ORIGINAL RESEARCH

Association of Frailty Score and Surgical Site Infection After Open Lower Extremity Revascularization

Andrew Edsall, MD; Andrew J. Borgert, PhD; Alec Fitzsimmons, MPH; Irina Shakhnovich, MD

ABSTRACT

Introduction: Surgical site infection (SSI) after lower extremity procedures is a persistent source of significant morbidity for vascular surgery patients. Frailty scores capture risk factors for postoperative outcomes associated with SSI. This study aimed to retrospectively evaluate the association between SSI and a validated measure of frailty, the Vascular Quality Initiative-Risk Analysis Index (VQI-RAI).

Methods: A retrospective review was performed of patients who underwent open lower extremity revascularization at a single independent academic medical center from January 1, 2007, through December 31, 2019. Frailty score was calculated using VQI-RAI, a composite score based on patient demographic and clinical variables. VQI-RAI scores were compared between patients who developed SSI and those who did not. SSI outcomes were compared between patients defined as frail (VQI-RAI ≥ 35) and not frail (VQI-RAI < 35).

Results: The study population comprised 1130 patients. The overall SSI rate was 8.1%. The median VQI-RAI score was 29 for patients with SSI and 28 for patients without SSI ($P = 0.4$). No significant association was observed between VQI-RAI and SSI or between patients defined as frail and not frail. Of the individual components of the VQI-RAI score, only body mass index was significantly associated with SSI ($P < .0001$).

Conclusions: VQI-RAI frailty score was not associated with risk of SSI in our study population; however, body mass index was significantly associated with SSI. Obesity poses a high risk of SSI, whereas frailty alone may not be associated with an increased risk of SSI.

INTRODUCTION

Surgical site infection (SSI) poses a persistent challenge for vascular surgeons performing lower extremity procedures. The incidence of SSI after open lower extremity vascular surgery ranges from 5% to 32%.[1-2] Preoperative risk factors include diabetes, hypertension, smoking, dialysis, tissue loss, and obesity.[2-3] Strategies to address modifiable risk factors for SSI – such as antibiotic prophylaxis, preoperative showers, iodine-impregnated drapes, and negative pressure therapy – have been widely implemented.[1] Nevertheless, SSI rates remain elevated for lower extremity vascular surgeries relative to other procedures across surgical specialties.[4] These infections are associated with prolonged hospitalization, increased morbidity and mortality, and higher health care costs.[4]

Surgical frailty is a state of decreased physiologic reserve that predisposes patients to excess morbidity and mortality after surgery.[5,6] Frailty has been associated with longer hospitalization, higher 30-day readmission rates, and increased perioperative complications.[7,8] Historically, surgical frailty was assessed indirectly using metrics such as age and American Society of Anesthesiologists (ASA) physical status or subjectively using the "eyeball test" employed preoperatively by experienced surgeons.[7] More objective approaches have emerged, including using validated frailty models.[7] Two primary paradigms have been described: the phenotypic model, which focuses on physical manifestations such as sarcopenia, and the deficit accumulation model,[6] which assigns frailty based on current and past diagnoses.[9-10]

One widely employed frailty metric is the Risk Analysis Index (RAI) which, along with its vascular surgery–specific derivative Vascular Quality Initiative (VQI)-RAI, captures deficit accumulation across multiple domains.[8] VQI-RAI has been associated with outcomes related to abdominal aortic aneurysm repair.[11]

Although frailty has been linked to SSI in some circumstances, evidence is limited regarding its role in lower extremity SSI.[12] Therefore, we aimed to evaluate the utility of VQI-RAI in pre-

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Author affiliations: Gundersen Health System, La Crosse, Wisconsin (Edsall, Borgert, Fitzsimmons); Department of Surgery, Gundersen Health System, La Crosse, Wisconsin (Shakhnovich).

Corresponding author: Andrew Edsall, MD, Gundersen Health System, 1900 South Ave, La Crosse, WI 54601; email aedsall@gundersenhealth.org; ORCID ID 0000-0001-7696-5755

dicting SSI among patients undergoing open lower extremity procedures.

