Outcomes of Anterior Exposure for Spinal Surgery at an Independent Academic Medical Center

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ABSTRACT

Introduction: Anterior exposure for spinal surgery has expanded and is used for common spinal procedures, including anterior lumbar interbody fusion, disc replacement, and vertebral corpectomy. With this approach, vascular injuries have been reported ranging from 1% to 25%. The impact of resident participation on intraoperative and postoperative outcomes within an independent academic medical center has not been widely reported. The objective of this study was to determine the incidence of complications during anterior exposure spinal surgery at an independent academic medical center.

Methods: After institutional review board approval, we conducted a retrospective review of medical records of patients who underwent elective anterior exposure for spinal surgery from 2000 through 2014.

Results: The study included 335 patients; 60.3% were female. Thirty-day postoperative complications included surgical site infection (4.2%), urinary tract infection (2.7%), need for blood transfusion (2.1%), retrograde ejaculation (1.2%), and deep vein thrombosis (0.9%). There were 12 vascular injuries overall (3.6%); 2.7% were major vascular injuries. Surgery residents participated in 34% of cases. Resident involvement increased over the course of the study. There was no difference in operative time or complications with resident involvement.

Conclusions: The overall incidence of major vascular injury was 2.7%. Levels of exposure and blood loss were associated with vascular injury. Overall postoperative complication rates as well as major vascular injury rates compared favorably to published benchmarks. Complication rates were unaffected by surgical resident involvement.

INTRODUCTION

Approximately 31 million people in the United States experience low back pain, and 31% to 80% of the world's population experiences a back problem during their lifetime.[1-3] Surgical indications for back pain include degenerative disc disease, radiculopathy, spinal instability, and spondylolisthesis. Recently, anterior exposure of the lumbar spine for orthopedic and neurosurgical procedures have increased in popularity. Benefits to this approach include direct access to the interbody space with improved fusion rates.[4,5] This technique can be used as spinal access for disc replacement, anterior lumbar interbody fusion (ALIF), or a combination.[6] The anterior approach requires dissection and mobilization of peritoneal contents followed by vascular mobilization to provide exposure of the anterior surface of the spinal column. A review of methods and complications of anterior spine exposure identified that comprehensive technical descriptions of these procedures are present in spine surgical textbooks, but not in general or vascular surgical texts.[7] In addition, general surgery resident training for these exposures is not well described. Despite this, general and vascular surgeons frequently are relied upon for these exposures.

Previous studies have documented rates of vascular injuries, wound infection, venous thromboembolism (VTE), lymphedema, and ileus. Most carefully studied have been vascular injuries, ranging from <1% to 25%.[4,5,8-11] These injuries may occur during actual exposure or during the neurosurgical portion of the procedure. Various risk factors for vascular injury have been identified, including obesity, L4-L5 disc space exposure, multilevel exposure, and repeat anterior spine exposure. As medicine grows ever more transparent, patients are interested in knowing institutional, as well as individual surgeon outcomes for procedures. In addition, patients want reassur-

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ance that allowing residents to assist in their care has no additional risk.

The objectives of this study were to examine our experience with anterior spine exposure in an independent academic medical center with a general surgical residency program, specifically to (1) evaluate procedural outcomes, including perioperative complications, (2) delineate the incidence, characteristics, and risk factors of vascular complications, and (3) evaluate the effect of resident participation on perioperative complications and patient outcomes.

METHODS

Our organization is an integrated multispecialty health system with a 325-bed independent academic medical center serving 19 counties in a 3-state region. The accredited general surgery residency program graduates 3 categorical residents per year.

