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Can the ACS-NSQIP Surgical Risk Calculator Predict Post-Operative Complications in Patients Undergoing Flap Reconstruction Following Soft Tissue Sarcoma Resection?

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Introduction: The ACS-NSQIP surgical risk calculator is an open-access on-line tool that estimates the risk of adverse post-operative outcomes for a wide range of surgical procedures. Wide surgical resection of soft tissue sarcoma (STS) often requires complex reconstructive procedures that can be associated with relatively high rates of complications. This study evaluates the ability of this calculator to identify patients with STS at risk for post-operative complications following flap reconstruction.

Methods: Clinical details of 265 patients who underwent flap reconstruction following STS resection were entered into the online calculator. The predicted rates of complications were compared to the observed rates. The calculator model was validated using measures of prediction and discrimination.

Results: The mean predicted rate of any complication was $15.35 \pm 5.6\%$ which differed significantly from the observed rate of 32.5% ($P = 0.009$). The c-statistic was relatively low at 0.626 indicating poor discrimination between patients who are at risk of complications and those who are not. The Brier's score of 0.242 was significantly different from 0 ($P < 0.001$) indicating poor correlation between the predicted and actual probability of complications.

Conclusion: The ACS-NSQIP universal risk calculator did not maintain its predictive value in patients undergoing flap reconstruction following STS resection.

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Key Words: soft tissue sarcoma; flap reconstruction; risk calculation

INTRODUCTION

Wide surgical resection is the mainstay of treatment for most patients with soft tissue sarcomas (STS) and in many cases the resulting defect will require reconstruction. Plastic surgery is an essential part of the multi-disciplinary management of STS and improvements in reconstructive techniques have greatly extended the feasibility of extensive and curative resections [1,2]. Pedicled flaps or microvascular free tissue transfer may be necessary to achieve closure or coverage of vital structures including bones, joints, neurovascular bundles, and prosthetic devices. In the case of extremity STS, flap reconstruction plays a critical role in facilitating limb salvage and preservation of function [3,4]. Although advances in reconstructive techniques have made extensive resections possible, these complex reconstructions involve long operative procedures, extended hospital stays and protracted post-operative recovery and carry the associated risk of donor site morbidity [5–7]. While radical surgical resection and reconstruction offers a high chance of cure, limb salvage and functional recovery other treatment options including amputation may be associated with significantly lower morbidity rates. It is therefore critical that patients understand the risks associated with these complex procedures.

Quality assurance in surgery places increasing emphasis on the provision of information and involvement of the patient in the decision making process [8–10]. Traditionally patients are presented with a risk estimation based on published data and the surgeon's personal experience but the importance of including patient specific risk assessment in the pre-operative informed consent process is widely recognized [11,12]. The Institute of Medicine has identified the provision of information on treatment benefits and harm as a key priority in the delivery of high-quality cancer care [13].

The American College of Surgeons National Surgical Improvement Program (ACS-NSQIP) collects high-quality validated data on patient demographics, comorbidities, and 30-day post-operative complications. This data has been compiled in a standardized manner from more than 500 hospitals and comprises information on more than one million patients who have undergone a wide range of surgical procedures [14,15]. This database has been used to develop a universal risk calculator that generates a customized risk assessment for more than 1,500 individual surgical procedures [16–18]. The ACS-NSQIP surgical risk calculator is an open access on-line tool available to both surgeons and patients that uses 21 patient-specific variables combined

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with a single CPT code to deliver a personalized risk prediction for 11 adverse post-operative outcomes for that particular surgical procedure. It is recognized as a potentially valuable addition to pre-operative consultations with the Centers for Medicare and Medicaid Services providing financial incentives to physicians who use the calculator and document discussion of the results with their patients [19].

A universal risk calculator that can provide accurate and personalized risk estimation for multiple surgical procedures would be a very useful addition to the pre-operative planning and consent process. It seems unlikely, however that a single risk assessment tool that uses a standardized set of parameters would be able to effectively determine the risk of complications for a diverse range of surgical procedures. The calculator was developed and subsequently validated using data from colorectal procedures and its validity in other patient groups has not been clearly established . The aim of this study was to evaluate the accuracy of the ACS-NSQIP surgical risk calculator in sarcoma patients undergoing flap reconstruction of soft tissue defects. We hypothesize that this universal calculator may not be able to identify individuals at risk of complications in this patient group. We specifically examine the calculator's ability to predict the rate of complications in this patient population and to identify the individual patients who are at risk of developing post-operative complications.