METHODS

Institutional Review Board approval was obtained for this study. A retrospective review was conducted of electronic health records for all patients undergoing an open lower extremity procedure at a single independent academic medical center from January 1, 2007, through December 31, 2019. During the study period, vascular surgery services were provided predominantly by a team of 3 fellowship-trained vascular surgeons, with a small number of procedures performed by 2 general surgeons experienced in vascular surgical care. Percutaneous procedures (eg, endovascular aneurysm repair performed with percutaneous access and no open arterial exposure) were excluded from the analysis. The prespecified primary outcome was the incidence of SSI. Secondary outcomes were unplanned return to the operating room due to SSI and death within 30 days of surgery.

Preoperative frailty was evaluated using the VQI-RAI, a metric derived from the RAI, which uses American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) variables to predict postoperative morbidity and mortality.[5] Since its inception, the RAI has been cross-walked to Vascular Quality Initiative (VQI) variables to create the VQI-RAI.[8] The VQI-RAI is a composite score based on age, sex, body mass index (BMI), renal disease, congestive heart failure (CHF), dyspnea, living status, and functional status. For this study, frailty was defined as a VQI-RAI score ≥35, consistent with previous applications of the VQI-RAI.[11] The Wilcoxon rank sum test was used to compare the VQI-RAI scores between patients who developed SSI and those who did not. Chi-square and Fisher exact tests were used to compare SSI outcomes between patients defined as frail and not frail. Statistical significance was set at $P \leq .05$. All statistical analyses were performed using the SAS software, version 9.4 (SAS Institute Inc, Cary, North Carolina).

RESULTS

From January 1, 2007, through December 31, 2019, 1506 open lower extremity vascular surgery procedures were performed; 376 were excluded because of incomplete data. The remaining 1130 procedures were included in the analysis. Baseline study population demographics and clinical characteristics are shown in Table 1. The median age was 72 years. Women comprised 27.4% of the study population, and men comprised 72.6%. Participants with self-reported current smoking status accounted for 24.5% of the study population, 51.9% were former smokers, and 11.2% were never smokers. The median VQI-RAI score was 28 (range, 10-56). Fourteen percent of patients met criteria for frailty (VQI-RAI ≥35). Thirty-two percent of patients with VQI-RAI ≥35 had gangrene or ischemic ulcerations at the time of operation, compared with 15% of patients with VQI-RAI <35 ($P < .0001$) (Table 2). Hybrid procedures involving open arterial exposure for delivery of an arterial stent were the most common and accounted for 47.6% of the total. Femoral endarterectomy and lower extremity bypass accounted for 21.7% and 21% of procedures, respectively (Table 3).

Table 1. Baseline Patient Characteristics

Characteristic	Median (Range)[a]
Age	72 (29–99)
Body mass index (kg/m^2)	28.5 (12.6–58.7)
Sex, n (%)	
Female	310 (27.4)
Male	820 (72.6)
Preoperative creatinine (mg/dL)	0.97 (0.33–9.62}
VQI-RAI	28 (10–56)

Abbreviation: VQI-RAI, Vascular Quality Initiative-Risk Analysis Index.
[a]Data presented are median and range, unless otherwise specified.

Table 2. Preoperative Ulceration/Gangrene and Incidence of Surgical Site Infection by VQI-RAI Score

	Not Frail (VQI-RAI <35) (n=977)	Frail (VQI-RAI ≥35) (n=153)
Preoperative ulceration/gangrene, n (%)		
Yes	147 (15.0)	49 (32.0)
No	830 (85.0)	104 (68.0)
Surgical site infection, n (%)		
Yes	75 (7.7)	16 (10.5)
No	902 (92.3)	137 (89.5)

Abbreviation: VQI-RAI, Vascular Quality Initiative-Risk Analysis Index.

Table 3. Number of Patients by Type of Vascular Surgery Procedure

Primary Procedure	No. of Patients (%)[a]
Hybrid – Open exposure for delivery of endovascular stent (aorta, iliac, femoral, popliteal)	537 (47.6)
Femoral endarterectomy	245 (21.7)
Lower extremity bypass, non-vein graft	137 (12.1)
Lower extremity bypass, vein graft	101 (8.9)
Lower extremity embolectomy	53 (4.7)
Other (groin exposure during open aortic surgery)	57 (5.0)

[a]Total does not equal 100% due to rounding.

