Outcomes of acute intraoperative surgical conversion during endovascular aortic aneurysm repair

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Purpose: **Outcomes and predictors of acute surgical conversion during endovascular aortic aneurysm repair (EVAR) were examined using the American College of Surgeons-National Safety and Quality Improvement Project (ACS-NSQIP) Database (2005 to 2008).**

Methods: **Acute intraoperative surgical conversions occurring during elective EVAR were identified using Current Procedural Terminology codes. Nonemergent EVAR and primary open surgical repairs of infrarenal aneurysms were examined for comparison. Perioperative morbidity was categorized as wound, pulmonary, venous thromboembolic, genitourinary, cardiovascular, operative, and septic. Mortality, overall morbidity, and length of stay (LOS) were examined.**

Results: **We identified 72 acute conversions, 2414 open repairs, and 6332 EVAR without acute conversion. Demographics and comorbidities were generally similar among operative groups. Mean operative time was 274 minutes for acute conversion vs 226 minutes for primary open repair and 162 minutes for EVAR (conversion vs EVAR and open repair vs EVAR $P < .0001$ for each; conversion vs open repair $P = .0014$; analysis on rank operative time). Blood transfusion was required in 69% of acute conversions (mean volume, 6.0 units) vs 73% of open repairs (mean volume, 3.3 units) and 12% of EVARs (mean volume, 2.6 units; $P < .0001$ for each pair-wise comparison; analysis on rank number of units among those transfused). Major morbidity was 28% for acute conversions, 28% for open repairs, and 12% for EVARs. Mortality was 4.2% for acute conversions, 3.2% for open repairs, and 1.3% for EVARs. Median (quartile 1, quartile 3) LOS was 7 (5, 9) days for acute conversion and open repair, and 2 (1, 3) days for EVAR. Morbidity and mortality were significantly higher for acute conversion and open repair vs EVAR. The OR (95% confidence interval) for morbidity was 2.9 (1.7-4.8) after conversion and 2.8 (2.5-3.2) after open repair ($P < .0001$ for both) and for mortality was 3.4 (1.0-10.9; $P = .0437$) for conversion and 2.5 (1.9-3.5; $P < .0001$) for open repair. Morbidity and mortality were similar between acute conversion and open repair. A similar pattern among repair groups was demonstrated for LOS, with similar LOS for acute conversions and open repair, which were significantly longer than those observed for EVAR. No significant demographic or medical risk factor predictors of acute conversion during EVAR were identified.**

Conclusion: **Acute surgical conversion was a rare complication affecting 1.1% of EVAR cases, with no broadly identifiable at-risk population. When conversion did occur, morbidity and mortality rates paralleled those observed for elective open repair. (J Vasc Surg 2011;54:1244-50.)**

Endovascular aortic aneurysm repair (EVAR) represents a major advance in the history of infrarenal abdominal aortic aneurysm (AAA) treatment. From its initial description by Parodi et al[1] in 1990, through initial U.S. Food and Drug Administration approval for EVAR use in the United States in 1999 and the subsequent introduction of numerous device redesigns and innovations, EVAR has increased in popularity and become the treatment of choice for anatomically suitable infrarenal AAAs.

EVAR is associated with lower in-hospital mortality and major morbidity rates than open surgical repair.[2,3] EVAR is not without risk, however. One of the major complications that can occur is the need for an acute intraoperative surgical conversion. Acute surgical conversion can be necessitated by a number of events, including (but not limited to) aneurysm rupture, errors in device deployment, iliac artery rupture, or other access-related problems. Fortunately, acute surgical conversion during EVAR is a rare event. However, this relative infrequency of acute surgical conversion makes it difficult to study, and therefore, little is known about the occurrence and consequences of this adverse event.

This study examined contemporary surgical outcomes for acute surgical conversion of EVAR using the American College of Surgeons National Surgical Quality Improve-

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ment (ACS-NSQIP) public use database from 2005 to 2008 to further characterize the problem of acute surgical conversion during EVAR and its complications as well as mortality rates compared with elective EVAR and open AAA repair.

