Research Article

Predicting Risk of 30-day Postoperative Morbidity Using the Pathologic Fracture Mortality Index

Ashish Vankara, BS
Christopher R. Leland, MD
Ridge Maxson, BS
Micheal Raad, MD
Samir Sabharwal, MD, MPH
Carol D. Morris, MD, MS
Adam S. Levin, MD

ABSTRACT

Introduction: The purpose of this study was to evaluate the ability of the Pathologic Fracture Mortality Index (PFMI) to predict the risk of 30-day morbidity after pathologic fracture fixation and compare its efficacy with those of the American Society of Anesthesiologists (ASA) physical status, modified Charlson Comorbidity Index (mCCI), and modified frailty index (mFI-5).

Methods: Cohorts of 1,723 patients in the American College of Surgeons National Surgical Quality Improvement Program database from 2005 to 2020 and 159 patients from a tertiary cancer referral center who underwent fixation for impending or completed pathologic fractures of long bones were retrospectively analyzed. National Surgical Quality Improvement Program morbidity variables were categorized into medical, surgical, utilization, and all-cause. PFMI, ASA, mCCI, and mFI-5 scores were calculated for each patient. Area under the curve (AUC) was used to compare efficacies.

Results: AUCs predicting all-cause morbidity were 0.62, 0.54, and 0.56 for the PFMI, ASA, and mFI-5, respectively. The PFMI outperformed the ASA and mFI-5 in predicting all-cause ($P < 0.01$), medical ($P = 0.01$), and utilization ($P < 0.01$) morbidities. In the 2005 to 2012 subset, the PFMI outperformed the ASA, mFI-5, and mCCI in predicting all-cause ($P = 0.01$), medical ($P = 0.03$), and surgical ($P = 0.05$) morbidities but performed similarly to utilization morbidity ($P = 0.19$). In our institutional cohort, the AUC for the PFMI in morbidity stratification was 0.68. The PFMI was associated with all-cause (odds ratio [OR], 1.30; 95% confidence interval [CI], 1.12 to 1.51; $P < 0.001$), medical (OR, 1.19; 95% CI, 1.03 to 1.40; $P = 0.046$), and utilization (OR, 1.32; 95% CI, 1.14 to 1.52; $P < 0.001$) morbidities but not significantly associated with surgical morbidity (OR, 1.21; 95% CI, 0.98 to 1.49; $P = 0.08$) in this cohort.

Discussion: The PFMI is an advancement in postoperative morbidity risk stratification of patients with pathologic fracture from metastatic disease.

From the Department of Orthopaedic Surgery, Division of Orthopaedic Oncology, The Johns Hopkins Hospital, Baltimore, MD (Vankara, Leland, Maxson, Raad, Sabharwal, and Levin), Orthopaedic Surgery Service, Memorial Sloan-Kettering Cancer Center, New York, NY (Morris)

Correspondence to Dr. Levin: alevin25@jhmi.edu

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Pathologic fracture is a severe complication observed in patients with primary or metastatic bone lesions.[1] Among patients with advanced cancer resulting in skeletal metastasis, the incidence of pathologic fracture ranges from 17% to 43% depending on the cancer subtype.[2] By comparison, up to 65% of patients with multiple myeloma, a malignant plasma cell disorder, may sustain a pathologic fracture due to osteolytic destruction and diffuse osteopenia.[3] Such fractures can cause substantial pain, limit functional independence, and portend death. Determining an optimal treatment of these injuries can be challenging.[4] Patients with impending or completed pathologic fractures benefit from surgical stabilization, which can reduce pain, improve mobility, prevent future fractures, and prolong survival.[5,6] However, the possible advantages of surgery should be weighed against potential postoperative morbidity and life expectancy of the patient.

Unfortunately, early complications from surgical treatment of pathologic fractures are quite common.[7,8] Previous studies indicate that between 12% and 31% of patients experience at least one complication within 30 days after surgery.[9-12] Several independent predictors of short-term complications after pathologic fracture fixation have been identified, including older age; rapidly growing primary tumors; multiple bone metastases; and preoperative hypoalbuminemia, hyponatremia, and leukocytosis.[9,12] The introduction of the Metastatic Bone Disease module of the Musculoskeletal Tumor Registry (MsTR) may yield improved opportunities for comparison of postsurgical outcomes among surgical strategies, although no consensus exists regarding the best approach to postoperative morbidity risk stratification among patients with pathologic fractures to contextualize such a comparison among procedures. Current morbidity predictor tools, such as the American Society of Anesthesiologists (ASA)–Physical Status score, modified five-component frailty index (modified frailty index [mFI-5]), and Charlson Comorbidity Index (CCI), are widely used to predict the risk of early complications in nononcologic patients undergoing orthopaedic procedures,[13-15] but these tools fail to provide adequate granularity to risk-stratify complex oncologic patients accurately. In the orthopaedic surgery literature, ASA ≥ III and CCI ≥ 6 are each correlated with increased morbidity after hip fracture.[16,17] However, active metastatic carcinoma is a severe systemic disease consistent with ASA III on its own, so the ASA score does not have discriminatory ability to further distinguish risk among this already high-risk population; metastatic solid tumor already yields a CCI of 6 and is thus limited by the same concern. Notably, scoring systems, such as the Pathologic Fracture Mortality Index (PFMI), have been created to predict survival in the osseous metastatic cohort. The PFMI is a simple, reliable, and validated clinical tool used to predict 30-day postoperative mortality in patients with surgically managed pathologic fractures.[18] The utility of the PFMI in predicting postoperative morbidity risk in this population has not yet been explored.

