ORIGINAL ARTICLE

Effect of Physician and Hospital Experience on Patient Outcomes for Endovascular Treatment of Aortoiliac Occlusive Disease

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Objective: To evaluate the effect of physician volume and specialty and hospital volume on population-level outcomes after endovascular repair of aortoiliac occlusive disease (AIOD).

Design: A retrospective cross-sectional analysis of all inpatients undergoing endovascular repair of AIOD. Physician volume was classified as low (<17 procedures per year [<50th percentile]) or high (≥17 procedures per year). Physicians were defined as surgeons if they performed at least 1 carotid, aortic, or iliac endarterectomy; open aortic repair; above- or below-knee amputation; or aortoiliac-femoral bypass. Hospital volume was low (<116 procedures per year [<50th percentile]) or high (≥116 procedures per year).

Patients: Eight hundred eighteen inpatients who underwent endovascular repair of AIOD in the Healthcare Cost and Utilization Project Nationwide Inpatient Sample from January 2003 through December 2007.

Setting: National hospital database.

Main Outcome Measures: In-hospital complications and mortality, length of stay, and cost.

Results: Of the 818 procedures, 59.0% of high-volume physicians were surgeons and 65.0% practiced at high-volume hospitals. Unadjusted complication rates were significantly higher for low-volume compared with high-volume physicians (18.7% vs 12.6%; $P=.02$); rates were not significantly different by physician specialty ($P=.88$) or hospital volume ($P=.16$). Shorter length of stay was associated with high-volume physicians ($P=.001$), high-volume hospitals ($P=.001$), and surgeon providers ($P=.03$), whereas decreased cost was associated with physician specialty ($P=.004$). On multivariate analysis, high physician volume was associated with significantly lower complications ($P=.04$); high hospital volume, with shorter length of stay ($P=.002$); and nonsurgeons, with higher costs ($P=.05$).

Conclusions: Overall, volume at the physician and hospital levels appears to be a robust predictor of patient outcomes after endovascular interventions for AIOD. Surgeons performing endovascular procedures for AIOD have a decreased associated hospital cost compared with nonsurgeons.

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Innovations in surgical technology have influenced practice patterns in vascular surgery. Aortoiliac occlusive disease (AIOD) is increasingly being treated with endovascular techniques, such as angioplasty and stenting, regardless of disease severity. Many patients are now treated as outpatients for AIOD using endovascular techniques; however, these patients usually have less severe forms of the disease and fewer comorbidities. Advances in the ability to stent and treat more severe lesions and still achieve acceptable clinical outcomes have likely lowered the threshold for treatment and contributed to the rapid diffusion of this technology for the treatment of AIOD.[1-4] The ability to treat these lesions with an endovascular approach has grown to include different specialists, including cardiologists, interventional radiologists, and vascular surgeons.

See Invited Critique at end of article

Birkmeyer et al[5] showed that Medicare patients undergoing selected cardiovascular or cancer procedures can significantly reduce their risk of operative death by selecting a high-volume hospital. In addition, for many procedures, the observed associations between hospital volume and operative mortality are largely mediated by surgeon volume. Patients can often improve their chances of survival substantially, even at high-volume hospi-

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tals, by selecting surgeons who perform the operations more frequently.[6] Finally, the proportion of procedures performed by high-volume surgeons has increased, as evidence has mounted in support of an association between surgeon volume and outcome.[7]

Recent evidence suggests that endovascular aortic aneurysm repair performed at major teaching hospitals is associated with improved survival, decreased length of hospital stay (LOS), and lower cost.[8] More than half of carotid endarterectomies (CEAs) performed in the United States are by high-volume surgeons with superior outcomes.[9] In a recent study,[10] physician specialty was not found to significantly influence patient outcomes or complications for lower extremity percutaneous angioplasty (LE PTA). However, hospital resource utilization varied significantly by specialty, with vascular surgeons demonstrating the lowest utilization of hospital resources for LE PTA compared with cardiologists. High-volume practitioners also used significantly fewer medical supplies and had lower hospital resource utilization for performing LE PTA.