METHODS

Data source. The private sector ACS-NSQIP is a validated, prospective database derived from a systematic sampling of cases at 211 participating hospitals throughout North America. Available data include patient demographics, medical risk factors, detailed information about procedural specifics, and in-hospital and 30-day postoperative morbidity and mortality rates. All data are collected at participating sites by a trained research nurse. Data for follow-up >30 days and subsequent surgical procedures or hospitalizations are not included. Definitions for the variables collected in the NSQIP database have been described in previous reports.[4-6]

Study sample. Acute intraoperative open conversion of EVAR procedures performed between January 2005 and December 2008 were identified for analysis within the 2005 to 2008 ACS-NSQIP database using Current Procedural Terminology (CPT, American Medical Association, Chicago, Ill) codes 34830, 34831, and 34832, which describe open repair of infrarenal aortic aneurysm plus repair using a tube, aortobiiliac, or aortobifemoral prosthesis of associated arterial trauma immediately after unsuccessful EVAR. The CPT codes 34830 to 34832 "bundle," or remove, a number of other CPT codes once they are used, including essentially all of the codes describing the attempted EVAR, among them device configuration and arterial access, and the repair of the associated arterial trauma. Codes for associated visceral and renal bypass and lower extremity revascularization are not bundled or removed.

The study excluded cases with *International Classification of Diseases (9th Revision)* codes for ruptured aortic aneurysm (441.3) or designated as "emergency" to limit the study sample to acute conversions occurring during an elective EVAR. For the purposes of comparison, elective EVAR cases that were not converted and elective open surgical repairs of infrarenal aortic aneurysms were also identified for analysis. Cases performed emergently or for rupture were again excluded.

Elective EVAR procedures were identified using CPT codes for the elective deployment of the main body of an endovascular aortic stent graft (CPT codes 34800, 34802, 34803, 34804, 34805). Open surgical repairs of infrarenal AAAs were identified using CPT codes 35081 and 35102. Cases involving coincident codes for visceral (excluding inferior mesenteric artery reimplant) or renal artery reconstruction were excluded from consideration.

Demographics and medical risk factors. All demographic and medical risk factor data were extracted directly from the ACS-NSQIP database. Race was considered as white or nonwhite, including categories of Hispanic, Asian, Native American, and black. Age was considered as a continuous variable, with ages >90 years coded as 90 years in the ACS-NSQIP database to prevent the potential for individual patient identification. Estimated glomerular filtration rate (eGFR) was used to assess renal function and was calculated using the abbreviated Modification of Diet in Renal Disease formula.[7] Body mass index (BMI) was calculated using height and weight data (kg/m^2). Decreased functional status was defined as partial or total dependence before hospitalization.

End points. This investigation analyzed three major outcomes: morbidity, mortality, and length of stay (LOS). Postoperative complications (morbidity) were analyzed individually and in aggregate categories, including:

- wound—superficial or deep surgical site infections;
- pulmonary—pneumonia, reintubation, or failure to wean from ventilator ≤48 hours;
- renal—postoperative renal function decline or need for dialysis;
- venous thromboembolic—deep vein thrombosis or pulmonary embolism;
- cardiovascular—myocardial infarction, cardiac arrest, or stroke;
- operative—return to operating room, postoperative bleeding, or graft failure; and
- septic—sepsis and septic shock.

Postoperative mortality was defined as death ≤30 days or during the same acute care hospital stay, regardless of time. LOS was defined as the time from the EVAR procedure to hospital discharge or death.

Statistical analysis. Preoperative characteristics, medical risk factors, and procedural data were described using mean ± standard deviation or count (%), and compared across procedure groups using the χ^2 test for categoric variables and simple linear regression for continuous variables.

Tests of association across procedure groups were performed for morbidity and mortality using logistic regression, and for log-LOS using linear regression techniques. Owing to the relative rarity of morbidity and mortality associated with acute intraoperative surgical conversions of EVAR, robust multivariable analyses using these end points were not possible. Predictors of acute surgical conversion among all patients having attempted elective EVAR were explored using simple and multivariable logistic regressions. Analyses were performed using SAS 9.2 software (SAS Institute, Cary, NC). Odds ratios (OR) are presented with 95% confidence intervals (CI).

