Evidence-Based Bundled Quality Improvement Intervention for Reducing Surgical Site Infection in Lower Extremity Vascular Bypass Procedures

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BACKGROUND: Surgical site infection (SSI) poses a significant burden to patients and healthcare resources. Vascular Quality Initiative (VQI) data identify a higher rate of SSIs for lower extremity bypass than other vascular procedures. Bundled interventions have successfully reduced SSIs in other surgical procedures.

STUDY DESIGN: We evaluated our institution-specific VQI data for modifiable risk factors associated with index hospitalization SSI from January 2012 through October 2015. We implemented an evidence-based lower extremity bypass operation SSI reduction bundle (ie perioperative chlorhexidine showers and transverse groin incisions) and prospectively enrolled all patients who had lower extremity bypass procedures, with a target adherence rate of 50% per bundle component. Bundle adherence and SSI events were measured from March 2016 through August 2017. We carried out a pre-post evaluation of bundle effectiveness in reducing index hospitalization SSI.

RESULTS: In the pre-intervention period, 43 of 234 (18%) patients had SSI events. The only risk factors associated with SSI (ie female sex, diabetes, overweight BMI) were not readily modifiable. In an 18-month period after introduction of our intervention, adherence rates to preoperative chlorhexidine showers, a transverse incision, and a postoperative chlorhexidine shower were 71% (52 of 73), 48% (24 of 50), and 88% (64 of 73), respectively. Compliance with all applicable bundle components was 36% (26 of 73). The SSI rate post-intervention decreased from 18% to 4% (3 of 73). Intention-to-treat multivariable analysis showed a 97% SSI risk reduction with the bundle ($p = 0.002$). As-treated analysis identified 85% ($p = 0.02$) and 62% ($p = 0.047$) SSI risk reductions from the preoperative and postoperative chlorhexidine showers, respectively.

CONCLUSIONS: In this evaluation study of the effectiveness of a quality improvement intervention, SSIs were markedly decreased after implementation of our evidence-based bundle for lower extremity vascular bypass procedures. (J Am Coll Surg 2019;228:44−53. © 2018 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Surgical site infection (SSI) poses a significant burden to both patients and healthcare resources. Among vascular surgery procedures, the lower extremity bypass has the highest rate of SSI, at approximately 10%.[1] These SSI events lead to prolonged hospital stays and greater resource use.[2] More importantly, in the setting of

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concomitant microvascular disease impeding wound healing, and often the presence an implanted prosthetic bypass conduit, SSIs can have devastating consequences, such as loss of limb or even loss of life.[1]

Several risk factors contributing to SSIs have been identified for lower extremity bypass patients, including female sex, diabetes, smoking, obesity, steroid use, and prosthetic bypass conduit.[3-7] Although many SSI risk factors are not readily amenable to modification, bundled interventions targeting modifiable risk factors have successfully reduced SSI in other surgical procedures.[2,8,9] Despite the significant sequelae of SSI, a prospectively validated bundled intervention to reduce SSI for lower extremity vascular bypass has yet to be described.

Our hypothesis was that a bundled intervention could be used to target modifiable risk factors for SSI in lower extremity bypass patients and be implemented successfully, reducing SSI events. Our goal in the current study was 3-fold: First, we aimed to use the Vascular Quality Initiative (VQI) data from our institution to identify risk factors for SSI in our lower extremity bypass patients, and to use these data along with existing literature to generate a bundled intervention targeting modifiable risk factors for SSI. Our second goal was to successfully implement a bundled intervention based on these findings. Third, we aimed to evaluate the efficacy of this bundled intervention in reducing SSI events.

METHODS

Study design

This retrospective and prospective chart review was reviewed and deemed exempt by the IRB at Northwestern University. Institutional VQI data were used to identify pre-intervention patients who underwent lower extremity bypass operations from January 1, 2012 through October 15, 2015. Inclusion criteria were the same as for inclusion into the VQI lower extremity bypass module. Institutional VQI data were pulled every 6 months after implementation of the bundle to track outcomes from March 1, 2016 through August 31, 2017. Patient demographics, comorbidities, intraoperative factors, and SSIs during the index hospitalization were drawn from the VQI data. Surgical site infection was defined as per the VQI criteria: the presence of a positive culture or the use of antibiotics during the index hospitalization. Bundle compliance was monitored through supplemental chart review.