Following Institutional Review Board approval, our electronic medical record system was queried by procedure code to identify all patients who underwent anterior spine exposure from January 2000 through June 2014. Exclusion criteria included pediatric patients (<16 years old) and surgical indications of infection, malignancy, or trauma. We completed a retrospective review of the medical records of patients who met inclusion criteria. Variables included patient demographics and preoperative comorbidities as noted on the preoperative history and physical exam; operative data including operative time, operative room staff, procedure performed, estimated blood loss, and intraoperative complications; and 30-day postoperative morbidity and mortality as documented in the operative notes, discharge summary, and outpatient follow-up notes. The occurrence of hernias was reviewed for the entire duration of follow-up data available for each patient. Surgical site infections were noted if they met Centers for Disease Control and Prevention criteria[12] and if the patient received treatment. Vascular injuries were classified as major or minor based on operative records. Major injuries were defined as injuries to the aorta, inferior vena cava, common iliac vessels, internal or external iliac vessels. Injury to any vessel resulting in ≥250 cc of blood loss also was considered a major vascular injury. Minor injuries were defined as injuries to the lumbar vessels, nutrient vertebral body vessels, or median sacral vessels resulting in <250 cc blood loss.

All patients undergoing elective surgery were evaluated by a neurosurgeon, followed by an exposing surgical team consisting of a general or vascular surgeon and surgical resident to determine surgical candidacy. Preoperative antibiotics consisted of weight-based first generation cephalosporins administered within 1 hour prior to the skin incision. Initially, a patient body mass index (BMI) <30 kg/m2 was required for surgical candidates; as surgeon comfort and experience increased, a BMI ≥30 kg/m2 was no longer considered a contraindication. Previous extensive retroperitoneal surgery (excluding previous anterior spinal exposure) or retroperitoneal external beam radiation were considered con-

traindications to this approach. Significant vascular calcifications in the distal aorta, or common iliacs, defined as ≥50% circumferential calcifications on preoperative imaging, also was a contraindication.

Operative Technique

A 2-team approach was utilized in all cases. General or vascular surgeons provided the desired exposure and wound closure; spine procedures were performed by neurosurgeons. The patient was placed in lithotomy position. Fluoroscopy confirmed vertebral level and incision planning. For single-level approaches, a transverse incision was used. For multilevel exposure, a paramedian incision was used. For exposures of L4-L5 level and above, exposure was obtained from the left side. A preoperative vascular exam was performed and intraoperative pulse oximetry monitored perfusion of the left lower extremity. The anterior rectus sheath was opened transversely and the muscle mobilized laterally. The retroperitoneal space was entered and peritoneal contents were mobilized medially. Iliolumbar vessels were divided 1 level above and below the desire disc space(s). The iliac vessels were then mobilized off the anterior surface of the spine. A fixed retractor system was placed and care transitioned to the neurosurgical team. Closure was performed by allowing the vasculature and peritoneal contents to return to normal anatomic position. The rectus muscle was then approximated to the midline to prevent diastasis. The anterior fascia followed by skin was closed with absorbable suture. At case completion, patients were transferred to the postanesthesia care unit and then to the neurosurgery unit with frequent neurological and vascular exams of the lower extremities at the following intervals: admission, 1 hour, every 2 hours for a total of 4 hours, every 4 hours for a total of 8 hours, then every 8 hours thereafter. Symptom-based evaluations and neurovascular exams also were performed.

During our early experience, exposure of the L5-S1 disc space was obtained in a similar fashion from the left side. Once the peritoneum was mobilized, the L5-S1 disc space was exposed between the iliac vessels requiring double ligation of the median sacral vessels. Beginning in 2011, access for L5-S1 was transitioned to the right side to preserve the left side for subsequent anterior approaches if required.

For multilevel exposures, the inferior most disc space was exposed first. Following completion of the neurosurgical portion of the inferior level, the fixed retractor was replaced to expose the upper level. In all cases, the general or vascular surgeon was available immediately during the neurosurgical portion.

During exposure and closure, categorical surgical residents at all postgraduate years (PGY) participated when available and, when unavailable, a second general or vascular surgeon was present. In preparation for these cases, surgical residents participated in annual cadaver simulation laboratories focused on retroperitoneal and abdominal wall exposures. In general, junior residents

(PGY 1-3) were required to observe 5 cases prior to acting as a surgical assistant. Once they had acted as a first assistant for 5 cases, they acted as primary surgeon with the attending surgeon assisting them with the procedure. Senior residents (PGY 4-5) typically had performed 5 observations and 5 first assistant roles prior to acting as primary surgeon. In all cases, a general or vascular surgeon was scrubbed in with the resident. This provided direct supervision of the residents through all steps of the case. No additional trainees (neurosurgery, orthopedic surgery, or vascular residents/fellows) were present at our institution to participate in these cases.