Primary Outcome

Ninety-one of the 1130 patients (8.1%) developed at least 1 SSI. Among SSIs, 76.3% were classified as Superficial Incisional SSI, 17.2% as Deep Incisional SSI, and 6.5% as Organ/Space SSI. The incidence of SSI among frail patients was 10.5% compared with 7.7% among non-frail patients ($P = .31$) (Table 2). The median VQI-RAI score among patients who experienced SSI was 29, compared with a median of 28 for those who did not experience SSI ($P = .4$). The receiver operating characteristic (ROC) area under the curve for VQI-RAI association with SSI was 0.53 (Figure).

Associations between SSI and each individual component of

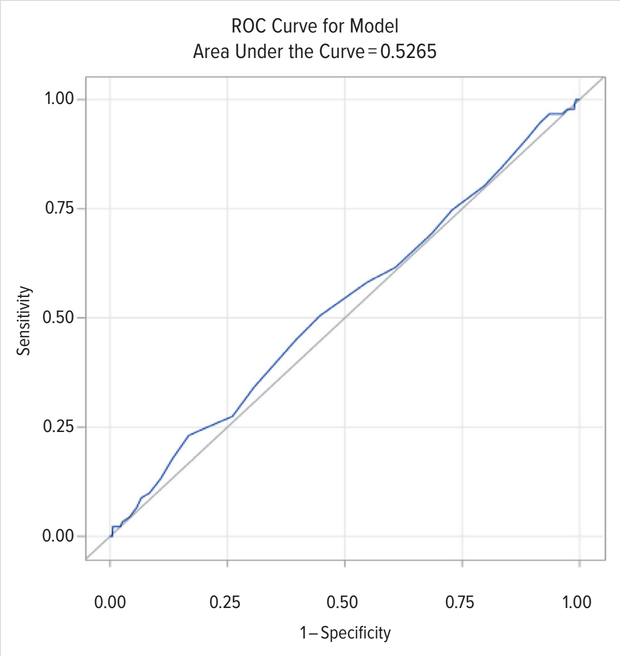

Figure. VQI-RAI Association With Surgical Site Infection

Abbreviation: VQI-RAI, Vascular Quality Initiative-Risk Analysis Index; ROC, receiver operating characteristic.

Table 4. Individual VQI-RAI Component Association With Surgical Site Infection

VQI-RAI Component	No SSI (n = 1039) n (%)[a]	SSI (n = 91) n (%)[a]	*P* value
Age, mean (SD)	70.9 (10.7)	70.3 (10.1)	.66
BMI (kg/m^2), mean (SD)	28.7 (5.9)	31.3 (6.2)	< .0001
Preop creatinine (mg/dL), mean (SD)	1.2 (0.9)	1.4 (1.3)	.36
Sex			
Female	281 (27.0)	29 (31.9)	.32
Male	758 (73.0)	62 (68.1)	
Requiring dialysis			
No	1002 (96.4)	86 (94.5)	.38
Yes	37 (3.6)	5 (5.5)	
Dyspnea			
No	223 (24.5)	19 (20.9)	.9
Yes	816 (78.5)	72 (79.1)	
Congestive heart failure within 30 days			
No	1029 (99.0)	89 (97.8)	.25
Yes	10 (1.0)	2 (2.2)	
Functional status			
Independent	955 (91.9)	80 (87.9)	.23
Partially dependent	78 (7.5)	11 (12.1)	
Totally dependent	6 (0.6)	0 (0.0)	
Transfer status			
Acute care hospital	14 (1.3)	1 (1.1)	.88
Directly from home	950 (91.4)	82 (90.1)	
Chronic care facility	22 (2.1)	2 (2.2)	
Other	52 (5.0)	6 (6.6)	
VA acute care hospital	1 (0.1)	0 (0.0)	

[a]Data presented are n (%) unless specified otherwise.
Abbreviations: VQI-RAI, Vascular Quality Initiative-Risk Analysis Index; preop, preoperative.

the VQI-RAI frailty score were independently assessed (Table 4). Of these, a statistically significant association was observed only between SSI and BMI, with a mean BMI of 31.3 kg/m^2 among patients with SSI compared with 28.7 kg/m^2 among those without SSI ($P < .0001$).

Secondary Outcomes

A total of 53 patients (4.7%) died within 30 days of surgery. These patients had a median VQI-RAI score of 29, compared with 28 for those who did not die within 30 days of surgery ($P = .03$). Thirty-six patients (3.2%) experienced SSI and unplanned return to the operating room; their median VQI-RAI score was 26, compared with a median score of 28 for those who did not have SSI and unplanned return to the OR ($P = .12$).