Surgical site infection bundle

The SSI bundle was developed through the input of a multidisciplinary team, including surgeons, house staff, clinic nurses, advanced practice providers, unit nurses, and patient care technicians. The bundle implementation was coordinated by the lead author (KEH), who met with the study stakeholders regularly to discuss bundle compliance and SSI outcomes, and to address any barriers to bundle implementation.

The bundle was devised using evidence-based factors and practical suggestions from the multidisciplinary team. The final bundle included preoperative chlorhexidine showers—one the night before the operation and one the morning of operation; a transverse groin incision when clinically applicable; and a chlorhexidine shower within 2 postoperative days when the dressings were removed. All study stakeholders were educated on the importance of preventing SSIs and on the bundle components. This was conducted through division quality improvement meetings for surgeons, house staff, and inpatient advanced practice providers; through meetings with clinic advanced practice providers and with unit nursing leadership; and during morning huddles for unit nurses and patient care technicians.

For the preoperative chlorhexidine showers, patients were provided chlorhexidine soap and written instructions at the time of their clinic visit, following Edmiston and colleagues.[10] The scheduling coordinator called all patients the day before their operation to remind them of the details for their procedure, including the need to complete the preoperative showers. For inpatient showers, chlorhexidine soap was routinely stocked on the units of our institution before bundle implementation. Inpatients were also provided a laminated placard in their room to check off completion of their shower tasks before and after operation. In circumstances where patients had significantly impaired mobility, particularly in the postoperative period, a “bed-bath” was substituted for a full shower.

Groin incision type and postoperative shower during hospitalization were routinely documented in the electronic medical record before implementation of the bundle. The preoperative history and physical form was modified to include a check box for compliance with the preoperative chlorhexidine shower regimen. Target compliance was set at 50% per component.

Statistical analysis

The VQI data are reported to the institution without risk adjustment. To adjust for covariates, a pre-post intervention intention-to-treat analysis was performed to assess the effect of the bundle on SSI outcomes, in which a multivariable logistic regression model for SSI was used that included the prespecified covariates and also an indicator variable for the intervention period (post-intervention vs pre-intervention [reference]) as a covariable in the model. A secondary analysis using the bundle components as treated was done to test the effect of the various components of the bundle on SSI outcomes. Patients with missing values for covariates were excluded from the analyses by STATA software (Stata Corp). Distributions of demographic and baseline characteristics were compared with Fisher's exact test. Odds ratios (ORs) were generated in a univariate analysis to identify risk factors associated with SSIs in our pre-intervention group. Pre- and post-intervention hospital lengths of stay were compared with a 2-sided Student's *t*-test.

RESULTS

Patient population

During the pre-intervention period examined, 234 patients underwent lower extremity bypass operation. In our post-intervention period, 73 patients underwent lower extremity bypass operation. Patient demographic and baseline characteristics for the pre- and post-intervention arms are represented in Table 1. The difference in sex distribution between our pre- and post-intervention cohorts was not statistically significant (60.7% vs 72.6% males; p = 0.07). The groups did not differ significantly in percentage with diabetes (45.7% vs 47.2%), past or current smokers (78.2% vs 81.9%), patients with an earlier lower extremity bypass procedure (37.2% vs 34.7%), or urgency of the index case (73.5% vs 75.3% elective). The groups did differ in the distribution of BMI quartiles, as the post-intervention group had fewer patients in the highest and lowest BMI quartiles (46% vs 71% in the middle quartiles, p = 0.002 for distribution among all quartiles). The groups also differed in the distribution of indications for bypass operation. The post-intervention

Table 1. Demographic and Baseline Characteristics and Surgical Site Infection Outcomes Events of the Pre-Intervention (January 2012 through October 2015) and Post-Intervention (March 2016 through August 2017) Cohorts