RESULTS

Study sample characteristics. The methods detailed above were used to identify 72 cases of acute intraoperative surgical conversion during EVAR, 2414 elective open surgical repairs of infrarenal AAA, and 6332 completed elective EVARs without acute conversion. The incidence of acute surgical conversion during attempted EVAR was 1.1%. During the interval of the study (2005 to 2008), the yearly incidence of acute conversion was 1%, 1.7%, 1.3%,

Table I. Demographics for patients undergoing abdominal aortic aneurysm (AAA) repair

Variable[a]	*Elective EVAR (n = 6332)*	*Immediate open conversion (n = 72)*	*Elective open repair (n = 2414)*	P[b]
Age[c]	74.1 ± 8.5	73.3 ± 9.4	71.2 ± 8.6	<.0001
Nonwhite race	927 (14.6)	10 (13.9)	317 (13.1)	.1954
Female sex	1069 (16.9)	15 (20.8)	608 (25.2)	<.0001
Body mass index, kg/m^2	28.0 ± 5.6	26.9 ± 4.6	27.5 ± 5.3	.0004
Diabetes	920 (14.5)	6 (8.3)	290 (12.0)	.0038
Current smoker	1812 (28.6)	21 (29.2)	999 (41.4)	<.0001
Functional status before surgery				
Independent	6046 (95.5)	66 (91.7)	2323 (96.2)	.0769
Partially or totally dependent	286 (4.5)	6 (8.3)	91 (3.8)	
History of				
Chronic obstructive pulmonary disease	1178 (18.6)	10 (13.9)	447 (18.5)	.5918
Congestive heart failure	88 (1.4)	1 (1.4)	17 (0.7)	.0312
Myocardial infarction	75 (1.2)	1 (1.4)	38 (1.6)	.3526
Angina	138 (2.2)	0 (0)	48 (2.0)	.3920
Prior coronary artery bypass grafting	1550 (24.5)	17 (23.6)	563 (23.3)	.5252
Prior PTCI	1322 (20.9)	10 (13.9)	454 (18.8)	.0395
Hypertension	5026 (79.4)	58 (80.6)	1996 (82.7)	.0024
Revascularization or amputation	369 (5.8)	5 (6.9)	136 (5.6)	.8608
Acute renal failure	18 (0.3)	1 (1.4)	3 (0.1)	.0613
Dialysis dependence[d]	82 (1.3)	2 (2.8)	14 (0.6)	.0069
Transient ischemic attack	441 (7.0)	8 (11.1)	158 (6.6)	.2860
Stroke				
Without disability	296 (4.7)	2 (2.8)	118 (4.9)	.6754
With disability	319 (5.0)	4 (5.6)	127 (5.3)	.9002
Transfer status				
Other hospital or facility	151 (2.4)	4 (5.6)	65 (2.7)	.1758
Admitted directly from home	6181 (97.6)	68 (94.4)	2349 (97.3)	
ASA class				
Normal, mild, severe (1-3)	5151 (81.4)	56 (77.8)	1854 (76.9)	<.0001
Life-threatening, moribund (4-5)	1178 (18.6)	16 (22.2)	557 (23.1)	
Estimated glomerular filtration rate[e]	68.7 ± 23.1	67.3 ± 28.4	68.5 ± 22.7	.8399

ASA, American Society of Anesthesiologists; *EVAR,* endovascular aneurysm repair; *PTCI,* percutaneous transluminal coronary intervention.
[a]Continuous values are expressed as mean ± standard deviation; categoric values are shown as number (%).
[b]*P* for association across all groups using χ^2 tests for categoric variables and simple linear regressions for continuous variables.
[c]Age ≥90 years set to 90 years.
[d]Dialysis indicated or creatinine >6.0 mg/dL.
[e]Set to 0 for preoperative dialysis.

and 0.8%. Demographic and risk factor data for these groups are summarized in Table I. Patients with acute surgical conversion of EVAR were a mean age of 73 years and 21% were women. The mean BMI was 26.9 kg/m^2. From a functional standpoint, 8% were partially or totally dependent. Significant differences were observed in patient age, sex, BMI, smoking status, diabetes, history of congestive heart failure, prior percutaneous transluminal coronary interventions, history of hypertension, dialysis-dependence, and American Association of Anesthesiologists class according to aneurysm repair type performed.

Procedural specifics. Procedural specifics are summarized in Table II. Mean operative time for acute surgical EVAR conversions was 274 minutes, and 69% of patients required blood transfusion with a mean volume of 6.0 units. Significant differences were observed with regard to surgeon speciality, resident involvement, need for transfusion, and operative time according to aneurysm repair type performed.

A listing of all other reported CPT codes was also examined. Of the 72 acute intraoperative surgical conversions, 8 (11%) included additional CPT codes indicating added complexity, including renal/visceral endarterectomy or reimplant, nephrectomy, iliac bypass, or lower extremity arterial embolectomy. No deaths were observed in these eight "added complexity" cases.