In the present study, we evaluated the effects of physician volume and specialty and hospital volume on population-level outcomes of endovascular repair in inpatients with AIOD.

METHODS

DATA SOURCE

We conducted a cross-sectional analysis of hospital discharge information from the Healthcare Cost and Utilization Project Nationwide Inpatient Sample (HCUP-NIS) database, a 20% stratified sample of inpatient admissions from acute care hospitals maintained by the Agency for Healthcare Research and Quality.[11] Data were obtained from January 2003 through December 2007. The HCUP-NIS is the largest all-payer inpatient database in the United States, with approximately 8 million hospital admissions per year. *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes for diagnoses of AIOD and procedures related to endovascular repair were used to identify all patients 18 years or older.

We initially identified AIOD using a principal diagnosis of atherosclerosis of the aorta (*ICD-9* code 440.0), arterial embolism and thrombosis of the abdominal aorta (*ICD-9* code 444.0), or arterial embolism and thrombosis of the iliac artery (*ICD-9* code 444.81) grouped according to anatomic location of disease (aortic vs iliac disease). Patients with the following diagnoses were excluded to limit the analysis to AIOD: renovascular hypertension (*ICD-9* codes 405.01, 405.11, and 405.91), renal artery atherosclerosis (*ICD-9* code 440.1), renal artery thrombosis/occlusion, (*ICD-9* code 593.81), chronic vascular insufficiency of the intestine (mesenteric) (*ICD-9* code 557.1), embolism and/or thrombosis of the upper extremity (*ICD-9* code 444.21), and arterial embolism or thrombosis (femoral, peripheral, not otherwise specified, or popliteal) (*ICD-9* code 444.22). Endovascular cases were abstracted (angioplasty or atherectomy of noncoronary vessels [*ICD-9* code 39.50]; insertion of non–drug-eluting peripheral vessel stents [*ICD-9* code 39.90]) on the basis of principal procedure. Patients receiving endovascular and open procedures in the same hospitalization were also excluded from analysis.

Independent demographic variables included calendar year, sex, race (white, black, Hispanic, and other, which included but was not limited to Asians, Pacific Islanders, and Native Americans), median household income (in quartiles), admission type (elective vs nonelective), and principal diagnosis. Patient comorbidity was measured using the enhanced Charlson Comorbidity Index.[12,13] Hospital region (Northeast, Midwest, South, and West) was included to assess differences in geographic practice patterns.

Table 1. Characteristics of 818 Patients Undergoing Endovascular Procedures for AIOD in the HCUP-NIS Database, 2003-2007[a]

Patient Characteristic	Analytic Cohort, %
Female sex	54.9
Race	
White	80.7
Black	10.4
Hispanic	5.4
Other	3.5
Charlson Comorbidity Index	
None	15.8
Low	56.6
Moderate	21.0
High	6.6
Nonelective admission	35.4
Diagnosis	
Aorta	33.6
Iliac	66.4

Abbreviations: AIOD, aortoiliac occlusive disease; HCUP-NIS, Healthcare Cost and Utilization Project Nationwide Inpatient Sample.
[a] Mean (SD) age of the patients was 64 (12) years.

Provider specialty (surgeon vs nonsurgeon) was identified using the HCUP primary physician identifier. Physician volume was low (<17 procedures per year [<50th percentile]) or high (≥17 procedures per year). Physicians were defined as surgeons if they had performed at least 1 carotid, aortic, or iliac endarterectomy; open aortic repair; above- or below-knee amputation; or aortoiliac-femoral bypass. Hospital volume was low (<116 procedures per year [<50th percentile]) or high (≥116 procedures per year).

