcomes for endovascular aneurysm repairs (EVARs) done with and without trainees

	Trainees (n = 53)	No trainees (n = 95)	P value/OR	95% CI
Surgical time, minutes	84 ± 5	71 ± 3	<0.01 <sup>a</sup>	
Fluoroscopy time, minutes	19 ± 1	14 ± 1	<0.001 <sup>a</sup>	
Total rad dose, mGy	531 ± 74	381 ± 53	0.10	
Fluoroscopy dose, mGy	274 ± 49	178 ± 37	0.12	
DSA dose, mGy	257 ± 31	203 ± 24	0.18	
No. of DSA runs	7.0 ± 0.5	6.4 ± 0.3	0.24	
Contrast, mL	86 ± 6	72 ± 3	0.02 <sup>a</sup>	
Endograft type			NS	
Cook	27 (51)	56 (59)		
Gore	25 (47)	37 (39)		
Medtronic	1 (2)	2 (2)		
Complication	6 (11)	11 (12)	1.03	0.36-2.95
Length of stay, days	3.2 ± 1.2	2.9 ± 0.6	0.83	
Perioperative mortality	0	1 (1)	NS	

CI, Confidence interval; DSA, digital subtraction angiography; NS, not significant.  
Continuous variables are presented as mean ± standard error of the mean and analyzed using the Student *t* test.  
Categorical variables were analyzed using ORs.  
<sup>a</sup>*P* < .05.

Although no evidence exists that trainees are at greater risk than attendings regarding cumulative radiation exposure during endovascular procedures, the potential long-term effects remain uncertain.<sup>14</sup>

Previous studies have reported increased radiation exposure with resident involvement owing to trainees' inclination to obtain additional images and their involvement in more complex cases.<sup>9,15,16</sup> In our study, standardization of anatomical and procedural variables likely minimized these factors.

The impact of this increased radiation exposure should also be considered relative to the patient. EVAR necessitates follow-up computed tomography scans to assess sac expansion, endoleak resolution, and overall graft positioning. This intraoperative increase during the index operation increases their cumulative exposure and potential health risks. However, the clinical significance of this difference is likely unclear.

Increased contrast volume with resident involvement is an interesting finding that has yet to be discussed extensively in prior literature and is important clinically given the high prevalence of chronic kidney disease in the vascular patient population. This finding may be due to several factors, such as trainees' reliance on more frequent, higher-volume runs to ensure optimal visualization. The longer operative times and potential unfamiliarity with the equipment may contribute to suboptimal results, requiring additional contrast runs. When adjusted for BMI, this difference was no longer statistically significant; however, the trend toward greater volumes persisted.

Consistent with previous publications, cases involving residents had a significantly longer operative time, even when adjusted for BMI.<sup>2,7,8,17–19</sup> Prolonged operative time is a known independent risk factor for postoperative complications, including renal and cardiopulmonary issues, infection, and reintervention.<sup>20,21</sup> On average, resident involvement extended operative time by 13 minutes, or 18%, and remained significant after adjustment for BMI. This result is likely related to a lack of device familiarity, overall comfort with endovascular procedures, and teaching during resident cases. Although many residents had prior experience operating and deploying various devices, this specific rotation marks an opportunity for increased autonomy and participation in cases and likely contributes to the observed difference. Unfortunately, we could not collect data to quantify each resident's prior experience with endovascular devices before the rotation. This factor is a limitation of the study and may contribute to the observed difference between groups.

One study evaluating the impact of residents on outcomes after carotid endarterectomy found that, although operative times increased, it was not associated with concurrent increases in perioperative morbidity.<sup>7</sup> Conversely, other vascular surgery studies have reported

increased major morbidity, bypass graft failure, and length of stay with resident involvement.<sup>6,8,19,22</sup> The close supervision residents receive and the experience of the attending surgeons likely mitigate complication risks. Most trainees in our study were PGY-3 residents. Previous research has shown an inverse relationship between training level and postoperative complications, which may reflect the increasing autonomy with experience rather than strictly improved outcomes.<sup>2</sup>

Integrating surgical residents into operations is vital for their growth, but this study highlights specific procedural implications of their involvement. Although resident involvement did not increase postoperative complications, length of stay, or mortality, the financial and clinical workflow costs of longer operative times and increased resource use require some consideration.<sup>23</sup> For this reason, surgical training programs are increasingly integrating training modalities, such as simulation, digital progress tracking, and competency-based assessments, to complement sole operating room exposure and potentially minimize risk.<sup>24–26</sup>

Although statistical significance was observed, these findings' clinical significance is another consideration. Operative times increased on average by 13 minutes; however, the impact on potential postoperative complications is likely minimal. Previous works found a relative increase of 14% in postoperative complications for every 30 additional minutes.<sup>21</sup> Most investigations also focus on open surgical procedures and not percutaneous, further decreasing the risk of infection. This shows that although the increased time spent with a resident is statistically significant, it does not lead to poorer patient outcomes, thereby reinforcing the safety of resident teaching.

Although the mean fluoroscopy time increased by 5 minutes with resident involvement ( $P < .05$ ), the trend toward a greater total radiation, despite a nonsignificant difference of 150 mGy between groups, warrants closer attention. This seemingly small per case increase compounds throughout an academic surgeon's career. Established radiation safety thresholds have reported a yearly chronic dose of 0.4 Sieverts associated with potential deterministic effects on hematopoiesis, and 0.2 Sieverts with cataract formation.<sup>27</sup> Furthermore, the stochastic effects of long-term, low-dose radiation exposure remain a concern, and the impact of radiation on uncovered body regions such as the head, face, and long bones of the extremities is poorly understood.

Our study's design included rigorous criteria to standardize case complexity and ensure a homogenous dataset. However, several limitations must be acknowledged. First, the retrospective nature of our study introduces potential bias in the selection of cases. The lack of a formal power calculation represents a potential limitation, increasing the risk of a type II error. We were also unable to complete a temporal analysis to investigate practice and teaching trends over time. Furthermore, the single-

center setting and presence of two attending surgeons at most operations also decrease the generalizability of the results. The site functions as a training site only for part of the year and thus operates differently from a traditional academic or community hospital. Resident experience before the rotation was not standardized or accounted for, which may have influenced operative outcomes. The rotation serves as an early opportunity for residents to act as primary operators; however, the sequence of rotations during the third year of training is not standardized. As a result, this may influence familiarity with the procedure and our primary outcome.

## CONCLUSIONS

Resident involvement in standard infrarenal EVAR procedures was associated with increased operative time, fluoroscopy time, and contrast use despite the presence of two attending surgeons. However, this factor did not impact mortality, length of stay, or the rate of postoperative complications. These findings highlight the need for multimodal surgical training that provides trainees hands-on experience and technical feedback outside the operating room. This study contributes to an essential discussion on balancing resident training and patient and operator safety.

## AUTHOR CONTRIBUTIONS

Conception and design: NR, SC, GY  
 Analysis and interpretation: NR, SC, GY  
 Data collection: NR, SC, GY  
 Writing the article: NR, SC, GY  
 Critical revision of the article: NR, SC, GY  
 Final approval of the article: NR, SC, GY  
 Statistical analysis: SC, GY  
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 Overall responsibility: NR

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## DISCLOSURES

None.

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