	Pre-intervention (n = 234)		Post-intervention (n = 73)		
Variable	**n**	**%**	**n**	**%**	**p Value**
Factor					
Male sex	142	60.7	53	72.6	0.07
Diabetes	107	45.7	34/72	47.2	0.89
BMI quartile, kg/m^2					0.002*
≤23.5	62	26.5	10/72	13.9	
23.5<BMI ≤26.8	58	24.8	23/72	31.9	
26.8<BMI ≤31.5	49	20.9	28/72	38.9	
>31.5	65	27.8	11/72	15.3	
Earlier bypass	87	37.2	25/72	34.7	0.78
Dialysis	20	8.5	6/71	8.45	0.99
Smoking†	183	78.2	59/72	81.9	0.62
Indication					0.001*
Asymptomatic/claudication	47	20.1	15	20.5	
Rest pain	88	37.6	14	19.2	
Tissue loss	69	29.5	21	28.8	
Acute ischemia	30	12.8	23	31.5	
Preoperative hemoglobin, g/dL					0.89
≤12	113	48.3	37	50.7	
>12	118	51.1	36	49.3	
Urgency					0.97
Elective	172	73.5	55	75.3	
Urgent	51	21.8	15	20.5	
Emergent	11	4.7	3	4.1	
Non-autogenous conduit	120	52.3	38	52.1	1.0
Outcome					0.002*
Surgical site infection	43	18.4	3	4.1	

*Statistically significant.
†Smoking defined as past or current.

group had a lower frequency of rest pain and a higher frequency of acute ischemia compared with the pre-intervention group (post- vs pre-intervention 19.2% vs 37.6% for rest pain, and 31.5 vs 12.8% for acute ischemia; p = 0.001).

We evaluated our pre-intervention arm for risk factors associated with SSI in a univariate analysis. Diabetes (odds ratio [OR] 2.59; 95% CI 1.29 to 5.18; p = 0.007) and female sex (OR 2.17; 95% CI 1.11 to 4.27; p = 0.02) were associated with SSIs (Table 2).

Bundle compliance

Bundle compliance rates during an 18-month period after implementation are shown in Figure 1. Both pre- and postoperative shower components achieved 71% (n = 52 of 73) and 88% (n = 64 of 73) compliance, meeting the target rate of 50% compliance. The transverse incision component achieved 48% (n = 24 of 50) compliance, just below the target compliance rate, but 3-fold higher than pre-intervention. Of note, only 35.6% (n = 26 of 73) of patients received all relevant

Table 2. Results from Univariate Logistic Regression Models for Surgical Site Infection as End Point and Selected Risk Factors as Predictors in the Pre-Intervention Study Population

Factor, category	Odds ratio	95% CI	p Value
Sex			
Male	ref	ref	—
Female	2.17	1.11−4.27	0.02*
Diabetes			
None	ref	ref	—
Managed with diet, non-insulin medication, or insulin	2.56	1.29−5.18	0.007*
BMI quartile, kg/m^2			
≤23.5	ref	ref	—
23.5<BMI≤26.8	1.47	0.50−4.37	0.57
26.8<BMI≤31.5	2.69	0.97−7.45	0.16
>31.5	2.49	0.94−6.58	0.22
Earlier bypass			
No	ref	ref	—
Yes	0.72	0.35−1.47	0.37
Dialysis			
Never on dialysis/functioning transplant	ref	ref	—
On dialysis	1.58	0.54−4.61	0.41
Smoking			
Never	ref	ref	—
Past or current	0.75	0.35−1.63	0.47
Indication			
Asymptomatic/claudication	ref	ref	—
Rest pain	1.00	0.39−2.57	0.53
Tissue loss	0.73	0.26−2.06	0.12
Acute ischemia	2.71	0.92−8.01	0.01
Preoperative hemoglobin, g/dL			
>12	ref	ref	—
≤12	1.56	0.79−3.06	0.21
Urgency			
Elective	ref	ref	—
Urgent	1.32	0.59−2.95	0.59
Emergent	2.94	0.81−10.71	0.15
Non-autogenous conduit			
Autogenous vein	ref	ref	—
Other	0.70	0.37−1.31	0.26

*Statistically significant.
ref, reference value.