OUTCOME VARIABLES

Primary outcomes of interest were (1) in-hospital patient complications, (2) in-hospital patient mortality, (3) mean LOS, and (4) total inpatient hospital costs. Postoperative complications were categorized as cardiovascular, vascular, bleeding, or embolic; respiratory or infection; and other (including incisional, neurological, and urology related). Acute posthemorrhagic anemia (*ICD-9* code 285.1) was included as a complication only if a concurrent diagnosis of transfusion (*ICD-9* codes 99.00, 99.01, 99.02, or 99.03) was present. Complications were treated as a binomial outcome (complication vs no complication). Mean LOS and total inpatient hospital cost were log transformed to achieve a more normal distribution. Cost information for the years 2003 through 2006 were available in the HCUP-NIS at the time of this study. Total inpatient costs were calculated using the HCUP-NIS–adjusted, hospital-group average cost to charge ratios. Costs were then adjusted for inflation, converting all costs to 2007 dollars, using rates from the Bureau of Labor Statistics.[14]

DATA ANALYSIS

Bivariate analysis of independent variables by outcomes was performed using χ^2 statistical analysis for categorical variables and analysis of variance for continuous variables. Multivariate

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Table 2. Characteristics of Physicians and Hospitals Performing 818 Endovascular Procedures for AIOD in the HCUP-NIS Database, 2003-2007[a]

Characteristic	Nonsurgeon/ Surgeon, %	*P* Value	Physician Volume, Low/High, %	*P* Value	Hospital Volume, Low/High, %	*P* Value
Sex						
Female	53.8/55.7	.59	53.4/56.3	.41	56.3/53.5	.43
Male	46.2/44.3		46.6/43.7		43.7/46.5	
Charlson Comorbidity Index						
None	16.7/15.1	.91	17.7/13.8	.37	19.7/11.9	.03
Low	55.8/57.2		54.2/59.0		53.6/59.6	
Moderate	21.2/20.9		20.9/21.1		20.1/21.9	
High	6.2/6.9		7.1/6.1		6.6/6.6	
Admission						
Elective	59.5/68.4	.009	60.1/69.0	.008	35.6/35.2	.90
Nonelective	40.5/31.6		39.9/31.0		64.4/64.8	
Diagnosis						
Aorta	26.9/38.7	<.001	30.3/36.9	.03	28.7/38.4	<.001
Iliac	73.1/61.3		69.7/63.1		71.3/61.6	
Provider type						
Nonsurgeon	NA		45.3/41.0	.21	42.5/43.8	.71
Surgeon	NA		54.7/59.0		57.5/56.2	

Abbreviations: AIOD, aortoiliac occlusive disease; HCUP-NIS, Healthcare Cost and Utilization Project Nationwide Inpatient Sample; NA, not applicable.
[a] Because of rounding, percentages might not total 100.

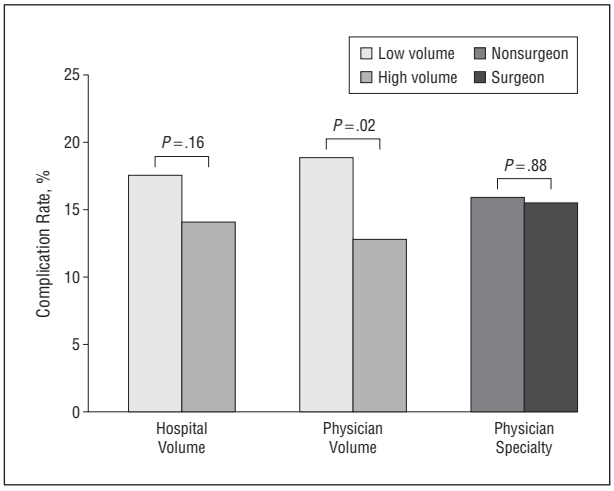

Figure 1. Complication rates by hospital volume, physician volume, and physician specialty.

linear regression models were used to adjust for significant independent variables for LOS and total inpatient costs. Multivariate logistic regression models were used to adjust for in-hospital patient complications and in-hospital patient mortality. All probability values are the results of 2-sided tests, and $P \leq .05$ was considered significant. Data analysis and management were performed using commercially available software (SPSS, version 16.0; SPSS, Inc, Chicago, Illinois). This study was deemed exempt at our institution from institutional review board approval because HCUP-NIS is a public database with no personal identifying information.