DISCUSSION

Our results should be interpreted within the context of the SSI and frailty score literature. The overall incidence of SSI observed in our study aligns with published estimates of SSI for lower extremity procedures.[1-2] Similarly, our finding of a significant association between BMI and SSI is consistent with previous work using the VQI database.[13] Finally, our finding that patients who died within 30 days of surgery had significantly higher frailty scores than those who did not die is consistent with extensive studies of frailty in both vascular and general surgery populations.[5,7]

Study population demographics (median age, 72 years; 27.4% female), as well as the median VQI-RAI score of 28 and overall frailty rate of 14%, are generally similar to those reported for patients undergoing open lower extremity vascular procedures nationally in studies using VQI data.[12] Similarly, the self-reported smoking prevalence of 24.5% mirrors the prevalence of smoking among patients with clinical peripheral artery disease (PAD).[14] While these findings support the comparability of our study population with the population of PAD patients more broadly, center-specific factors may limit such comparisons. In particular, our center is located in a urban area of the Upper Midwest with a population of fewer than 200 000 and serves a primarily rural referral region.[15] As such, regional trends in antibiotic resistance – particularly to gram-positive organisms – and associated infection-related outcomes may differ from other regions in the United States and abroad.[16] Moreover, the predominantly rural patient population served by our center may experience different outcomes than populations with a greater proportion of urban and suburban residents.[17]

The primary motivation for this study was to further elucidate causes of persistently high SSI rates among patients undergoing lower extremity revascularization. During the study period, interventions were implemented at our institution to reduce SSI rates, including patient education, preoperative scrub and normothermia protocols, and standardized protocols among all vascular surgeons. After reviewing operative cultures following SSI, antibiotic prophylaxis coverage was broadened to include anaerobic flora. Postoperative dressings included silver-impregnated and incisional negative pressure dressings. In addition, muscle flaps were performed for selected high-risk patients, including those with reoperative groins and obesity. Despite these efforts, no significant decrease in SSI rates was observed.

Our study also found that frail patients were significantly more likely to have gangrene/ischemic ulceration present at the time of surgery, yet they were no more likely to experience SSI than nonfrail patients. This suggests that frail patients have a higher incidence of tissue ischemia at presentation, and that spread of preexisting infection may be effectively mitigated through current infection control measures.

In finding no significant association between frailty score and SSI, our results diverge from earlier published work. In contrast, 1 prior VQI-based study demonstrated a significant association between frailty score and SSI after infra-inguinal bypass.[12] That study also found a significant association between frailty and unplanned return to the operating room attributable to SSI.[12] However, differences in study design may limit comparability. First, our study included a large proportion of hybrid procedures and femoral endarterectomies, in addition to lower extremity bypass procedures. Moreover, we did not differentiate between patients who experienced an unplanned return to the operating room with SSI and those who underwent re-operation for SSI, as opposed to another indication, such as proximal amputation.

The limitations of our study relate primarily to our single-center, nonrandomized sample. All patients underwent open procedures, which may have produced a study population significantly different from the general vascular surgery population. Open procedures – particularly open arterial exposures for endovascular access – may have been selected over percutaneous approaches based on preoperative surgeon assessment of each patient's morbidity and mortality risk. Patients with higher frailty scores may have undergone percutaneous procedures and thus been excluded, potentially confounding the relationship between frailty and SSA. Surgeon decision making may represent an additional confounder: when highly frail patients underwent open procedures, intra-operative choices – such as incision location and size – may have been influenced by awareness of frailty. However, this may not threaten external validity, as similar considerations likely apply to procedure selection in the broader vascular surgery population. Our results may therefore provide pragmatic insights into patients who undergo open revascularization procedures.

CONCLUSIONS

Frailty, as measured by VQI-RAI score, was not significantly associated with SSI in patients undergoing open lower extremity revascularization. VQI-RAI score was significantly associated with death within 30 days of surgery. Given prior evidence supporting VQI-RAI as a robust measure of surgical frailty, these findings do not necessarily indicate a need for a more sensitive frailty model; rather, investigation of specific pathophysiologic drivers of SSI – such as BMI – may be a more fruitful approach to estimating SSI risk preoperatively. Such work will undoubtedly be challenged by the non-modifiability of risk factors, such as BMI, in the context of urgent or emergent procedures. However, better understanding of the mechanisms underlying these associations may help inform strategies to mitigate, if not eliminate, their impact.

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