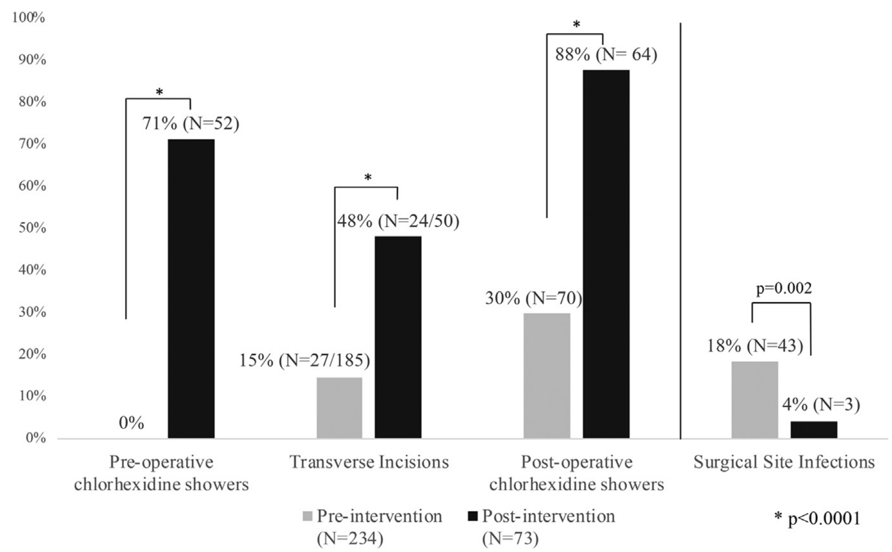

Figure 1. Surgical site infection reduction bundle results. Compliance with each component of the bundle 18 months after implementation showed a significant increase in use of the bundle components compared with pre-intervention ($p < 0.0001$ for each component). Compliance with all 3 bundle components was 35.6%. In-hospital surgical site infection rates in infra-inguinal bypass operations fell from 18% to 4% after implementation of the surgical site infection reduction bundle ($p = 0.002$).

components of the bundle (preoperative showers with transverse groin incision and postoperative shower for patients with a groin incision; pre- and postoperative showers for patients without a groin incision).

Surgical site infection outcomes

In our pre-intervention period, there were 43 SSI events, representing an SSI rate of 18.4%. In our post-intervention group, there were 3 SSI events, representing an SSI rate of 4.1% (Fig. 1). An intention-to-treat multivariable analysis was carried out to evaluate the effect of the bundle and adjusted for covariates: sex, BMI quartile (derived from the entire cohort), history of smoking, diabetes, dialysis, preoperative hemoglobin, history of bypass, indication for bypass, type of conduit, and type of groin incision (when applicable). This multivariable analysis showed a 97% SSI risk reduction with the bundle ($p = 0.002$) (Table 3). Additional variables emerged as risk factors for SSI in our multivariable model, including the third BMI quartile (OR 5.08; 95% CI 1.59 to 16.23; $p = 0.008$) and female sex (OR 3.09; 95% CI 1.34 to 7.12; $p = 0.008$). Because the main end point was SSI during the index hospitalization, we compared the average length of stay pre- and post-intervention. For patients without SSIs, there was no significant difference in the postoperative lengths of stay between pre- and post-intervention cohorts (mean $\pm$ SD 7.94 $\pm$ 8.32 days vs 7.67 $\pm$ 6.24 days; $p = 0.80$). The occurrence of SSI, however, was significantly associated with an extended postoperative length of stay across the entire cohort (mean $\pm$ SD with SSI 11.78 $\pm$ 6.01 vs without SSI 7.87 $\pm$ 7.81; $p = 0.0014$).