Statistical analysis included chi-square and Wilcoxon rank sum tests using SAS version 9.3 (Cary, NC). A *P* value <0.05 was considered significant.

RESULTS

Preoperative Characteristics

During the study period, 415 patients underwent anterior spine exposure; 335 patients met inclusion criteria. Previous surgeries included posterior spine surgery, lower abdominal surgery, and anterior exposure spine surgery (Table 1).

Operative Data

Sixty-six percent of cases had 2 attending general or vascular surgeons providing exposure and closure; 34% had a resident present with an attending general or vascular surgeon. Median operative time was 210.0 minutes (Table 2), and was similar among cases with versus without resident involvement (Table 3). Of participating residents, 9% were PGY 1, 27% were PGY 2, 20% were PGY 3, 21% were PGY 4, and 23% were PGY 5. Most patients (80%) underwent single-level procedures. Two hundred thirty-three (70%) patients underwent ALIF, 74 (22%) arthroplasty, and 28 (8%) a combination of the two or another procedure. In 7 patients (2.1%), safe exposure was unable to be obtained and the procedure was abandoned. Reasons for failed anterior approach included failure to obtain retroperitoneal access (n=2) and failure to expose disc space due to patient anatomy (n=5). Fifty-two (15%) patients had a concomitant posterior surgery. These operations included completion of posterior instrumentation (n=47) and posterior fusion (n=5). Almost half of patients had surgery at the L5-S1 disc space (Table 2).

Postoperative Outcomes

Intraoperative and 30-day postoperative mortality was nil. The most frequent complication was surgical site infection (Figure). Three patients experienced both an early (<30 day) complication, and a late incisional hernia over the follow-up period. There were no postoperative pulmonary emboli, abscesses, or ureteral injuries. When comparing cases with resident participation to those performed by attending surgeons only, there was no significant increase in complication rates for vascular injury, surgical site infection, urinary tract infection, nerve injury, retrograde ejacula-

tion, deep vein thrombosis (DVT), or ileus (Table 3). Resident participation did not significantly increase mean operative times, length of stay, or overall complication rates (8% vs 14%, *P*=0.793) compared to cases involving attending surgeons only (Table 3). When divided into quartiles by date of surgery, only 25% of cases had resident participation in the first quartile, increasing to 34%

Table 1. Preoperative Characteristics

Demographics	N (%)
Sex	
Male	133 (39.7)
Female	202 (60.3)
Age (years) mean ± SD	45.3 ± 12.2
Body mass index (kg/m2)	
< 30	228 (68.1)
30.0-34.9	83 (24.8)
35.0-39.9	22 (6.6)
≥ 40.0	2 (0.6)
Tobacco	
Current	94 (28.1)
Former	105 (31.3)
Never	136 (40.6)
Comorbidities, n (%)	
Hypertension	64 (19.1)
Type 2 diabetes mellitus	17 (5.1)
Chronic kidney disease	3 (0.9)
Peripheral vascular disease	3 (0.9)
Coronary artery disease	3 (0.9)
History of DVT/PE	3 (0.9)
Significant vascular calcifications	4 (1.2)
Past surgical history	
Anterior spine surgery	3 (0.9)
Posterior spine surgery	131 (39.1)
Lower abdominal surgery	97 (28.9)

Abbreviations: DVT, deep vein thrombosis, PE, pulmonary embolism.

Table 2. Operative Data and Lumbar Disc Space Exposed

Variable	Value
American Society of Anesthesiologists class, n (%)	
I	68 (20.3)
II	225 (67.2)
III	42 (12.5)
Operative time, minutes; median (range)[a]	210 (52–686)
Estimated blood loss, cc; median (range)[b]	100 (0–1800)
Resident present, n (%)	114 (34.0)
Single-level exposure	269 (80.3)
Multilevel exposure	66 (19.7)
Levels exposed, n (%)	
L2-L3	3 (0.9)
L3-L4	12 (3.6)
L4-L5	94 (28.1)
L5-L6	2 (0.6)
L5-S1	158 (47.2)
L4-L5 and L5-S1	56 (16.7)
All other multilevel	10 (3.0)

[a]Operative times were missing for 2 patients.
[b]Estimated blood loss was missing for 68 patients.