Therefore, the purpose of this study was to assess and validate the ability of the PFMI to predict the risk of 30-day all-cause, medical, surgical, and utilization morbidity after pathologic fracture fixation. We hypothesized that the PFMI would be superior to existing methods at predicting 30-day morbidity in oncologic patients managed surgically for impending or completed pathologic fractures.

Methods

Study Cohort

In this study, data extracted from American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database from 2005 to 2020 were analyzed. The NSQIP registry includes preoperative and 30-day postoperative data of patients undergoing surgeries at 705 participating hospitals worldwide.[19] We included adult patients (18 years and older) with an impending or completed pathologic long-bone fracture secondary to malignancy. Patients with nonmyelomatous primary bone cancers (International Classification of Diseases [ICD]-10 C40–41.99) or incomplete data were excluded from the analysis. Cancer diagnoses and subsequent pathologic fractures were identified using the ICD-9 and ICD-10 systems (Supplemental Table 1, http://links.lww.com/JAAOS/A965). The location of each fracture was coded using Current Procedural Terminology codes (Supplemental Table 2, http://links.lww.com/JAAOS/A966).

After the application of the inclusion criteria, 1,723 patients who underwent completed or impending fixation for pathologic fracture of a long bone (ie, femur, humerus, or tibia) were identified. All data to determine the PFMI, mFI-5, and ASA scores were readily available in this database. Because of modifications in NSQIP variables that prohibited data concatenation, the

modified Charlson Comorbidity Index (mCCI) could be calculated only in a smaller subset of the larger cohort using data from 2005 to 2012.

Institutional Cohort

To validate our findings, the efficacy of the PFMI was assessed in a separate cohort of 159 patients using an internal registry from a high-volume tertiary cancer referral center. After institutional review board approval was obtained, a retrospective chart review of prospectively collected data was performed to identify patients who underwent fixation of impending or completed pathologic fractures at our institution between 2013 and 2021. Adult patients undergoing surgical stabilization of impending or completed pathologic long-bone fracture from metastatic or myelomatous bone disease were included, and we excluded patients with nonmyelomatous primary bone neoplasms, non-neoplastic pathologic bone diseases (eg, osteoporosis), aneurysmal bone cysts, or primary benign bone lesions (eg, enchondroma and nonossifying fibroma). We collected the parameters comprising the PFMI (see 'Comorbidity Index Parameters') along with demographic data, preoperative characteristics, and postoperative morbidity using identical definitions of the NSQIP cohort (see 'Postoperative Morbidity') (Supplemental Table 3, http://links.lww.com/JAAOS/A967).

Comorbidity Index Parameters

The PFMI, mFI-5, ASA, and mCCI indices were calculated for each patient in the NSQIP cohort. The PFMI is composed of seven validated preoperative predictors of perioperative mortality in patients with pathologic fractures secondary to metastatic disease (Supplemental Table 4, http://links.lww.com/JAAOS/A968).[18] A point value between 1 and 3 is ascribed to each variable commensurate with its predictive capacity. Preoperative hypoalbuminemia (<3.5 mg/dL) is ascribed three points. A history of recent weight loss of >10% in 6 months and a history of pulmonary disease (defined as having preoperative symptoms of dyspnea or having a diagnosis of chronic obstructive pulmonary disease) are each given two points. Preoperative anemia (hematocrit <36 in female patients and <39 in male patients), preoperative leukocytosis (white blood cell count >12,000), dependence for daily living, and alkaline phosphatase level >150 IU/L are each ascribed one point.