RESULTS

DEMOGRAPHICS

From 2003 through 2007, 818 patients underwent inpatient endovascular procedures for AIOD and had an identifiable provider (**Table 1**). The mean age was 64 (range, 52-76) years. Most of the patients were white (80.7%) and had a low Charlson Comorbidity Index score (56.6%) followed by a moderate score (21.0%). Most of the patients underwent elective admissions to the hospital (64.6%) and had a diagnosis of iliac occlusive disease (66.4%). The majority of high-volume physicians were surgeons (59.0%) and practiced at high-volume hospitals (65.0%) (**Table 2**).

UNADJUSTED OUTCOMES

Physician volume and specialty were not associated with a significant difference in mortality ($P = .35$ and $P = .54$, respectively). There were no significant differences in the rate of complications based on hospital volume (17.4% vs 13.9% for low-volume vs high-volume hospitals; $P = .16$) or between surgeons and nonsurgeons (15.5% vs 15.9%; $P = .88$) (**Figure 1**). However, high-volume physicians (surgeons and nonsurgeons) had significantly fewer complications when compared with low-volume physicians (12.6% vs 18.7%; $P = .02$).

High-volume hospitals had a significantly shorter LOS than low-volume hospitals (2.8 vs 3.3 days; $P = .001$), as did high-volume physicians compared with their low-volume colleagues (2.8 vs 3.3 days; $P = .001$) (**Figure 2**). Surgeons had a significantly shorter LOS compared with nonsurgeons (2.9 vs 3.2 days; $P = .03$), as well as a lower associated cost ($11 692 vs $13 656; $P = .004$).

ADJUSTED OUTCOMES

All patient and provider characteristics associated with clinical and economic outcomes on bivariate analysis were included in the multivariate model. After adjustment, physician volume and specialty were not associated with a significant difference in mortality. High-volume physi-

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cians were associated with significantly lower complication rates (**Figure 3**). Female sex, patient age of 45 through 64 years and 65 years or older, and nonelective admission were independently associated with higher complication rates. In addition, patients with low, moderate, and high Charlson Comorbidity index scores sustained a stepwise increase in their respective complication rates. A diagnosis of aortic disease and having a procedure performed at a high-volume hospital were associated with a shorter LOS. The characteristics associated with a longer LOS were female sex; low, moderate, and high Charlson Comorbidity indexes; and nonelective admission. There were no significant differences associated with costs pertaining to hospital or physician volume. However, costs were significantly lower when surgeons performed the procedures compared with nonsurgeons (−$1321; 95% confidence interval, −$381 to −$2878; $P = .05$) after controlling for sex, admission type, and patient comorbidity.

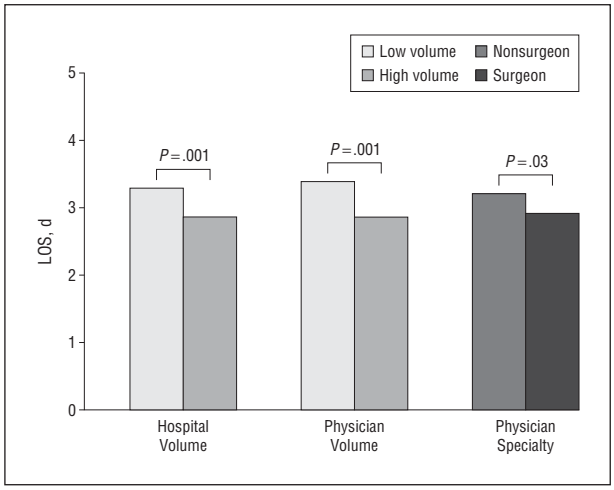

Figure 2. Length of stay (LOS) by hospital volume, physician volume, and physician specialty.

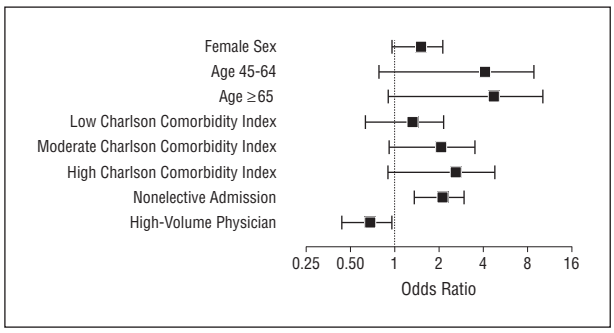

Figure 3. Forest plot illustrating adjusted predictors of higher and lower complication rates.