Table 3. Patient Outcomes Based on Resident Involvement in Spinal Surgery

Variable	Resident Present N = 115	No Resident N = 220	P value
Mean operative time, minutes	227 ± 82	220 ± 86	0.349
Mean length of stay, days	2.9 ± 2.7	2.9 ± 2.2	0.917
Complication, n (%)			
Vascular injury	5 (4.3)	7 (3.2)	0.554
Surgical site infection	5 (4.3)	14 (6.4)	0.449
Urinary tract infection	3 (2.6)	6 (2.7)	0.999
Nerve injury	0	2 (0.91)	0.548
Deep vein thrombosis/pulmonary embolism	0	3 (1.4)	0.554
Retrograde ejaculation	3 (2.6)	1 (0.5)	0.119

Table 4. Patient Characteristics and Associations With Vascular Injuries

Variable	No Vascular Injury N = 323	Vascular Injury N = 12	P value
Body mass index, kg/m^2; mean ± SD	27.5 ± 4.5	28.4 ± 4.6	0.649
Age, years; mean ± SD	44.3 ± 12.2	44.5 ± 11.2	0.635
Vascular calcification, n (%)	4 (1.2)	0	0.999
Past surgical history, n (%)			
Posterior spine surgery	123 (38.1)	7 (58.3)	0.227
Anterior spine surgery	2 (0.6)	0	0.999
Abdominal surgery	91 (28.2)	5 (41.7)	0.336
Retroperitoneal surgery	1 (0.3)	0	0.999
Number of attending surgeons, n (%)			0.226
1	106 (32.8)	6 (50.0)	
2	217 (67.2)	6 (50.0)	
Resident present, n (%)	110 (34.1)	5 (41.7)	0.554
Operative time, minutes; median (range)	209.0 (52.0-686.0)	219.5 (90.0-368.0)	0.876
Length of stay, days; median (range)	2.5 (1.0-29.0)	3.0 (1.5-14.0)	0.184
Estimated blood loss, cc; median (range)	100.0 (0-1500)	250.0 (75-1800)	0.002
Number of levels exposed, n (%)			0.022
1	263 (81.4)	6 (50.0)	
2	56 (17.4)	6 (50.0)	
3	4 (1.2)	0	
Specific level exposed, n (%)			0.049
L5-S1	156 (48.3)	2 (16.7)	
L4-L5	90 (27.9)	4 (33.3)	
L4-L5 and L5-S1	51 (15.8)	5 (41.7)	
Other	26 (8.1)	1 (8.3)	

in both the second and third quartiles, to 52% of cases with resident involvement in the last quartile. No difference was noted in complication rates over time despite changes in surgical approach.

Overall, the mean length of stay was 3.0±2.4 days. Seven patients underwent additional anterior or posterior surgery during their hospital stay; four were planned. Indications for additional surgeries performed via a posterior approach included foraminotomy (n=1), open debridement of wound (n=1), posterior fusion (n=2), and vertebroplasty (n=1). Indications for a second anterior procedure were increased stabilization (n=1) and fascial dehiscence (n=1).

Mean follow-up duration was 5.0±3.6 years. Readmission within 30 days of discharge occurred in 18 patients (5.4%). Reason for readmissions included other planned interventions (n=4), pain control (n=4), hematoma/seroma (n=3), surgical site infection/dehiscence (n=3), lower leg swelling (n=2; one with a documented DVT and the other without evidence of DVT), and other (n=2).

Vascular Injuries

There were 12 vascular injuries, for an overall rate of 3.6%. Of these, 9 were major (2.7%) and 3 (0.9%) were minor. The majority of vascular injuries were to the left common iliac vein (n=7; 58.3%). The remaining injuries were at the junction of venous branches with iliac veins, as well as a single minor injury to a lumbar artery. The majority of injuries were treated with clips to control bleeding (n=8; 66.7%). Only 2 injuries required suture repair, and 2 minor injuries were controlled with pressure and packed with thrombin. Among the 12 patients with a vascular injury, failure of case completion occurred in one patient due to failure to expose disc space due to patient habitus/vasculature. One patient with a vascular injury required admission on postoperative day 21 due to a symptomatic VTE involving the left iliac vein and subsequently underwent percutaneous thrombolysis/thrombectomy.

