

Review Article

An Alternative Wound Class for Orthopedic Surgery is more Strongly Associated with Risk for Postoperative Infection in Total Joint Arthroplasty than the Current Surgical Wound Classification System

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Introduction

Surgical site infections (SSI) continue to be a risk associated with surgery. The Centers for Disease Control (CDC) uses surgical wound class (SWC) to predict SSI postoperatively. Prior studies have shown that the current wound class definitions are unreliable for surgical subspecialties. Therefore, an alternative surgical wound classification (ASWC) was created to more accurately reflect risk of SSI following orthopedic procedures. The purpose of this study was to compare the two systems.

Methods

Seventy patients who developed 90-day SSI following total joint arthroplasty (TJA) were matched 1:1 to patients without postoperative SSI. The SWC was recorded from operative

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reports. Wounds were then retrospectively reclassified according to the ASWC based on preoperative history from the medical record. The degree of agreement and degree of association with occurrence of SSI was compared between the two systems.

Results

The proportion of agreement between the systems was poor (41.4%). The current SWC was associated with risk of SSI in both unadjusted ($p=0.045$) and multivariable analysis ($p=0.050$). Comparatively, the ASWC demonstrated a stronger association with SSI in both unadjusted ($p=0.001$) and multivariable analysis ($p=0.001$).

Conclusion

The results of this study suggest that the ASWC is more predictive for SSI following TJA than the current SWC definitions for total joint arthroplasty.

INTRODUCTION

Surgical site infections (SSI) are classically defined by an infection of the incision, organ, or space following a surgical procedure (Berrios-Torres et al. 2017; O'Hara, Thom, and Preas 2018). In spite of modern advances in sterile technique and perioperative antibiotic administration, surgical site infections continue to be a significant inherent risk associated with surgery. In 2011, The Centers for Disease Control and Prevention (CDC) found SSI to be the most common healthcare-associated infection, accounting for \$3.5-\$10 billion in healthcare expenditure annually (Magill et al. 2014).

In an attempt to better stratify those at risk for developing a SSI, The CDC uses surgical wound class (SWC) as part of a multifactorial risk model that can be allocated to each patient. The current classification system includes four classes (I-IV) based on degree of microbial contamination (Onyekwelu et al. 2017). Historical data established a correlation between increasing surgical wound class and postoperative infections, but nearly all of the reports are based on visceral tissue procedures (Culver et al. 1991; Kao et al. 2011; Ortega et al. 2012). Previous studies have shown that the current wound class definitions are unreliable for surgical subspecialties, including orthopedics (Onyekwelu et al. 2017).

Defining features of the current wound class definitions are centered on contamination from the alimentary and genitourinary tracts (Berrios-Torres et al. 2017). With few exceptions, this is rarely relevant in orthopedic surgery. In contrast, it has been shown that conditions such as prior surgery or immune-compromised status are independently associated with SSI following orthopedic procedures (Reich et al. 2019; de Boer et al. 1999; Cochran et al. 2016; Kunutsor et al. 2016). We therefore created alternative surgical wound class definitions that are focused on both local wound characteristics as well as host factors in order to more accurately reflect risk of subsequent SSI following orthopedic surgery.

The purpose of this study was to examine the degree of agreement between the current and proposed alternative surgical wound classification (ASWC) and to assess associations of each classification with risk of infection following total joint arthroplasty (TJA). We hypothesized that the current SWC and ASWC would demonstrate poor agree-

ment, and that the ASWC would be more predictive for surgical site infections in orthopedic patients.

METHODS

Following institutional review board approval, 70 patients who underwent TJA and developed a postoperative surgical site infection (SSI) at our institution between March 2010 and October 2019 were reviewed. Postoperative SSI was defined by a return to the operating room for either a superficial or deep infection within 90 days following the index procedure. A case-control 1:1 match to patients that did not develop postoperative infection was then performed based upon same procedure (hip versus knee), type of surgery (primary versus revision), and surgical year (± 8 years). A total of 140 patients were available for the retrospective review and comparison of the current SWC and ASWC for orthopedic surgery.

Routine preoperative data was collected, including demographic information, past medical history (including high risk conditions), previous surgical history on the operative limb, and American Society of Anesthesiologist (ASA) score. Operative reports were reviewed to identify the assigned CDC surgical wound class, and 90-day postoperative clinical follow-up notes examined for the presence of infection.