Morbidity, mortality, and LOS. Morbidity and mortality results are summarized in Table III. Unadjusted major morbidity rates of 12%, 28%, and 28% and mortality rates of 1.3%, 4.2%, and 3.2% were observed for elective EVAR, acute surgical conversion of EVAR, and open surgical infrarenal AAA repair, respectively. Morbidity and mortality were significantly higher for conversion and open repair vs EVAR, with OR for morbidity of 2.9 (95% CI, 1.7-4.8) for conversion and 2.8 (95% CI, 2.5-3.2) for open repair, vs EVAR ($P < .0001$ for each), and OR for mortality of 3.4 (95% CI, 1.0-10.9; $P = .0437$) for conversion and 2.5 (95% CI, 1.9-3.5; $P < .0001$) for open repair vs EVAR. Morbidity and mortality were similar between conversion and open repair. A similar pattern among repair groups was demonstrated for log-LOS, with similar LOS for conver-

Table II. Procedural specifics of abdominal aortic aneurysm repairs

Variable[a]	*Elective EVAR (n = 6332)*	*Immediate open conversion (n = 72)*	*Elective open repair (n = 2414)*	P[b]
Surgeon speciality[c]				
Vascular surgeon	6183 (97.7)	69 (95.8)	2335 (96.7)	.0407
Other	149 (2.4)	3 (4.2)	79 (3.3)	
Resident involved[d]	4063 (64.3)	49 (68.1)	1691 (70.3)	<.0001
Anesthesia type				
General	5099 (80.5)	71 (98.6)	2372 (98.3)	<.0001
Regional, local, other	1233 (19.5)	1 (1.4)	42 (1.7)	
Patients requiring transfusion[e]	777 (12.3)	50 (69.4)	1770 (73.3)	<.0001
Units transfused[f]	2.6 ± 2.5	6.0 ± 6.3	3.3 ± 3.3	<.0001
Operative time,[g] min	162.0 ± 74.3	274.3 ± 112.8	225.5 ± 92.8	<.0001

[a]Categoric variables are shown as number (%) and continuous variables as mean ± standard deviation.
[b]Value for association across all groups using logistic regression for categoric variables and linear regressions performed on ranks for continuous variables.
[c]Logistic regression modeling odds of other than vascular surgeon: conversion vs EVAR, $P = .3217$; open vs EVAR, $P = .0163$; and conversion vs open, $P = .6763$.
[d]Logistic regression modeling odds of resident involvement: conversion vs EVAR, $P = .5108$; open vs EVAR, $P < .0001$; and conversion vs open, $P = .6880$.
[e]Logistic regression modeling odds of requiring transfusion: conversion vs EVAR, $P < .0001$; open vs EVAR, $P < .0001$; and conversion vs EVAR, $P = .4647$.
[f]Rank analysis for units transfused (subgroup): conversion vs EVAR, open vs EVAR, and conversion vs EVAR, $P < .0001$ for each.
[g]Rank analysis for operative time: conversion vs EVAR and open vs EVAR, $P < .0001$; conversion vs open, $P = .0014$.

sions and open repair, which were significantly longer than those observed for EVAR.

Predictors of conversion. Univariate and multivariable analyses found no significant associations between acute surgical conversion and any demographic characteristics or medical risk factors ($P > .05$ for all examined variables). Variables examined included age, race, sex, BMI, weight, diabetes, smoking status, functional status, medical comorbidities (Table I), surgeon speciality, resident involvement, and eGFR.

DISCUSSION

This investigation demonstrated a low incidence of acute intraoperative surgical conversion during the conduct of elective EVARs detailed in a large multicenter surgical database. Acute surgical conversion complicated 1.1% of EVARs, and these conversions were associated with prolonged operative times and a higher transfusion volume among those patients who required a transfusion. Patients undergoing acute surgical conversion experienced more morbidity and a higher rate of mortality than patients undergoing successful EVAR. Surprisingly though, the observed morbidity and mortality associated with acute surgical conversion during EVAR was similar to that observed for elective open repair of infrarenal AAAs.

Concerns have existed since the inception of EVAR about the need for immediate intraoperative conversions to open repair. Conversions can be precipitated by issues such as arterial access problems, arterial rupture during device delivery or deployment, malfunctions in device deployment, inaccurate device deployment, or acute type I endoleaks that cannot be resolved. In early reports regarding the first commercially available EVAR devices in the United States, low rates of acute surgical conversion were reported. No acute surgical conversions were reported in the report by Zarins et al[8] detailing the pivotal multicenter experience leading to approval of the AneuRx device (Medtronic, Minneapolis, Minn).