When comparing patients with a vascular injury versus those without, there were no associations between BMI, age, previous surgery, or vascular calcification (Table 4). Estimated blood loss was greater in patients with vascular injury. Number of attending surgeons, resident involvement, operative time, and length of stay were not associated with vascular injury (Table 4). Patients with 2-level exposures were more likely to have a vascular injury than those with only 1 level of exposure. No patient with a 3-level exposure sustained an injury. Exposure of L4-L5 alone or combination with other levels resulted in an injury rate higher than all other exposures (Table 4).

DISCUSSION

Anterior exposure for spinal surgery, which included general surgery resident participation, was associated with a high immediate

success rate (97.9%) and low complication rates at our community teaching hospital. These outcomes compare favorably to benchmarks. Although resident participation has been studied in various neurosurgical procedures, our study is unique in that it focused solely on anterior exposures and the distinct set of complications that can occur with this approach within an independent academic community medical center. The unique aspects within our organization and this study include (1) immediate availability and presence of faculty and resident surgeons for the duration of the case, as opposed to only being present during exposure and closure; (2) resident participation included only categorical PGY 1-5 general surgery residents, as no neurosurgery,

Figure. Postoperative Complications

Incisional hernias included any occurence throughout the follow-up period. All other complications were limited to 30 days postoperative.

orthopedic surgery residency programs exist at our teaching institution. These exposures provide excellent opportunities for teaching without significantly increasing operative time or complication rates. Given that nationally the majority of anterior spine exposures are provided by general or vascular surgeons, this is an important component of training.

As surgical training and surgical needs in the United States evolve, general surgeons are increasingly seeking fellowship training, and minimally invasive surgical techniques including laparoscopy and robotic surgery are increasingly common. Similarly, many vascular surgical procedures previously performed in an open fashion are transitioning to endovascular techniques. Anterior spine exposures provide residents with open surgical experience, including open vascular experience with arterial and venous dissection, vascular mobilization, and injury management. The multiple benefits of open vascular surgical experience have been supported in vascular surgical/fellowship training.[13] These skills also translate well to the management of trauma patients. Urban or metropolitan general surgeons as well as fellowship-trained general surgeons can benefit from experience with anterior spine exposure.

The results of our study were similar to those reported in a systematic review of the literature.[5] Wood and associates reported a vascular injury rate of <5% in anterior lumbosacral surgery. Adverse effects of vascular injury were infrequent, but included thrombosis, pulmonary embolism, and prolonged hospital stay. Others have identified more significant morbidity following vascular injuries, with some requiring reoperation to control bleeding, fasciotomies for compartment syndrome, or revascularizing an extremity with stent placement or bypass surgery.[5,9-11] In our series,

the vascular injury rate was 3.6%. Major vascular injuries occurred in 2.7% and resulted in little morbidity and no additional surgeries. While patients who experienced a vascular injury had a slightly longer length of stay, the difference was not significant.

Multilevel exposures at L4–L5 and L5-S1 have been associated with increased rates of vascular injury, often due to the need for mobilization of the left common iliac vessels.[5,8-11,13] Consequently, the left common iliac vein is a common site of injury.[4,11,14] Our experience was similar as we observed a greater rate of vascular injury among patients with combined L4-L5 and L5-S1 exposure, and those with exposure of L4-L5 alone. The left common iliac vein injury was most frequently injured (58.3%). BMI was not associated with vascular injury; the maximum BMI was 43.7kg/m².