After review of the preoperative history, orthopedic TJA surgical wounds were then retrospectively reclassified according to the alternative surgical wound class. The proposed ASWC definitions were as follows: Class I - clean wound, healthy host (no history of prior procedure at surgical site), Class II - previous surgery, healthy host (no history of prior infection at surgical site), Class III - compromised host (no history of prior infection at surgical site), and Class IV - previous or active infection at surgical site ([Table 1](#)). A compromised host was defined as having at least one of the following high-risk conditions: end-stage organ disease, organ transplant recipient, inflammatory arthritis on immunomodulator therapy, cancer diagnosis on leukopenic chemotherapy, or poorly controlled diabetes mellitus ($HbA1c >8$ at time of surgery). Previous surgery or infection was only pertinent if it was at the site/joint of interest.

Table 1. The current CDC surgical wound class definitions, as well as our proposed alternative

CDC Surgical Wound Class		Alternative Surgical Wound Class
Class I	Clean - Uninfected wound with no inflammation. Respiratory, alimentary, genital, or uninfected urinary tract is not entered.	Clean wound, healthy host (no history of prior procedure at surgical site)
Class II	Clean/Contaminated - Wound in which respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination.	Previous surgery, healthy host (no history of prior infection at surgical site)
Class III	Contaminated - Open fresh/open surgical wounds return to OR, accidental wounds. Gross spillage from GI tract, incisions with acute / nonpurulent inflammation, including necrotic tissue without purulence (dry gangrene).	Compromised host (no history of prior infection at surgical site)
Class IV	Dirty/Infected - Old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera. Suggests that organisms causing postop infection were present preoperatively.	Previous or active infection at site of surgery

STATISTICAL ANALYSIS

The degree of agreement between the current SWC and proposed ASWC was assessed by estimating the proportion of agreement, as well as by estimating weighted kappa. Comparisons of baseline and operative characteristics between patients who did and did not develop an infection following surgery were made using a Wilcoxon rank sum test (continuous or ordinal variables) or Fisher's exact test (categorical variables). Associations of both the current and proposed alternative wound classifications with occurrence of an infection following surgery were evaluated using Cox proportional hazards regression models, where censoring occurred on the date of last follow-up in the controls. Unadjusted Cox regression models were examined, as well as multivariable models that were adjusted for age, sex, and any variable that differed between patients who did and did not develop an infection following surgery with a *p*-value <0.10. Hazard ratios (HRs) and 95% confidence intervals (CIs) were estimated. Each wound classification was examined as a categorical variable where comparisons were made versus a reference wound classification of 1, and also as a continuous variable where an "overall test of association" examined the degree of linear association between wound classification and occurrence of an infection following surgery. *P*-values <0.05 were considered statistically significant. All statistical tests were two-sided. Statistical analyses were performed using SAS (version 9.4; SAS Institute, Inc., Cary, North Carolina).

RESULTS

A comparison of patient characteristics between the postoperative infection and non-infection group is listed in [Table 2](#). Differences were noted between the two groups regarding race (Caucasian: 95.7% vs. 82.9%, *p*=0.026) and, although not quite statistically significant, end-stage organ disease (12.9% vs. 2.9%, *p*=0.055). There were no other significant differences between the groups.

A summary of the degree of agreement between the current SWC and ASWC is shown in [Table 3](#) and [Figure 1](#). There was poor agreement between the two wound classi-

fications with only 41.4% (58/140) proportion of agreement (weighted kappa of 0.15).

An evaluation of associations of the current SWC and ASWC with risk of infection following surgery is displayed in [Table 4](#). The SWC was significantly associated with risk of SSI following surgery in both unadjusted analysis (*p*=0.045) and in multivariable analysis adjusting for age, sex, race, and end-stage organ disease (*p*=0.050). There was a higher proportion of SSI in patients who had CDC surgical wound Class II (9/10; 90%) and Class III/IV (5/7; 71.4%) wounds when compared to those with Class I wounds (56/123; 45.5%).

Comparatively, the ASWC was more strongly associated with risk of infection following surgery than SWC in both unadjusted (*p*=0.001) and adjusted (*p*=0.001) analysis. There was an overall trend towards increased risk of SSI with higher alternative surgical wound classes, from 48.2% in Class I wounds (27/56), 30.2% in Class II wounds (13/43), 65.0% in Class III (13/20), and 81.0% in Class IV (17/21).

The inclusion of BMI ≥ 40 as a criterion for a compromised host (Class III wound) did not improve the ASWC system's ability to predict SSI (*p*=0.004 compared to *p*= 0.001).