METHODS

Institutional Research Ethics Board approval was obtained for this study. Patients who underwent resection of a soft tissue sarcoma from the extremities or trunk and required reconstruction with either a pedicled or free flap between January 2006 and January 2015 were identified from a prospectively maintained institutional database at Mount Sinai Hospital, Toronto, Canada. Data was collected for the 21 pre-operative factors used by the calculator for risk prediction. These include patient demographics (age, sex, weight, height, functional status, and smoking status), comorbidities (American Society of Anesthesiologists (ASA) score, hypertension, diabetes, congestive heart failure, cardiac event, dyspnea, ascites, steroid use, chronic obstructive pulmonary disease, dialysis, renal failure, systemic sepsis, ventilator dependence, and disseminated cancer), and the nature of the procedure (CPT code, emergency or elective procedure, clean or contaminated).

The calculator includes five CPT codes relevant to this patient group (15,756 free muscle or myocutaneous flap with microvascular anastomosis, 15,757 free skin flap with microvascular anastomosis, 15,736 pedicled muscle, myocutaneous or fasciocutaneous flap upper extremity, 15,738 pedicled muscle, myocutaneous or fasciocutaneous flap lower extremity and 15,734 pedicled muscle, myocutaneous or fasciocutaneous flap trunk), and patients were categorized accordingly. Patient body mass index was categorized into five groups; underweight ($BMI < 18.5$), normal ($18.5 < BMI \leq 25$), overweight ($25 < BMI \leq 30$), obese 1 ($30 < BMI \leq 35$), obese 2 ($35 < BMI \leq 40$), and obese 3 ($BMI > 40$).

Data were entered in the calculator for each patient and the predicted complications were recorded. The actual rate of 30-day post-operative complications was then determined from our institutional prospective sarcoma database and patient chart review. The observed complications were categorized into the options provided by the calculator. *Any complication* included superficial incisional surgical site infection, deep incisional surgical site infection, organ space surgical site infection, wound disruption, unplanned intubation, pulmonary embolism, deep vein thrombosis, ventilator>48 hr, progressive renal insufficiency, acute renal failure, urinary tract infection, stroke, cardiac arrest, myocardial infarction, return to the operating room, or systemic sepsis and *serious complication* included cardiac arrest, myocardial infarction, pneumonia, progressive renal insufficiency, acute renal failure, pulmonary embolism, deep vein thrombosis, return to the operative room, deep incisional surgical site infection, organ space surgical site infection, systemic sepsis, unplanned intubation, urinary tract infection, and wound disruption. The predicted risk was compared to the observed rate of complications to determine the accuracy of the calculator as a predictive tool in this patient population.

Statistical analysis was performed using R version 3.0.2. *P*-values less than or equal to 0.05 were considered significant. Mean, standard deviation and range of all continuous variables, and frequency of all categorical variables were calculated. Bivariate analysis was performed to compare the overall rate of the predicted risk of complications with the observed risk of complications. The accuracy of the model was assessed for both calibration and discrimination using the same statistical tools that were used in the original validation of the calculator. Calibration measures how well the predicted risk of complication matches the observed complication rate and was assessed using the Hosmer–Lemeshow (H–L) goodness of fit test.

Discrimination measures how well the model can separate those who are at risk of complications from those who are not and was measured using c-statistics or the area under the Receiver Operating Characteristics (ROC) curve. The ideal model of discrimination would have a value approaching 1 while a value close to 0.5 indicates that the model has a random performance. Brier's score, defined as the average squared difference between patients' predicted probabilities and observed outcome, was also determined as this is a more global measurement that simultaneously combines both calibration and discrimination and was favored by the developers of the ACS NSQIP risk calculator in the validation of their model. In a perfect model of prediction, the Brier's score will approach 0.

RESULTS

Two hundred and sixty-five patients underwent flap reconstruction following STS resection. The mean age was 59.1 ± 18.5 years and mean BMI was 26.8 ± 6.7. Patient demographics and risk factors recorded in the calculator are outlined in Table I. Bivariate analysis did not identify an association between any of the variables recorded in the calculator and increased complication rates ($P > 0.05$ in all cases, Table I).

Tumors were resected from the lower extremity (52%), upper extremity (33%), and trunk (15%). Pedicled flaps were performed in 186 patients while 79 had free flaps (Table II). The actual observed rates of complications in our patient cohort were 32.5% and 15.9% for *any complication* and *serious complications*, respectively. The observed complications are outlined in Table III. Forty-two patients experienced serious complications as defined by the calculator, the majority ($n = 36$) of which were returns to the operating room for secondary surgery. The most common indication for a return to the operating room was wound infection. Flap related complications required secondary surgery in 15 patients with total flap loss occurring in six (2.3%). Other serious complications included myocardial infarction ($n = 2$), deep vein thrombosis ($n = 2$), pulmonary embolism ($n = 1$), and systemic sepsis ($n = 1$).