We next ran our multivariable model, using the same covariates mentioned, with each of the 3 individual bundle components as-treated. In the as-treated analysis for the preoperative chlorhexidine showers alone, the showers conferred an 85% SSI risk reduction (OR 0.15; 95% CI 0.03 to 0.70; $p = 0.02$) (Table 4). In this preoperative shower multivariable model, female sex (OR 3.07; 95% CI 1.40 to 6.72; $p = 0.005$) and the third BMI quartile (OR 2.96; 95% CI 1.03 to 8.54; $p = 0.04$) remained significant risk factors for SSI. This individual as-treated analysis for the postoperative chlorhexidine shower element also found female sex to be a risk factor for SSI, and showed a 62% SSI risk reduction from the postoperative chlorhexidine showers (OR 0.38; 95% CI 0.15 to 0.99; $p = 0.047$). Finally, the model examining the transverse incision by itself did not find this element to be associated with a significant risk reduction. However, this transverse incision multivariable model additionally found diabetes to be associated with SSI (OR 2.75; 95% CI 1.06 to 7.10; $p = 0.04$), and current/past smoking (OR 0.29; 95% CI 0.11 to 0.82; $p = 0.02$) and non-autogenous conduit (OR 0.37; 95% CI 0.14 to 0.93; $p = 0.03$) were found to be protective against SSI.

Table 3. Results from Multivariable Logistic Regression for Surgical Site Infection as End Point with Selected Risk Factors and Intention-to-Treat with the Bundled Intervention as an Indicator Covariable (n = 295)

Factor, category	Odds ratio	95% CI	p Value
Intention-to-treat			
Pre-intervention	ref	ref	—
Post-intervention	0.032	0.004–0.277	0.002*
Sex			
Male	ref	ref	—
Female	3.09	1.34–7.12	0.008*
Diabetes			
None	ref	ref	—
Managed with diet, non-insulin medication, or insulin	1.92	0.85–4.34	0.12
BMI quartile, kg/m^2			
BMI≤23.5	ref	ref	—
23.5<BMI≤26.8	1.28	0.39–4.25	0.21
26.8<BMI≤31.5	5.08	1.59–16.23	0.008*
31.5<BMI	2.66	0.88–7.99	0. 40
Earlier bypass			
No	ref	ref	—
Yes	0.55	0.23–1.28	0.17
Dialysis			
Never on dialysis/functioning transplant	ref	ref	—
On dialysis	1.38	0.73–2.60	0.32
Smoking			
Never	ref	ref	—
Past or current	0.57	0.24–1.38	0.21
Indication			
Asymptomatic/claudication	ref	ref	—
Rest pain	0.63	0.22–1.82	0.20
Tissue loss	0.48	0.15–1.58	0.06
Acute ischemia	2.77	0.68–11.20	0.02
Preoperative hemoglobin, g/dL			
>12	ref	ref	—
≤12	1.04	0.47–2.28	0.93
Urgency			
Elective	ref	ref	—
Urgent	1.09	0.41–2.90	0.76
Emergent	1.71	0.30–9.57	0.57
Conduit			
Autogenous vein	ref	ref	—
Other	0.66	0.30–1.44	0.29
Groin incision			
None	ref	ref	—
Vertical incision	0.81	0.29–2.26	0.28
Transverse incision	1.58	0.44–5.76	0.29

*Statistically significant.
ref, reference value.

Table 4. Results from Multivariable Logistic Regressions for Surgical Site Infection as End Point with Selected Risk Factors and Each Bundle Element As-Treated as an Indicator Covariable