Overall, postoperative complications included low rates of surgical site infection, urinary tract infection, blood transfusion, retrograde ejaculation, and DVT. The most frequent complication encountered was surgical site infection in 4.2% of cases. This was similar to the literature, in which SSI rates up to 4.8% have been reported.[11] The rates of urinary tract infection and blood transfusion in our series were 2.7% and 2.1% respectively, which are slightly higher than other reports of anterior spine exposure, with urinary tract infections reported in 0.6% of patients and blood transfusions in 1.5% to 1.9%.[8,10] Retrograde ejaculation has been reported in 0.9% to 6.3% of cases[15-17] and occurred in 1.2% of our patients. VTE has been reported from 0% to 2.0%[18] and occurred in 0.9% of our patients. In a review of the literature, Ikard reported a 0.7% mortality rate after anterior exposure of the thoracic and lumber spine.[7] Perioperative mortality was nil in our series.
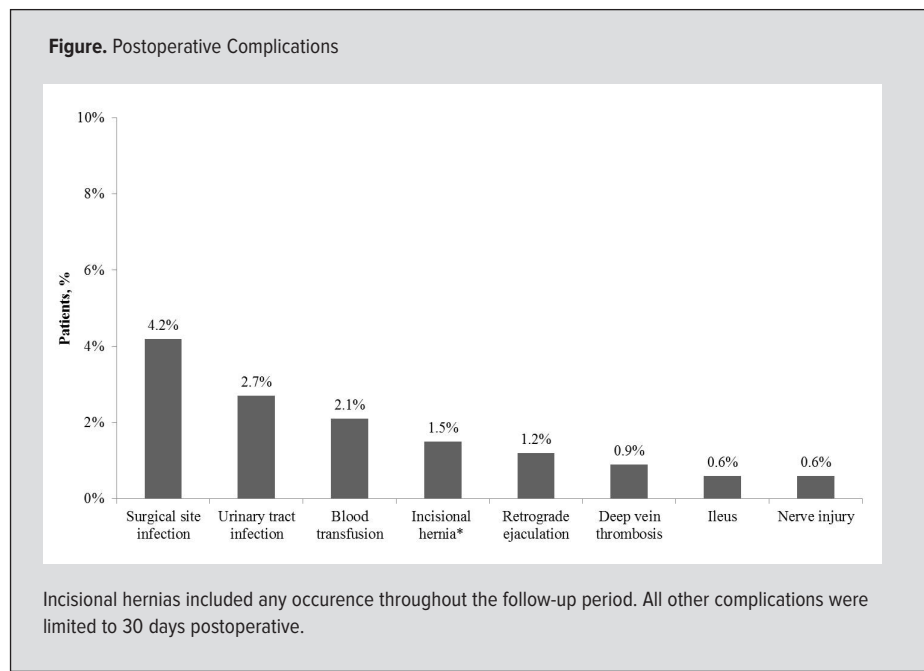
Recent studies have suggested that increased complication rates occur with resident involvement in emergency general surgery procedures and in spinal arthrodesis procedures.[19,20] Schoenfeld and colleagues analyzed data from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) concerning patients who underwent spinal arthrodesis from 2005 to 2010.[20] Residents were involved in 33% of cases. Using a multivariate model, they found that resident involvement was associated with increased risk of surgical site infection (OR 1.04 [1.02-1.06, 95% CI]; $P<0.001$) and thromboembolic disease (OR 1.9 [1.2-3.1, 95% CI]; $P=0.006$). In contrast, Bydon et al and Lim et al also independently analyzed NSQIP data for neurosurgical cases from 2006 to 2012 and 2011, respectively.[21,22] The proportion of resident participation observed in those studies was 49% and 52% of cases, respectively. Both Bydon et al and Lim et al found a higher overall complication rate among cases with resident participation (18.8% vs 11.2%, $P<0.001$; and 20.12% vs 11.7%, $P<0.001$, respectively). However, after controlling for potential confounding factors (case volume, age, sex, BMI, tobacco use, wound class, American Society of Anesthesiologists class, medical comorbidities, steroid use, operative time, surgical history), resident participation was not an independent risk factor for increased complications.[21,22] Lim et al found residents were more likely to be involved in more complex neurosurgery cases with longer operative times.[22] Although they observed higher rates of surgical site infection and VTE in cases with resident participation, these differences were not significant in a multivariate analysis.