However, Jacobowitz et al[9] reported 19 acute conversions in a series of 669 EVARs (3% incidence) using Endovascular Technologies (EVT, Menlo Park, Calif) devices. Significant perioperative morbidity was common in that series, with acute surgical conversion and an 11% mortality rate. These series and other predominantly single-center experiences early in the evolution of EVAR demonstrated that acute conversion was an uncommon occurrence but one that carried a significant attendant morbidity and mortality.[10,11] All of these studies, though, were limited in their abilities to characterize acute surgical conversion during EVAR due to limited numbers of observed events.

The issue of acute surgical conversion has also been examined in the context of large clinical trials and meta-analyses. Acute conversion data were reported in the two large European trials of EVAR compared with open surgical repair. In the reports detailing the 30-day results of the Dutch Randomised Endovascular Aneurysm Management (DREAM)[2,12] and Comparison of Endovascular Aneurysm Repair with Open Repair in Patients with Abdominal Aortic Aneurysm (EVAR)[3,13] trials, three and four acute conversions were reported during 175 and 516 attempted EVAR procedures, respectively. The outcome details for these acute conversions were not included in either report, but the reported data supported the notion that acute conversion was an uncommon event.

This issue was also evaluated in a recent meta-analysis by Moulakakis et al,[14] who examined early (<30 days) EVAR conversions. Their analysis demonstrated an aggregate 1.5% incidence of early conversion, with an average mortality rate of 12.4%, reinforcing the results detailed above.

Given these reports of high morbidity and mortality, considerable efforts have been made to predict patients at-risk

Table III. Outcomes after abdominal aortic aneurysm repair (*EVAR*)

Variable[a]	*Elective EVAR (n = 6332)*	*Immediate open conversion (n = 72)*	*Elective open repair (n = 2414)*
Morbidity (any type)[b]	754 (11.9)	20 (27.8)	667 (27.6)
Wound problems			
Superficial wound infection	104 (1.6)	1 (1.4)	45 (1.9)
Deep wound infection	35 (0.6)	1 (1.4)	16 (0.7)
Organ space wound infection	5 (0.1)	0 (0)	12 (0.5)
Wound dehiscence	17 (0.3)	0 (0)	34 (1.4)
Any superficial or deep wound infection	138 (2.2)	2 (2.8)	61 (2.5)
Pulmonary			
Pneumonia	90 (1.4)	7 (9.7)	208 (8.6)
Unplanned reintubation	109 (1.7)	4 (5.6)	170 (7.0)
Failure to wean from ventilator	100 (1.6)	7 (9.7)	251 (10.4)
Any pulmonary morbidity	201 (3.2)	12 (16.7)	377 (15.6)
Venous thromboembolic			
Deep venous thrombosis	43 (0.7)	2 (2.8)	33 (1.4)
Pulmonary embolism	10 (0.2)	1 (1.4)	13 (0.5)
Any venous thromboembolic morbidity	50 (0.8)	3 (4.2)	45 (1.9)
Genitourinary			
Acute renal insufficiency	42 (0.7)	0 (0)	62 (2.6)
Acute renal failure	63 (1.0)	2 (2.8)	76 (3.2)
Urinary tract infection	112 (1.8)	1 (1.4)	80 (3.3)
Any renal insufficiency or renal failure	97 (1.5)	2 (2.8)	124 (5.1)
Cardiovascular			
Stroke	29 (0.5)	2 (2.8)	23 (1.0)
Cardiac arrest	26 (0.4)	1 (1.4)	28 (1.2)
Myocardial infarction	17 (0.3)	0 (0)	25 (1.0)
Any cardiovascular morbidity	71 (1.1)	3 (4.2)	70 (2.9)
Operative			
Postoperative hemorrhage	41 (0.7)	2 (2.8)	71 (2.9)
Graft failure	67 (1.1)	2 (2.8)	20 (0.8)
Return to operating room	294 (4.6)	4 (5.6)	196 (8.1)
Any operative morbidity	331 (5.2)	5 (6.9)	230 (9.5)
Septic			
Sepsis	69 (1.1)	2 (2.8)	118 (4.9)
Septic shock	68 (1.1)	4 (5.6)	140 (5.8)
Any septic morbidity	131 (2.1)	6 (8.3)	241 (10.0)
Mortality[c]	81 (1.3)	3 (4.2)	77 (3.2)
Postoperative length of stay[d]	2 (1, 3)	7 (5, 9)	7 (5, 9)