The mean predicted rate of *any complication* was $15.35 \pm 5.6\%$ while the mean predicted rate for *serious complications* was $10.7 \pm 3.9\%$. This differed significantly from the actual observed complication rates (32.5%, $P = 0.009$, and 15.9, $P = 0.041$ for *any* and *serious complications*, respectively). The predicted risk of the most commonly recorded complication (return to operating room) was 7.7%, which was significantly lower than the rate observed in our cohort (13.6% $P = 0.038$).

The risk calculator model exhibited a lack of fit, based on the H–L test of calibration ($P = < 0.001$) for *any complication)* indicating that the predicted number of complications did not match the actual number of complications in this patient population.

Based on receiver operating curve (ROC) analysis, the area under the curve for *any complication* was found to be 0.626 (Fig. 1). An ideal

TABLE I. Patient Demographics and Risk Factors as Recorded in the Risk Calculator and Bivariate Analysis for Complications

Variable/risk factor	N = 265 (%)	Complications		
		No	Yes	
Sex				
Male	149 (56)	101	48	
Female	116 (44)	78	38	0.93
Functionally independent				
No	6 (2)	5	2	0.89
Yes	259 (98)	174	84	
Emergency				
No	265 (100)	179	86	N/A
Yes	0 (0)	0	0	
ASA class				
1	16 (6)	14	2	0.29
2	98 (37)	67	31	
3	134 (51)	86	48	
4	17 (6)	12	5	
Wound class clean				
No	4 (1)	3	1	N/A
Yes	261 (99)	176	85	
Chronic steroid use				
No	263 (99)	178	85	N/A
Yes	2 (1)	1	1	
Ascites				
No	265 (100)	179	86	N/A
Yes	0 (0)	0	0	
Systemic sepsis				
No	265 (100)	179	86	N/A
Yes	0 (0)	0	0	
Ventilator dependent				
No	265 (100)	179	86	N/A
Yes	0 (0)	0	0	
Disseminated cancer				
No	247 (93)	169	78	0.26
Yes	18 (7)	10	8	
Diabetes				
No	240 (90)	166	74	0.08
Oral	18 (7)	13	12	
Insulin	7 (3)			
Dialysis				
No	265 (100)	179	86	N/A
Yes	0 (0)	0	0	
Dyspnea				
No	247 (93)	170	77	0.1
Yes	18 (7)	9	9	
Hypertension				
No	170 (64)	119	51	0.25
Yes	95 (36)	60	35	
Previous cardiac event				
No	243 (92)	161	82	0.24
Yes	22 (8)	18	4	
Congestive heart failure				
No	262 (99)	177	85	N/A
Yes	3 (1)	2	1	
Severe COPD				
No	256 (97)	173	83	0.62
Yes	9 (3)	6	3	
Acute renal failure				
No	265 (100)	179	86	N/A
Yes	0 (0)	0	0	
Current smoker				
No	214 (81)	147	67	0.42
Yes	51 (19)	32	19	
BMI				
Underweight	14 (5)	11	3	0.16
Normal	98 (37)	72	26	
Overweight	89 (34)	53	36	
Obese 1	34 (13)	26	8	
Obese 2	20 (7)	11	9	
Obese 3	10 (4)	6	4	
Age				
<65 years	157 (59)	112	45	0.17
65–74 years	46 (17)	31	15	
75–84 years	49 (18)	28	21	
≥85 years	13 (5)	8	5	

Statistical comparisons were not performed for variables occurring in ≤1% of study population.

TABLE II. Distribution of Pedicled and Free Flaps

	n (% of total)
Pedicled flaps (n = 186)	
Gastrocnemius	58 (22)
Latissimus dorsi	44 (17)
Radial forearm	27 (10)
Anterolateral thigh	17 (7)
Rectus abdominus	17 (7)
Perforator	6 (2)
Gluteus maximus	5 (1.8)
Soleus	3 (1)
Tensor fascia lata	2 (0.8)
Rectus femoris	2 (0.8)
Pectoralis	2 (0.8)
Paraspinal	1 (0.3)
Gracilis	1 (0.3)
Trapezius	1 (0.3)
Free flaps (n = 79)	
Anterolateral thigh	46 (17)
Latissimus dorsi	16 (6)
Rectus abdominus	8 (3)
Radial forearm	6 (2)
Gracilis	2 (0.8)
Parascapular	1 (0.3)

model of discrimination would have an AUC of 1.0 while a value closer to 0.5 indicates random performance of the tool.