Factor, category	Odds ratio	95% CI	p Value	Odds ratio	95% CI	p Value	Odds ratio	95% CI	p Value
As-treated									
Preoperative chlorhexidine shower (n = 301)	0.15	0.03−0.70	0.02*	—	—	—	—	—	—
Transverse vs vertical incision (n = 229)	—	—	—	1.01	0.37−2.80	0.98	—	—	—
Postoperative chlorhexidine shower (n = 301)	—	—	—	—	—	—	0.38	0.15−0.99	0.047*
Sex									
Male	ref	ref	—	ref	ref	—	ref	ref	—
Female	3.07	1.40−6.72	0.005*	4.66	1.81−12.01	0.002*	2.87	1.33−6.19	0.007*
Diabetes									
None	ref	ref	—	ref	ref	—	ref	ref	—
Managed with diet, non-insulin medication, or insulin	1.95	0.89−4.27	0.10	2.75	1.06−7.10	0.04*	2.07	0.94−4.57	0.07
BMI quartile, kg/m^2									
BMI≤23.5	ref	ref	—	ref	ref	—	ref	ref	—
23.5<BMI≤26.8	0.86	0.28−2.61	0.12	1.17	0.30−4.54	0.39	0.88	0.29−2.63	0.13
26.8<BMI≤31.5	2.96	1.03−8.54	0.04*	4.01	1.14−14.14	0.01*	2.81	0.97−8.11	0.048
31.5<BMI	1.97	0.72−5.41	0.36	1.67	0.45−6.16	1.00	1.98	0.72−5.44	0.34
Earlier bypass									
No	ref	ref	—	ref	ref	—	ref	ref	—
Yes	0.53	0.24−1.18	0.12	0.93	0.36−2.38	0.88	0.51	0.23−1.14	0.10
Dialysis									
Never on dialysis/functioning transplant	ref	ref	—	ref	ref	—	ref	ref	—
On dialysis	1.32	0.72−2.44	0.37	0.77	0.33−1.82	0.55	1.27	0.69−2.32	0.44
Smoking									
Never	ref	ref	—	ref	ref	—	ref	ref	—
Past or current	0.54	0.24−1.23	0.14	0.31	0.12−0.81	0.02*	0.60	0.27−1.35	0.22
Indication									
Asymptomatic/claudication	ref	ref	—	ref	ref	—	ref	ref	—
Rest pain	0.74	0.27−2.05	0.53	0.98	0.31−3.16	0.43	0.72	0.26−1.99	0.56
Tissue loss	0.45	0.14−1.43	0.04	0.33	0.08−1.36	0.05	0.42	0.13−1.35	0.04
Acute ischemia	1.99	0.56−7.01	0.048	0.99	0.22−4.51	0.56	1.81	0.52−6.25	0.06
Preoperative hemoglobin, g/dL									
>12	ref	ref	—	ref	ref	—	ref	ref	—
≤12	1.25	0.58−2.66	0.57	1.14	0.46−2.79	0.78	1.22	0.57−2.59	0.61
Urgency									
Elective	ref	ref	—	ref	ref	—	ref	ref	—
Urgent	1.15	0.46−2.85	0.61	2.32	0.81−6.62	0.96	1.21	0.49−2.99	0.77
Emergent	2.27	0.49−10.54	0.32	†	†	—	1.98	0.44−8.97	0.43
Conduit									
Autogenous vein	ref	ref	—	ref	ref	—	ref	ref	—
Other	0.55	0.26−1.15	0.11	0.41	0.17−0.98	0.046*	0.61	0.30−1.27	0.19

*Statistically significant.
†Unable to estimate.

DISCUSSION

In this analysis, we showed a paucity of modifiable risk factors for SSI in our patient cohort, successful implementation of a bundled SSI reduction intervention based on earlier literature, and SSI risk reduction in our patients with implementation of this intervention.

Our analysis of the pre-intervention cohort did not reveal any readily modifiable risk factors for inclusion in our bundled intervention. In the univariate analysis of our pre-intervention cohort, only female sex and diabetes were associated with SSI, and the multivariable analysis, adjusting for covariates of the entire cohort, additionally found BMI to be associated with SSIs. We did, however, identify from the literature that chlorhexidine showers and transverse groin incisions reduced SSI in other, similar patient cohorts. Our evidence-based bundle, therefore, was based on the existing literature.

Implementation of the bundled intervention to reduce SSIs met our target rate of compliance for the pre- and postoperative chlorhexidine showers, likely due in part to the ongoing feedback of compliance rates communicated through regular meetings with stakeholders. Transverse groin incisions, when a groin incision was used, fell short of the target compliance rate, likely due to inadequate anatomic exposure for certain types of procedures. Overall compliance with all applicable bundle components was 35.6%, limited primarily by the low adherence to the transverse groin incision component. The SSI rates in our cohort fell from 18.4% to 4.1% after 18 months of bundle implementation. Intention-to-treat analysis adjusting for covariates showed a 97% SSI risk reduction with the bundle. The as-treated analysis for each bundle component individually suggested that the preoperative and postoperative showers drove the index hospitalization SSI reduction effect of the bundle. Given the nature of the quality improvement process, the stakeholder investment required to implement an initiative might have contributed to improved awareness and engagement of the treatment team about SSI prevention. This might have contributed non-measurable effects to the SSI reduction seen here. These results showed significant SSI risk reduction after implementation of our evidence-based bundle in our lower extremity vascular bypass patient population.