[a]Variables are shown as number (%) and median (quartile 1, quartile 3).
[b]Logistic regression modeling odds of any morbidity showed significant differences across the three groups ($P < .0001$). Odds ratio (95% confidence interval) are 2.85 (1.69-4.79), $P < .0001$, for conversion vs EVAR; 2.82 (2.51-3.18), $P < .0001$, for open vs EVAR; and 1.01 (0.60-1.70), $P = .9780$, for conversion vs open.
[c]Logistic regression modeling odds of mortality showed significant differences across the 3 groups ($P < .0001$). Odds ratio (95% confidence interval) are 3.36 (1.03-10.88), $P = .0437$, for conversion vs EVAR; 2.54 (1.85-3.49), $P < .0001$, for open vs EVAR; and 1.32 (0.41-4.29), $P = .6445$, for conversion vs open.
[d]Linear regression of log-length of stay differences across the three groups ($P < .0001$), back-transformed ratios (95% confidence interval) are 2.75 (2.37-3.19), $P < .0001$, for conversion vs EVAR; 2.99 (2.90-3.08), $P < .0001$, for open vs EVAR; and 0.92 (0.79-1.07), $P = .2753$, for conversion vs open.

for these acute intraoperative conversions. Unfortunately—or fortunately, depending upon one's perspective—predictors of acute conversion have been difficult to examine because of the relative rarity of the problem. The large European Collaborators on Stent-Graft Techniques for Aortic Aneurysm Repair (EUROSTAR) registry has been used to try to examine this issue.

Cuypers et al[15] detailed the experience with early (<30 days) and delayed conversions in 1871 patients. An early conversion rate of slightly >2% was observed, and the predictors of conversion included increased age, lower body weight, presence of chronic obstructive pulmonary disease, shorter aneurysm necks, and larger aneurysm diameters. Their analysis also suggested that increased operating team experience and performance later in the evolution of EVAR (ie, further along the general learning curve for physicians performing EVAR) were associated with a lower likelihood of acute conversion. These data from EUROSTAR and the details of the previously referenced reports detailing that access-related issues are a major cause of acute conversions have provided significant insights to the problem of acute conversion and its avoidance.

The data reported here support the referenced findings that acute surgical conversions during elective EVAR are rare but do not support the previously reported high incidences of morbidity and mortality. In this report detailing contemporary surgical practice and outcomes in 211 North

American hospitals, a 1.1% incidence of acute EVAR conversion was observed. However, the observed morbidity and mortality rates were much more modest and very similar to the results observed for the elective infrarenal open surgical aneurysm repairs that were examined for comparison purposes. Explanations for these observations include the timing of the sample (2005 to 2008) representing a mature period in the history of EVAR, with large numbers of EVAR-experienced surgeons, derivation of the study sample from a quality improvement database likely including a disproportionate number of high-volume and high-quality institutions, and a growing understanding of the problem patterns that lead to acute conversion and the mechanisms for salvage detailed in the referenced literature.

Extending this latter explanation, it is possible that North American surgeons have greatly enhanced their understanding of situations that may precipitate conversion or have developed a much better understanding of when acute conversion is necessary, or both, which has led to more rapid decision making in these situations, thus avoiding an escalation of morbidity. It is also possible that the collective skill set among all involved—including anesthesiologists—and understanding of the necessary techniques for salvaging these acute conversions has improved in step with the cognitive gains described and that these factors together have contributed to the improvements in morbidity and mortality relative to the reports from earlier eras in the history of EVAR.

These excellent results would suggest that the prevailing patterns of EVAR performance involving vascular surgeons as the primary provider with the nearly universal involvement of an anesthesiologist, as evidenced by the high prevalence of general and regional anesthesia, are effective and merit continuation. Nonetheless, these data should be investigated in other available data sources and an investigation of this issue using the Nationwide Inpatient Sample is underway within our group.

The data reported here, do not, however, support the previously referenced findings of the influence of age and body weight on the risk of acute conversion. No significant association was observed for age, sex, body weight, BMI, or any other anthropometric data or medical conditions and the subsequent occurrence of acute surgical conversion. Furthermore, the presented data suggest a fairly comparable patient population without major clinically significant differences among those undergoing the three repair types, suggesting that overall patient-risk status was not a factor in predicting acute surgical conversion or in leading surgeons to avoid conversion when required.