The Brier's Score for *any complication* was 0.242, which was significantly different from 0 ($P < 0.001$). This indicates a poor correlation between the observed and predicted probability of complications and is illustrated in Figure 2.

DISCUSSION

This study demonstrates that the ACS-NSQIP surgical risk calculator is not the ideal tool for identifying STS patients at risk for complications following flap reconstruction. The calculator significantly underestimated the overall rate of complications in this patient cohort. The low c-statistic value of 0.626 confirmed that the calculator had poor discriminatory value in this population and was unable to effectively

TABLE III. Observed Complications in the Study Group

Complication	n % (of total)
Minor complications	44 (16.6)
Infection	21 (7.9)
Dehiscence	10 (3.8)
Delayed wound healing	8 (3.0)
Partial necrosis	4 (1.5)
Urinary tract infection	1 (0.4)
Serious complications	42 (15.9)
Return to operation room	36 (13.6)
Infection	13 (4.9
Hematoma	5 (1.9)
Dehiscence	3 (1.1)
Flap compromise	4 (1.5)
Partial flap loss	5 (1.9)
Total flap loss	6 (2.3)
Myocardial infarction	2 (0.8)
Deep vein thrombosis	2 (0.8)
Systemic sepsis	1 (0.4)
Pulmonary embolism	1 (0.4)
Total	86 (32.5)

Minor complications are those recorded as "any complication" that did not reach the criteria for "serious complication" as defined by the calculator. Complications were classified as minor if they did not require readmission or return to the operating room for secondary surgical procedures.

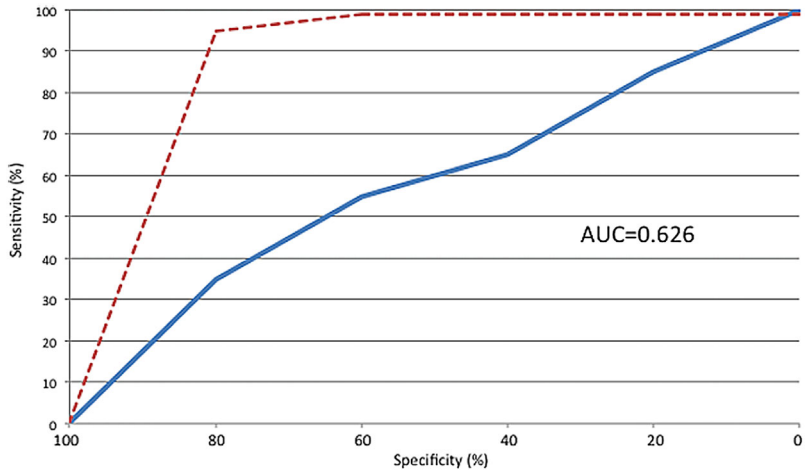

Fig. 1. Area under the receiver operating curve (ROC; c-statistic) indicating poor discriminatory power of the model for any complication (solid blue line). Dashed red line shows ideal model where area under the curve would be greater than 0.8.

differentiate between patients who would develop complications post-operatively and those who would not. This contrasts with the higher c-statistics (>0.8) reported by the developers in their validation of the model.{Bilimoria, 2013 #16} In addition, the high Brier's score of 0.242 indicates that the calculator had low predictive power in this series.

This universal risk calculator was developed from a disease specific colorectal risk calculator and was subsequently validated in a similar patient population [17]. The results of our study are perhaps unsurprising as it is ambitious to expect a single tool to be able to accurately predict complications for a diverse range of surgical procedures. Our findings support previous reports demonstrating lack of validity of the universal risk calculator in both arthroplasty and pulmonary surgery [20,21]. Many of the parameters collected in the calculator pertain to acutely ill patients and may be less relevant to elective surgery. Although the patient cohort in this study was a heterogenous group with a wide age range and a relatively high rate of comorbidities they were unlikely to have severe disease such as acute renal failure, systemic sepsis, or ventilator dependence. Nine of the 21 parameters included in the calculator were recorded in less than 1% of the patients in our study. Conversely, other factors that we know to be clinically relevant in the assessment of risk in the context of sarcoma resection and flap reconstruction are not considered [22–24]. Conditions such as peripheral vascular disease, connective tissue disease, autoimmune disease, or clotting disorders are not included in the risk assessment. The size and site of the tumour can be expected to have significant impact on the complication rate following surgery [25,26]. Adjuvant therapies such as chemotherapy and most importantly pre-operative radiation are known to have a major impact on wound healing complication rates both with and without flap reconstruction following resection of STS but are not recorded in this model [27–29].