DISCUSSION

First introduced by the National Academy of Sciences in 1964, the surgical wound classification was adopted by the Centers for Disease Control as a tool to help predict SSI based on level of wound contamination (Zens, Rusy, and Gosain 2016; Onyekwelu et al. 2017; Centers for and Medicaid Services 2011). According to the CDC guidelines, expected postoperative infection rates increase with wound class; Class I wounds have an expected rate of 1-5%, increasing to over 27% for Class IV wounds (Ortega et al. 2012). This information is used to analyze outcomes by quality improvement organizations as well as third-party payers to dictate reimbursement. Therefore, accuracy and reproducibility in the classification system becomes paramount (Ortega et al. 2012; Levy et al. 2015; Zens, Rusy, and Gosain 2016; Onyekwelu et al. 2017).

The predictive utility for SSI in the CDC SWC system has been best demonstrated following general surgical pro-

Table 2. Comparison of characteristics between patients who developed an infection following surgery and patients who did not develop an infection following surgery

Variable	Infection following surgery (N=70)	No infection following surgery (N=70)	P-value
Age at surgery (years)	69 (32, 93)	67 (26, 88)	0.76
Sex (Male)	37 (52.9%)	30 (42.9%)	0.31
Race (Caucasian)	67 (95.7%)	58 (82.9%)	0.026
BMI	31.0 (15.9, 59.8)	31.2 (19.2, 48.6)	0.83
End stage organ disease	9 (12.9%)	2 (2.9%)	0.055
Transplant	1 (1.4%)	1 (1.4%)	1.00
Inflammatory arthritis on immunomodulators	4 (5.7%)	1 (1.4%)	0.37
Cancer patient on chemotherapy	2 (2.9%)	1 (1.4%)	1.00
Poorly controlled DM (HbA1c > 8)	3 (4.3%)	3 (4.3%)	1.00
ASA classification			0.26
1	0 (0.0%)	1 (1.4%)	
2	24 (34.3%)	29 (41.4%)	
3	43 (61.4%)	38 (54.3%)	
4	3 (4.3%)	2 (2.9%)	
Previous surgery	36 (51.4%)	36 (51.4%)	1.00
Previous open or traumatic wound at site of surgery	0 (0.0%)	0 (0.0%)	1.00
Type of surgery			1.00
TKA	35 (50.0%)	35 (50.0%)	
THA	35 (50.0%)	35 (50.0%)	
Primary or revision			1.00
Primary	34 (48.6%)	34 (48.6%)	
Revision	36 (51.4%)	36 (51.4%)	

The sample median (minimum, maximum) is given for continuous variables. P-values result from a Wilcoxon rank sum test (continuous or ordinal variables) or Fisher's exact test (categorical variables).

Table 3. Degree of agreement between the current surgical wound classification and the alternative surgical wound classification systems

		Alternative Surgical Wound Classification			
		1	2	3	4
Current CDC wound classification	1	54 (38.6%)	42 (30.0%)	20 (14.3%)	7 (5.0%)
	2	1 (0.7%)	0 (0.0%)	0 (0.0%)	9 (6.4%)
	3	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.7%)
	4	1 (0.7%)	1 (0.7%)	0 (0.0%)	4 (2.9%)

cedures (Ortega et al. 2012; Kao et al. 2011; Culver et al. 1991). It has been shown to have a lower predictive value for surgical subspecialties (Campwala, Unsell, and Gupta 2019; Ortega et al. 2012). As an example, Onyekwelu et al. reviewed 400 orthopedic trauma patients and found no correlation with postoperative SSI and the reported SWC (Onyekwelu et al. 2017). One reason for the poor correlation with SSI in surgical subspecialties may be due to inaccurate reporting related to errors in interpretation with the current definitions. For example, while a Class II wound is defined by “a wound in which respiratory, alimentary, genital, or urinary tracts are entered under controlled condi-

tions and without unusual contamination”, we were unable to corroborate such an incursion in the 10 operative reports of patients who were labeled as Class II during their total joint arthroplasty.