Our series identified no difference in the frequency of vascular injury, surgical site infection, urinary tract infection, blood transfusion, retrograde ejaculation, VTE, ileus, or nerve injury with trainee involvement. By excluding cases of infection, malignancy, or trauma from our series, we were able to compare a homogenous neurosurgical patient population. The immediate availability of attending surgeons during the neurosurgical portion of the procedure and the elective nature of these procedures may contribute to the positive perioperative outcomes.

As institutional experience and surgeon comfort with these procedures increased, restrictions decreased—specifically surgery was offered to patients with BMI>30kg/m^{2} and those who had previous lower abdominal surgeries. In addition to this change, operative approach to L5-S1 also was modified, but resulted in no difference in complications. Finally, resident involvement increased over time, which also resulted in no significant changes in outcomes.

At our independent academic medical center, we have a long-standing history of training general surgeons who choose to practice in rural settings. Our graduates have a broad scope of practice, including many general surgical, urologic, and gynecologic procedures.[23,24] Anterior spine exposure requires dissection and mobilization of the abdominal wall, which is applicable to complex ventral hernia repairs including retrorectus approaches and component separation. The vascular exposure and mobilization requires a command of the retroperitoneal and pelvic anatomy and vessel manipulation. Ureter identification and preservation during this procedure increases residents' comfort with colorectal and gynecologic procedures that require ureter identification. These cases provide valuable opportunities to enhance resident's operative experience, which are applicable to many additional general and vascular surgical procedures.

Limitations of this study include the inherent limitations of a retrospective, single institution study. Minor vascular injuries may be underreported if these were felt to be of no consequence during the procedure and not documented by the surgeon. Although the small number of vascular injuries observed in this study was encouraging, the small sample size made it difficult to detect any potential predictors of vascular injury. Another limitation is that no universal criteria exist to define a vascular injury in this setting. Exposures were evaluated over a 14-year period. Over this period, there may have been a learning curve, and the approach for L5-S1 exposure has evolved. In addition, improvements in anesthesia and neurosurgical care pathways occurred. These changing variables also may have contributed to the inability to identify specific patient variables as risk factors for complications. The inability to completely characterize resident involvement with a retrospective study design is also a weakness. Despite these limitations, we believe that this series is representative of outcomes in a community teaching hospital within an integrated health system.

Anterior spine exposures provided safe, reliable access for neurosurgical procedures. The overall incidence of major vascular injury for elective anterior spine procedures at our institution was 2.7%. Levels of exposure and greater intraoperative blood loss were associated with frequency of vascular injury. We were unable to identify preoperative characteristics associated with an increased risk of vascular injury. Postoperative complication rates and major vascular injury rates compared favorably to benchmarks in the literature. These low complications rates were unaffected by surgical resident involvement.

REFERENCES

1. Deyo RA, Mirza SK, Martin BI. Back pain prevalence and visit rates: estimates from U.S. national surveys, 2002. *Spine* (Phila Pa 1976). 2006;31(23):2724-2727.

2. Hoy D, Bain C, Williams G, et al. A systematic review of the global prevalence of low back pain. *Arthritis Rheum*. 2012;64(6):2028-2037.

3. Manchikanti L, Singh V, Datta S, Cohen, SP, Hirsch JA; American Society of Interventional Pain Physicians. Comprehensive review of epidemiology, scope, and impact of spinal pain. *Pain Physician*. 2009;12(4):E35-70.

4. Zahradnik V, Lubelski D, Abdullah KG, Kelso R, Mroz T, Kashyap VS. Vascular injuries during anterior exposure of the thoracolumbar spine. *Ann Vasc Surg*. 2013;27(3):306-313.

5. Wood KB, Devine J, Fischer D, Dettori JR, Janssen. Vascular injury in elective anterior lumbosacral surgery. *Spine* (Phila Pa 1976). 2010;35(suppl 9):S66-75.

6. Fantini GA, Pawar AY. Access related complications during anterior exposure of the lumbar spine. *World J Orthop*. 2013;4(1):19-23.

7. Ikard RW. Methods and complications of anterior exposure of the thoracic and lumbar spine. *Arch Surg*. 2006;141(10):1025-1034.