The SSI risk factors in our population—female sex, diabetes, and BMI—concur with those in previously published studies.[3-5,7] However, our analysis did not find significant association between SSIs and other commonly cited risk factors in lower extremity bypass patients, such as smoking, dialysis, or procedure indication. These earlier studies, however, examined 30-day infection rates, and there might be a different subset of risk factors for SSI events that occur during the index hospitalization vs within 30 days of operation. In addition, several of these studies examined only subsets of lower extremity bypass patients undergoing specific approaches and reported 30-day SSI risk factors, including critical limb ischemia, earlier bypass operation, use of non-autogenous grafts, in situ autogenous technique, and location of distal bypass target (anterior tibial or dorsalis pedis arteries).[3,5,6,11,12] This might reflect a difference due to the inclusion of different technical approaches besides the in situ approach in our cohort.

In a larger study looking at index hospitalization SSIs, Kalish and colleagues[7] used the VQI database to analyze risk factors in 7,908 lower extremity bypass cases across 45 states. In univariate analysis, they found associations between SSI and obesity, dialysis, preoperative tissue loss, and vein graft conduit. Although earlier reports conflict on the positive vs negative association between SSI and non-autogenous bypass conduit, our as-treated results corroborate the findings of Kalish and colleagues,[5-7,13] that non-autogenous conduit does not significantly affect SSI risk. However, we found no association with dialysis and preoperative tissue loss. This unique set of risk factors for SSI might be a consequence of the smaller sample size in our study. These differences could also relate to regional variation in demographics and risk factors, as our study is limited to a single institution.

Our study is also the first to report efficacy of chlorhexidine showers for reducing SSIs in vascular patients, although it has been shown to be an effective component of *Staphylococcus aureus* decolonization before certain orthopaedic procedures.[14-16] Most studies evaluating chlorhexidine showering across diverse populations of surgical patients have not identified a significant SSI risk reduction.[15] This might have been due to a lower baseline rate of SSIs, lack of an optimized showering regimen, differences in patient populations, heterogeneity of procedures to which the showers were applied, or that the preoperative shower was not used in conjunction with routine postoperative showering, as in our bundled approach.[10]

There are several limitations to our study. These include being a single-center study and the small sample size. The small sample size impacted our study in 2 ways. First, it likely impaired our ability to identify SSI risk factors specific to our patient population. Second, with only 3 SSI events in the post-intervention period, this low rate of SSIs significantly limited our ability to apply and interpret conventional parametric statistical evaluations. In addition, our pre- and post-intervention cohorts were not identical, with significant differences in distributions of BMI and indication for operation. As for BMI, the third quartile was associated with SSIs, and the post-intervention population had a higher percentage of patients in this quartile, suggesting this difference would be unlikely to skew our post-intervention SSI rate down. As for indication for operation, there was a trend toward fewer patients with rest pain and more with acute ischemia in the post-intervention period. It is difficult to interpret the impact this shift might have had on the SSI rate, as our study did not identify an association between any indication category and SSIs. Earlier studies identified tissue loss or limb salvage as risk factors, but this category remained steady between pre- and post-intervention cohorts. Lastly, the VQI SSI metric is defined as an SSI that occurs during the index hospitalization, which does not capture all clinically significant SSIs and renders comparison of our findings with the existing literature more difficult. The index hospitalization SSI metric, however, is uniformly captured, facilitating more reliable analyses. With no significant difference in the postoperative lengths of stay before and after our intervention, this metric captured the same SSI risk window pre- and post-intervention. In addition, in our cohort of 307 patients, only 185 had 30-day SSI outcomes in the VQI database, impeding meaningful analysis. This was partly because the 30-day outcomes metric in VQI was initiated midway through our evaluation period. Analyzing the index hospitalization SSI rate allowed us to accurately track our target outcomes throughout the duration of our evaluation period.