COMMENT

We found no significant differences in the rate of complications with regard to hospital volume or between surgeons and nonsurgeons. High-volume physicians had significantly fewer complications. High-volume hospitals had a significantly shorter LOS, and surgeons had a significantly shorter LOS compared with nonsurgeons. Physician volume and specialty and hospital volume were not associated with a significant difference in mortality. There were no significant differences associated with costs related to hospital volume or physician volume. However, costs were significantly lower when surgeons performed the procedures compared with nonsurgeons.

Although the relationship between physician and hospital volume and patient outcomes has been well described for other procedures in the surgical literature, only recently has it been described for vascular surgical procedures. Many of the reports in the vascular literature examining volume-outcome relationships are restricted to mortality. In addition, there are very few reports examining how provider type affects outcomes associated with endovascular procedures because now interventionists performing these procedures are a heterogeneous group of specialists. Several studies have illustrated that high-volume specialist vascular surgeons operating in high-volume hospitals achieve the lowest mortality and reduced LOS for open abdominal aortic aneurysm repair. Board certification in vascular surgery, high-volume hospitals, and high-volume surgeons all are associated with superior patient outcomes.[15-18] The trend toward lower mortality at high-volume centers is also evident when examining endovascular techniques for elective abdominal aortic aneurysm repair.[19] Schermerhorn et al[20] found that, in patients treated with open repair for isolated descending thoracic aortic aneurysms, increased hospital volume was independently associated with lower mortality in multivariate analysis.

With respect to lower extremity arterial bypass surgery, evidence suggests that there is reduced postoperative mortality and increased limb salvage when these procedures are performed at high-volume centers.[5,21-24] Finally, with respect to LE PTA, there appears to be no difference in morbidity or mortality when surgeons are compared with nonsurgeons. However, hospital resource utilization varied significantly by specialty, with vascular surgeons demonstrating lower utilization of hospital resources for LE PTA compared with cardiologists. High-volume practitioners also used significantly fewer medical supplies and had lower hospital resource utilization when performing LE PTA.[10]

Although some evidence supports having specialized vascular surgeons perform high volumes of certain procedures at high-volume centers, our study is the first, to our knowledge, to specifically measure the effect of provider type, provider volume, and institution volume on the clinical and economic outcomes specific to AIOD. Innovations in surgical technology have made it possible to treat many vascular disorders with an endovascular approach, which is less invasive. Aortoiliac occlusive disease has been increasingly treated with endovascular techniques such as angioplasty and stenting, regardless of disease severity. Vascular surgeons are performing endovascular procedures in addition to other interventionists, such as radiologists and cardiologists. We recently showed that endovascular procedures are associated with superior short-term clinical and economic outcomes compared with open procedures for the treatment of AIOD

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in the inpatient setting, but physician volume and specialty and hospital volume were not considered in the analysis.[25]

Dimick et al[21] performed the only detailed analysis of the volume-outcomes association for AIOD, with a focus on patients treated with aortobifemoral bypass. This included hospital volume but failed to analyze physician volume or specialty. Hospitals that performed more than 25 aortobifemoral bypasses per year (33% of patients at 37 hospitals in the NIS) had a lower crude mortality rate compared with hospitals that performed fewer aortobifemoral bypasses (2.2% vs 3.7%). In multivariate analysis, aortobifemoral bypass at high-volume hospitals was associated with a 42% decreased risk for in-hospital mortality (odds ratio, 0.58; 95% confidence interval, 0.34-0.97; $P \leq .04$) compared with low-volume hospitals. We found no differences in mortality related to hospital volume. This is most likely because the overall mortality associated with endovascular treatment of AIOD is so low (2.4%).