This lack of any observed association in a large sample of acute surgical conversions examined in the context of >6000 EVAR procedures strongly suggests that in the era of experienced endovascular surgeons and second- and third-generation EVAR devices, no easily identifiable high-risk populations exist. Rather, these data suggest that factors not defined in this data set, such as anatomic features of the patient or the aneurysm, or both, are likely more important in defining those at highest risk.

This report represents an analysis of data collected from a large, prospectively generated, nonselected and nonrandom sample. The design of this database, and other factors specific to this analysis, create significant limitations that merit comment: First, the ACS-NSQIP database was not designed to critically evaluate the technical aspects of EVAR or the details of acute surgical EVAR conversions. Data for surgeon experience and volume, institution volume, intensity of resident/fellow supervision, acute indication for conversion, device type and sizing, aneurysm anatomy, access limitations, delayed surgical conversion, and hospital readmission are not encoded and are, therefore, lacking for analysis. Specifically, the reporting of the CPT code for an acute surgical conversion overrides and eliminates the codes for the attempted EVAR procedure, the access techniques used, and the specific arterial repairs that were needed. This precluded any meaningful analysis of access issues or device configurations in the study. Enhanced data collection in future iterations of the ACS-NSQIP would be extremely beneficial and enlightening in future analyses of this problem.

Furthermore, the ACS-NSQIP data set represents contemporary clinical practice at 211 hospitals, and there is no means for control to mitigate the effects of institutional practice pattern peculiarities and bias in the application of EVAR. Data are also not available within ACS-NSQIP with regard to institution type, surgeon volume, surgical team volume, or hospital volume, precluding analysis of these important variables and their effects on the occurrence of the complication in question. These weaknesses are major but not remediable within the framework of the available data. These limitations notwithstanding, to our knowledge, these data represent the largest collection of acute surgical EVAR conversions and provide important information regarding the expected incidence and results of such conversions.

CONCLUSIONS

Acute surgical conversion remains an uncommon complication of EVAR and cannot predicted by patient demographics, anthropometrics, or medical comorbidities. When acute conversion occurs, though, outcomes are similar to those for the performance of elective open surgical aneurysm repair—with the exception of higher transfusion volumes and operative duration—potentially representing a maturation of the cognitive and technical skill sets of surgeons who perform EVAR and their preparedness to deal with problems necessitating an acute surgical conversion. Given the excellent results observed for these acute surgical conversions, we believe that a lower threshold for conversion should be considered in cases where technical difficulties threatening the safety of the patient are encountered.

AUTHOR CONTRIBUTIONS

Conception and design: WN, JA, KH, MC, PG, ME
Analysis and interpretation: WN, JA, KH, MC, PG, ME, MS

Data collection: WN, JA, ME, MS
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Critical revision of the article: WN, KH, MC, PG, ME, MS
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REFERENCES

1. Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. Ann Vasc Surg 1991;5:491-9.
2. Prinssen M, Verhoeven ELG, Buth J, Cuypers PWM, van Sambeek MRHM, Balm R, et al. A randomized trial comparing conventional and endovascular repair of abdominal aortic aneurysms. N Engl J Med 2004;351:1607-18.
3. Greenhalgh RM, Brown LC, Kwong GP, Powell JT, Thompson SG; EVAR trial participants. Comparison of endovascular aneurysm repair with open repair in patients with abdominal aortic aneurysm (EVAR trial 1), 30-day operative mortality results: randomised controlled trial. Lancet 2004;364:843-8.
4. Crawford RS, Cambria RP, Abularrage CJ, Conrad MF, Lancaster RT, Watkins MT, et al. Preoperative functional status predicts perioperative outcomes after infrainguinal bypass surgery. J Vasc Surg 2010;51:351-9.
5. Hua HT, Cambria RP, Chuang SK, Stoner MC, Kwolek CJ, Rowell KS, et al. Early outcomes of endovascular versus open abdominal aortic aneurysm repair in the National Surgical Quality Improvement Program-Private Sector (NSQIP-PS). J Vasc Surg 2005;41:382-9.
6. LaMuraglia GM, Conrad MF, Chung T, Hutter M, Watkins MT, Cambria RP. Significant perioperative morbidity accompanies contemporary infrainguinal bypass surgery: an NSQIP report. J Vasc Surg 2009;50:299-304.
7. Levey AS, Coresh J, Greene T, Stevens LA, Zhang YP, Hendriksen S, et al. Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. Ann Intern Med 2006;145:247-54.
8. Zarins CK, White RA, Schwarten DE, Kinney EV, Diethrich EB, Hodgson KJ, et al. Endovascular versus open AAA repair: AneuRx stent-graft multicenter clinical trial. J Endovasc Surg 1999;6:122-3.
9. Jacobowitz GR, Lee AM, Riles TS. Immediate and late explantation of endovascular aortic grafts: the Endovascular Technologies experience. J Vasc Surg 1999;29:309-16.
10. Jimenez JC, Moore WS, Quinones-Baldrich WJ. Acute and chronic open conversion after endovascular aortic aneurysm repair: a 14-year review. J Vasc Surg 2007;46:642-7.
11. May J, White GH, Yu W, Waugh R, Stephen M, Sieunarine K. Conversion from endoluminal to open repair of abdominal aortic aneurysms: a hazardous procedure. Eur J Vasc Endovasc Surg 1997;14:4-11.
12. Prinssen M, Buskens E, Blankensteijn JD. The Dutch Randomised Endovascular Aneurysm Management (DREAM) trial − background, design and methods. J Cadiovsc Surg 2002;43:379-84.
13. Greenhalgh RM, Brown LC, Epstein D, Kwong GPS, Powell JT, Sculpher MJ, et al. Endovascular aneurysm repair versus open repair in patients with abdominal aortic aneurysm (EVAR trial 1): randomised controlled trial. Lancet 2005;365:2179-86.
14. Moulakakis KG, Dalainas I, Mylonas S, Giannakopoulos TG, Avgerinos ED, Liapis CD, et al. Conversion to open repair after endografting for abdominal aortic aneurysm: a review of causes, incidence, results, and surgical techniques of reconstruction. J Endovasc Ther 2010;17:694-702.
15. Cuypers PWM, Laheij RJF, Buth J. Which factors increase the risk of conversion to open surgery following endovascular abdominal aortic aneurysm repair? Eur J Vasc Endovasc Surg 2000;20:183-9.

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DISCUSSION

Dr Murray L. Shames (*Tampa, Fla*). I would like to thank Dr Newton and his fellow authors on an excellent presentation and for their timely submission of a well-written manuscript.

This report confirms what others have published in International registries and in Pivotal graft trials that acute surgical conversion rates during EVAR are very low. The data, however, are more optimistic with regard to the associated morbidity and mortality associated with acute conversion. Other than an increase in operative time and an increase in blood transfusion requirements in the acute conversion group, outcomes between elective open repair and acute conversions were equivalent.

Based on logistic regression analysis, the authors could not identify any pre-existing condition or operative detail that predicted an increase in the risk for conversion. They do mention in the discussion that based on the shortcomings of the NSQIP database, that information on anatomic factors, surgeon experience, device type and reason for conversion were not available for analysis.

In my experience, vessel rupture during EVAR is extremely rare, and with advancements in graft technology, hydrophilic sheaths, and lower profile devices there are not many patients that, if selected properly, you cannot deliver a graft. In the study, you excluded all cases that were coded as a ruptured AAA. Do you think the nature of the NSQIP database may have excluded those patients that were intraoperative ruptures and thus be biased toward more elective type conversions?

A primary reason for conversion to open repair is a persistent type I endoleak. However, this may be managed in a delayed fashion with a proximal cuff' or Palmaz stent. Did you look at the incidence of secondary procedures during the initial hospital stay or within 30 days in the EVAR group?

My final question is how should we use this knowledge in our practices; would you advise that we alter our patient selection criteria for EVAR?

I would like to thank the society for the privilege of discussing this paper.

Dr William B. Newton III. Dr Shames, thank you for your questions. To address your question regarding ruptures in the NSQIP database and their exclusion, we did exclude those and our feeling was that these coded ruptures represented patients who presented as ruptured aneurysms, not ruptures that occurred during their procedure. However, that is not definitive and depends upon research nurse coding.

With regard to secondary interventions, unfortunately one of the main limitations of the NSQIP database is that it doesn't allow for tracking of secondary interventions. There are improvements that have been proposed to the NSQIP database that hopefully will allow such tracking of secondary interventions in the future.

With regard to changes in practices resulting from our paper, we feel that these data suggest that a lower threshold for conversion should be considered during complicated endovascular aneurysm repairs in which difficulties are encountered.