CONCLUSIONS

Our study represents a successful systematic implementation of an evidence-based SSI reduction bundled intervention. Furthermore, our results suggest that pre- and postoperative chlorhexidine showers can be used to decrease SSIs in lower extremity bypass patients. Importantly, these findings also show that institution-level quality improvement data can be evaluated for risk factors, and that a bundled intervention can be successfully implemented to decrease SSIs in vascular bypass patients.

Author contributions

Study conception and design: Hekman, Michel, Hoel
Acquisition of data: Hekman, Michel
Analysis and interpretation of data: Hekman, Michel, Blay, Helenowski, Hoel
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REFERENCES

1. Bandyk DF. Vascular surgical site infection: risk factors and preventive measures. Semin Vasc Surg 2008;21:119–123.
2. Keenan JE, Speicher PJ, Thacker JK, et al. The preventive surgical site infection bundle in colorectal surgery: an effective approach to surgical site infection reduction and health care cost savings. JAMA Surg 2014;149: 1045–1052.
3. Wengrovitz M, Atnip RG, Gifford RRM, et al. Wound complications of autogenous subcutaneous infrainguinal arterial bypass surgery: predisposing factors and management. J Vasc Surg 1990;11:156–163.
4. Neumayer L, Hosokawa P, Itani K, et al. Multivariable predictors of postoperative surgical site infection after general and vascular surgery: results from the patient safety in surgery study. J Am Coll Surg 2007;204:1178–1187.
5. Fischer JP, Nelson JA, Mirzabeigi MN, et al. Prophylactic muscle flaps in vascular surgery. J Vasc Surg 2012;55: 1081–1086.
6. Johnson JA, Cogbill TH, Strutt PJ, Gundersen AL. Wound complications after infrainguinal bypass. Arch Surg 1988; 123:859–862.
7. Kalish JA, Farber A, Homa K, et al. Factors associated with surgical site infection after lower extremity bypass in the Society for Vascular Surgery (SVS) Vascular Quality Initiative (VQI). J Vasc Surg 2014;60:1238–1246.
8. Johnson MP, Kim SJ, Langstraat CL, et al. Using bundled interventions to reduce surgical site infection after major gynecologic cancer surgery. Obstet Gynecol 2016;127: 1135–1144.
9. Hewitt DB, Tannouri SS, Burkhart RA, et al. Reducing colorectal surgical site infections: a novel, resident-driven, quality initiative. Am J Surg 2017;213:36–42.
10. Edmiston CE Jr, Lee CJ, Krepel CJ, et al. Evidence for a standardized preadmission showering regimen to achieve maximal antiseptic skin surface concentrations of chlorhexidine gluconate, 4%, in surgical patients. JAMA Surg 2015;150: 1027–1033.
11. Feigenbaum HS, Reifsnyder TS, Bandyk DS, et al. Wound complications of the in situ saphenous vein bypass technique. J Vasc Surg 1992;15:0843–0850.
12. Schwartz ME, Harrington EB, Schanzer H. Wound complications after in situ bypass. J Vasc Surg 1988;7:802–807.

13. Szilagyi DE, Smith RF, Elliott JP, Vrandecic MP. Infection in arterial reconstruction with synthetic grafts. Ann Surg 1972; 176:321–333.
14. Lynch W, Davey PG, Malek M, et al. Cost-effectiveness analysis of the use of chlorhexidine detergent in preoperative whole-body disinfection in wound infection prophylaxis. J Hosp Infect 1992;21:179–191.
15. Webster J, Osborne S. Preoperative bathing or showering with skin antiseptics to prevent surgical site infection. Cochrane Database Syst Rev 2012:CD004985.
16. Chen AF, Wessel CB, Rao N. Staphylococcus aureus screening and decolonization in orthopaedic surgery and reduction of surgical site infections. Clin Orthop Relat Res 2013;471: 2383–2399.