Our findings with regard to AIOD are similar to those identified with regard to the treatment of carotid stenosis with CEA, except that there appears to be a stronger association between surgeon volume and mortality for CEA. Cowan et al[9] showed that most of the CEAs performed in the United States in 1996 and 1997 were by high-volume surgeons with superior results. The observed mortality by surgeon volume was 0.44% for high-, 0.63% for medium-, and 1.10% for low-volume surgeons ($P < .001$). The postoperative stroke rate was 1.14% for high-, 1.63% for medium-, and 2.03% for low-volume surgeons ($P < .001$). Surgeon specialty had no significant effect on mortality or post-CEA stroke. A low hospital volume of CEAs (<100 cases per year) was not an independent risk factor for mortality in the multivariate analysis.

Vogel et al[10] recently examined outcomes and hospital resource utilization for LE PTA performed by cardiologists and vascular surgeons. Although this study examined more distal peripheral artery disease than AIOD, some important similarities exist. The main differences between cardiologists and vascular surgeons were found in the analysis of hospital resource utilization. The study did not find a difference in LOS between cardiologists and vascular surgeons (2.38 vs 2.41 days; $P = .85$), but total hospital charges for cardiologists were greater than for vascular surgeons ($49 748 vs $42 158; $P < .001$). We found that surgeons had a shorter LOS and a lower cost associated with endovascular procedures for AIOD compared with nonsurgeons.

Limitations of our study include those inherent to any that use a large database, such as coding errors. Patient anatomy and disease severity, as illustrated by preoperative imaging, are not described in the HCUP-NIS. In addition, *ICD-9* coding does not perfectly differentiate acute conditions such as a "saddle embolus" from chronic total occlusion of the aorta; the former usually has a much greater severity of illness. Because HCUP-NIS captures only admitted patients, patients undergoing endovascular procedures in the outpatient setting were not included in our analysis. Information on each patient is limited to a single hospitalization, and longitudinal analysis with review of long-term outcomes, such as rates of readmission, survival, and patency, could not be measured.

In conclusion, volume at the physician and hospital levels appears to be a robust predictor of patient outcomes after endovascular interventions for AIOD. Physician volume, not specialty, is a significant predictor of complications, even after case-mix adjustment. Surgeons performing endovascular procedures for AIOD have a shorter LOS and decreased associated hospital costs compared with nonsurgeons. Increased referral to high-volume centers and physicians performing endovascular procedures for AIOD may improve patient outcomes.

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Author Contributions: *Study concept and design:* Indes, Tuggle, Muhs, and Sosa. *Acquisition of data:* Indes, Tuggle, Mandawat, and Sosa. *Analysis and interpretation of data:* Indes, Tuggle, Mandawat, Muhs, and Sosa. *Drafting of the manuscript:* Indes, Tuggle, Mandawat, Muhs, and Sosa. *Critical revision of the manuscript for important intellectual content*: Indes, Muhs, and Sosa. *Statistical analysis:* Tuggle, Mandawat, and Sosa. *Administrative, technical, and material support:* Indes. *Study supervision:* Indes, Tuggle, Muhs, and Sosa.
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INVITED CRITIQUE

Aortoiliac Endovascular Intervention

Add It to the List

Dr Indes and colleagues[1] have analyzed the effects of physician and hospital volume (as well as specialty) on the outcome of endovascular intervention for aortoiliac occlusive disease, and the results are reassuring to all those who believe in the concept of "practice makes perfect." Once again—not counterintuitively—high volume (for both physician and hospital) was associated with better outcomes, including reduced complications, reduced mortality, and reduced length of stay. However, surgeons were found to be less expensive than nonsurgical interventionalists—not an outcome that I would have predicted.

This finding adds support to those who believe that major vascular cases should be centralized. Aortic and carotid surgical procedures have been shown to have better outcomes when performed in high-volume centers by high-volume surgeons. To my knowledge, however, this correlation has not previously been documented for endovascular procedures. Some might argue that endovascular procedures are not as complex or risky as aortic or carotid procedures and thus that "anyone can do them safely." I would suggest that the new results from Indes et al support the concept that endovascular aortoiliac intervention can be performed well and can be performed poorly and that this difference is detectable. Those who perform this group of procedures often give their patients better outcomes than those who just dabble. In short, these results explicitly show that outcomes are related to volume but implicitly tell us that there is real skill involved in aortoiliac endovascular intervention.

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