8. Mogannam A, Bianchi C, Chiriano J, et al. Effects of prior abdominal surgery, obesity, and lumbar spine level on anterior retroperitoneal exposure of the lumbar spine. *Arch Surg*. 2012;147(12):1130-1134.

9. Hamdan AD, Malek JY, Schermerhorn ML, Aulivola B, Blattman SB, Pomposelli FB Jr. Vascular injury during anterior exposure of the spine. *J Vasc Surg*. 2008;48(3):650-654.

10. Garg J, Woo K, Hirsch J, Bruffey JD, Dilley RB. Vascular complications of exposure for anterior lumbar interbody fusion. *J Vasc Surg*. 2010;51(4):946-950.

11. Brau SA, Delamarter RB, Schiffman ML, Williams LA, Watkins RG. Vascular injury during anterior lumbar surgery. *Spine J.* 2004;4(4):409-412.

12. Mangram AJ, Horan TC, Pearson, ML, Silver LC, Jarvis WR. Guideline for Prevention of Surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. *Infect Control Hosp Epidemiol.* 1999;20(4):247-278.

13. Chiriano J, Abou-Zamzam AM Jr, Urayeneza O, Zang WW, Cheng W. The role of the vascular surgeon in anterior retroperitoneal spine exposure: preservation of open surgical training. *J Vasc Surg*. 2009;50(1):148-151.

14. Baker JK, Reardon PR, Reardon MJ, Heggeness MH. Vascular injury in anterior lumbar surgery. *Spine* (Phila Pa 1976). 1993;18(15):2227-2230.

15. Zigler J, Delamarter R, Spivak JM, et al. Results of the prospective, randomized, multicenter Food and Drug Administration investigational device exemption study of the ProDisc-L total disc replacement versus circumferential fusion for the treatment of 1-level degenerative disc disease. *Spine* (Phila Pa 1976). 2007;32(11):1155-1162.

16. Blumenthal S, McAfee PC, Guyer RD, et al. A prospective, randomized, multicenter Food and Drug Administration investigational device exemptions study of lumbar total disc replacement with the CHARITE artificial disc versus lumbar fusion: part I: evaluation of clinical outcomes. *Spine* (Phila Pa 1976). 2005;30(14):1565-1575.

17. Comer GC, Smith MW, Hurwitz EL, Mitsunaga KA, Kessler R, Carragee EJ. Retrograde ejaculation after anterior lumbar interbody fusion with and without bone morphogenetic protein-2 augmentation: a 10-year cohort controlled study. *Spine J.* 2012;12(10):881-890.

18. Ballard JL, Carlson G, Chen J, White J. Anterior thoracolumbar spine exposure: critical review and analysis. *Ann Vasc Surg*. 2014;28(2):465-469.

19. Kasotakis G, Lakha A, Sarkar B, et al. Trainee participation is associated with adverse outcomes in emergency general surgery: an analysis of the National Surgical Quality Improvement Program database. *Ann Surg*. 2014;260(3):483-490.

20. Schoenfeld AJ, Carey PA, Cleveland AW 3rd, Bader JO, Bono CM. Patient factors, comorbidities, and surgical characteristics that increase mortality and complication risk after spinal arthrodesis: a prognostic study based on 5,887 patients. *Spine J.* 2013;13(10):1171-1179.

21. Bydon M, Abt NB, De la Garza-Ramos R, et al. Impact of resident participation on morbidity and mortality in neurosurgical procedures: an analysis of 16,098 patients. *J Neurosurg*. 2015;122(4):955-961.

22. Lim S, Parsa AT, Kim BD, Rosenow JM, Kim JY. Impact of resident involvement in neurosurgery: an analysis of 8748 patients from the 2011 American College of Surgeons National Surgical Quality Improvement Program database. *J Neurosurg*. 2015;122(4):962-970.

23. Cogbill TH. The general surgery residency at Gundersen Lutheran Medical Foundation: a tradition of training the complete general surgeon. *Am Surg*. 2009;75(9):739-742.

24. Cogbill TH, Jarman BT. Rural general surgery training: the Gundersen Lutheran approach. *Surg Clin North Am*. 2009;89(6):1309-1312.