Errors in interpretation with the current classification system are well-documented. It has previously been shown that 35–40% of cases are incorrectly classified (Zens, Rusy, and Gosain 2016; Butler, Zarosinski, and Rockstroh 2018). Likewise, several studies have shown only poor to moderate interobserver agreement between clinicians when reporting surgical wound classifications (Hedrick et al. 2014; Wang-Chan et al. 2017). We recently performed an internal review

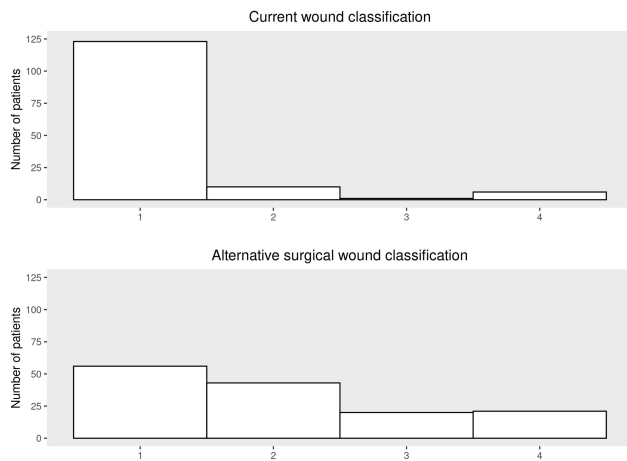


Figure 1.

A histogram demonstrating the frequency of each wound class, using the current surgical and alternative wound classification systems

Table 4. Associations of the two different wound classifications with occurrence of surgical site infection following surgery

		Unadjusted Analysis		Adjusting for age, sex, race and end stage organ disease	
Wound classification variable	Fraction (%) of patients with an infection	HR (95% CI)	P-value	HR (95% CI)	P-value
Current CDC Wound Classification		Overall test of difference: P=0.045		Overall test of association: P=0.050	
1	56/123 (45.5%)	1.00 (reference)	N/A	1.00 (reference)	N/A
2	9/10 (90.0%)	3.16 (1.54, 6.47)	0.002	3.00 (1.44, 6.25)	0.003
3 or 4	5/7 (71.4%)	1.89 (0.75, 4.71)	0.17	1.88 (0.73, 4.86)	0.19
Alternative Surgical Wound Classification		Overall test of difference: P=0.001		Overall test of association: P=0.001	
1	27/56 (48.2%)	1.00 (reference)	N/A	1.00 (reference)	N/A
2	13/43 (30.2%)	0.54 (0.28, 1.05)	0.068	0.68 (0.34, 1.33)	0.26
3	13/20 (65.0%)	1.66 (0.85, 3.21)	0.14	1.48 (0.68, 3.22)	0.32
4	17/21 (81.0%)	2.63 (1.43, 4.85)	0.002	3.61 (1.89, 6.91)	<0.001

HR=hazard ratio; CI=confidence interval. HRs, 95% CIs, and p-values results from Cox proportional hazards regression models. Each wound classification was examined as a categorical variable where comparisons were made vs. a reference wound classification of 1, and also as a continuous variable where an "overall test of association" examined the degree of linear association between wound classification and occurrence of an infection following surgery. Multivariable models were adjusted for age, sex, and any variable that differed between patients with and without an infection with a p-value <0.10.

between orthopedic surgeons at our institution and similarly found poor agreement at 66%.

Due to the questionable predictive power and poor inter-observer agreement when using the current surgical wound class definitions, we hypothesized that alternate, more specialty-specific definitions would lead to improved predictive power for SSI in orthopedic surgery. In creating the ASWC, we utilized known risk factors for SSI, including medical comorbidities and prior surgeries (Bowen and Widmaier 2005; de Boer et al. 1999; Cochran et al. 2016).

There was very little overlap with only 41% of cases demonstrating agreement in class designation when comparing the SWC and the ASWC systems. The current system classifications were significantly right-skewed in this patient population while the alternative definitions were more evenly distributed, indicating a more sensitive system for sorting orthopedic procedures. With the addition of larger numbers and a more diverse patient population we hypothesize that the ASWC will demonstrate an even

greater tendency towards a normal distribution than the current SWC system.

For the classification system to be useful it must accurately predict the outcome of interest. When evaluating the current SWC, unlike previous studies, we found that the tool was predictive for a subsequent SSI in the total joint arthroplasty population. This current system, however, was less strongly associated with risk of infection than the newly proposed ASWC system. In the new system, except for Class II wounds, there was an increased risk for infection with increasing wound class. We believe the discrepancy with Class II wounds was likely related to our small sample size and would demonstrate an increased risk compared to Class I with a larger population.

This study was a retrospective review and has all the inherent limitations encountered in that study design. Additionally, the patient population was small and homoge-

nous. The proposed classification system has not been validated, but is a common-sense approach to classifying orthopedic surgical wounds. Larger studies with more varied surgical procedures will be needed to verify the results.

In conclusion, the results of this study suggest that an alternative surgical wound classification system is more predictive for SSI following TJA than the current surgical wound classification definitions. Consideration should be given to revising the current definitions to more accurately predict SSI in orthopedic total joint arthroplasty patients.

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