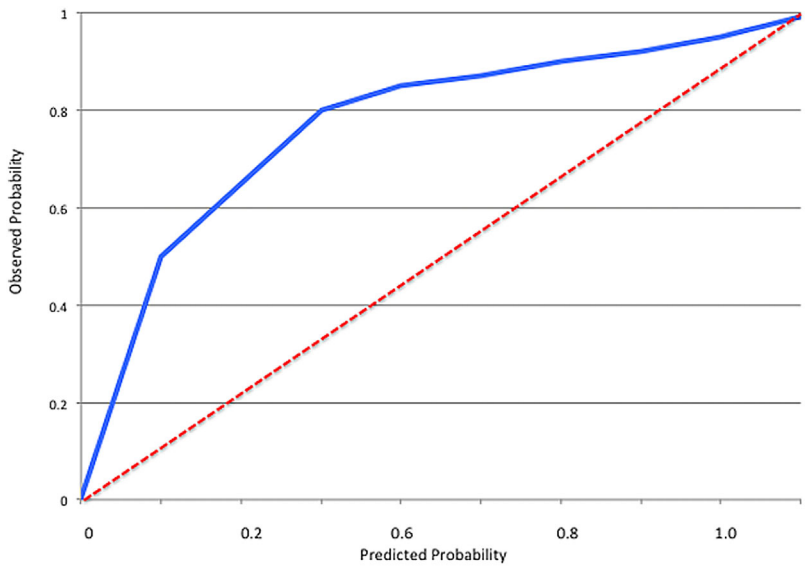

Fig. 2. Relationship between the predicted and observed probability of any complication (solid blue line). Dashed red line indicates the linear relationship between predicted and observed risk in an ideal model of prediction. Brier's score 0.242 ($P < 0.001$).

The calculator cannot accommodate multiple procedure codes, which limits its usefulness in complex multidisciplinary cases. In this study, flap procedure codes were used in all cases but the complications recorded resulted from a combination of both extirpative and reconstructive procedures. The discrepancy between predicted and observed complications rates may be due to the omission of factors related to the tumour itself and its resection. The complexity of the tumour based on the involvement of deep structures, as well as the need for vascular, neural, or bony reconstruction vary greatly between patients. The calculator includes multiple CPT codes for radical tumor resection and it is possible that these may give more precise risk predictions, but they were not assessed in this study. The CPT codes provided for soft tissue reconstruction may also be a source of discrepancy. Free flap codes do not consider the site of reconstruction as they are categorized according to the constituents of the flap (myocutaneous or fasciocutaneous) while pedicled flaps are divided by anatomical site (trunk, upper limb, or lower limb) and so do not consider the type of flap used.

We acknowledge that our study has limitations. The calculator was developed using cumulative data from multiple centres while our validation uses data collected at a single high volume institution. Previous studies have cautioned against the extrapolation of the NSQIP dataset to institutional complication rates in the context of elective and reconstructive surgery. Although most of the clinical data was obtained form our prospective database information regarding some complications and co-morbidities were collected retrospectively which may have lead to some inaccuracies. Observed complications were adjusted to fit the categories of the calculator, which may introduce an element of subjectivity. The developers acknowledge that the risk calculator cannot incorporate all relevant parameters for every individual procedure codes. The calculator therefore includes a function that allows surgeons to adjust the risk if they feel there was a salient factor that was not recorded. This, however, adds a subjective element and reduces the value of the calculator as an objective tool and was not used in this study. This "Surgeon Assessment Score" was not formally modeled in the development of the calculator and there is no quantitative evidence that this adjusted risk is more accurate. Our study only examined risk factors included in the calculator itself and while it demonstrates that these factors do not correlate with complication rates we did not examine other factors that may predict complications and as such this study does not provide the basis for the development of an alternative risk assessment tool.

Although the universal risk calculator is a very attractive concept, a disease-specific calculator may prove more effective in the prediction of risk in this population as it could incorporate more pertinent patient, surgery, and disease specific data related to elective STS resection and flap reconstruction. Recognition of the importance of tumour size, neo-adjuvant radiation and complexity of surgery, and the ability to combine procedure codes in cases of complex reconstruction may enhance the accuracy of the tool. In addition, the NSQIP calculator only considers complications that occur in the first 30 days post-operatively. In this patient group information on longer term sequelae such as need for reoperation, locoregional recurrence, and functional outcome may be of significant assistance to patients in their decision-making process.

CONCLUSIONS

The ACS NSQIP surgical risk calculator does not accurately predict complications in patients undergoing reconstruction following wide surgical resection of STS. This study highlights the importance of validation of this universal tool in individual patient populations and perhaps the need for disease specific calculators to provide individualized pre-operative risk assessment.

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