Postoperative Morbidity

NSQIP preoperative variables were categorized as medical, surgical, or utilization morbidity (Supplemental Table 3, http://links.lww.com/JAAOS/A967). We defined medical morbidity as instances of pneumonia, unplanned intubation, pulmonary embolism, cerebrovascular accidents with neurologic deficits, cardiopulmonary resuscitation administration, myocardial infarction, deep vein thrombosis, thrombophlebitis, sepsis, *Clostridioides difficile* infection, and renal failure. Utilization morbidity was defined as unplanned readmissions and postoperative stays longer than 12 days (>90% percentile length of stay). Surgical morbidity was defined as superficial surgical site infection, organ space infection, open wound infection, wound disruption occurrence, and unplanned revision surgery. Medical, surgical, and utilization morbidities were subsequently pooled together to derive all-cause morbidity.

Statistical Analysis

The accuracy of each clinical tool was determined from the NSQIP cohort using the area under the curve (AUC) calculated from a receiver operating characteristic curve analysis.[20] Previous studies in the orthopaedic literature have used AUC analyses to quantify the predictive ability of various clinical tools.[18,21] AUC values range from 0.5 to 1.0 and measure the capacity of a diagnostic or predictive model to correctly classify true-positive and true-negative cases. As defined for use in diagnostic tests, an AUC of 0.9 to 1.0 is generally deemed excellent, 0.8 to 0.9 is deemed good, 0.7 to 0.8 is deemed acceptable, 0.6 to 0.7 is deemed poor, and 0.5 to 0.6 is considered a failed classifier. However, predictive tools differ from diagnostic tests in that they attempt to predict outcomes that have not yet occurred. This stochastic element of time can result in lower AUC values when assessing predictive tools.[22] Descriptive statistics were used to describe rates of postoperative morbidity. A univariable logistic regression was used to render a per-point increase in PFMI odds ratio [OR] associated with developing postoperative all-cause, medical, surgical, or utilization morbidity in our institutional cohort. Alpha for all statistical analyses was set at 0.05. All analyses were performed using Stata statistical software: Release 17 (StataCorp LLC, 2021).

Results

National Surgical Quality Improvement Program Cohort

A total of 1,723 patients were analyzed in the 2005 to 2020 NSQIP cohort. Patient demographic data are presented in Table 1. In total, 271 patients (16%)

experienced medical morbidity, 68 (3.9%) experienced surgical morbidity, and 386 (22%) experienced utilization morbidity with a pooled 30-day postoperative morbidity incidence of 544 patients (32%). The PFMI was superior to the ASA and mFI-5 in predicting all-cause morbidity ($P < 0.01$), medical morbidity ($P = 0.02$), and utilization morbidity ($P < 0.01$), but performed similarly to the ASA and mFI-5 when predicting surgical morbidity (Table 2 and Figure 1). In the 2005 to 2012 subset, the PFMI performed superiorly to the ASA, mFI-5, and mCCI in predicting all-cause morbidity ($P = 0.01$), medical morbidity ($P = 0.03$), and surgical morbidity ($P = 0.05$) but performed similarly in utilization morbidity (Table 3).

Institutional Cohort

A total of 159 patients were included in the institutional cohort. All the patients were treated for impending or

Table 1. NSQIP Cohort Characteristics

Variable		N	Percentage of Cohort
		1723	
Age (yr)	<80	1,438	83.5
	≥80	285	16.5
	Mean (IQR)	67 (59–76)	
Sex	Male	737	42.8
	Female	986	57.2
Femur fixation		1,458	85
Humerus fixation		239	14
Tibial fixation		26	2
Hypoalbuminemia (mg/dL)	≥3.5	730	42.3
	<3.5	993	57.6
BMI (kg/m^2)	25–35	801	46.5
	<25	696	40.4
	>35	226	13.1
Dialysis	No	1,695	98.4
	Yes	28	1.6
Anemia	Hct ≥36 (female) or Hct ≥39 (male)	1,162	67.4
	Hct < 36 (female) or Hct < 39 (male)	561	32.6
Diabetes mellitus	No	1,622	94.1
	Yes	101	5.9
Dependence for daily living	No	1,424	82.6
	Yes	299	17.4
Weight loss	≤10% weight loss in past 6 months	1,554	90.2
	>10% weight loss in past 6 months	169	9.8
Leukocytosis (WBC/L)	$\leq 12.0 \times 10^9$	1,449	84
	$>12.0 \times 10^9$	274	15.9
Elevated alkaline phosphatase (U/L)	≤150	1,258	73
	>150	465	27.0
History of pulmonary disease (COPD and dyspnea)	No	1,416	82.1
	Yes	307	17.8

BMI = body mass index, COPD = chronic obstructive pulmonary disease, hct = hematocrit, IQR = interquartile range, NSQIP = National Surgical Quality Improvement Program, WBC = white blood cell

Table 2. Area Under the Receiver Operating Characteristic Curve (NSQIP 2005 to 2020)

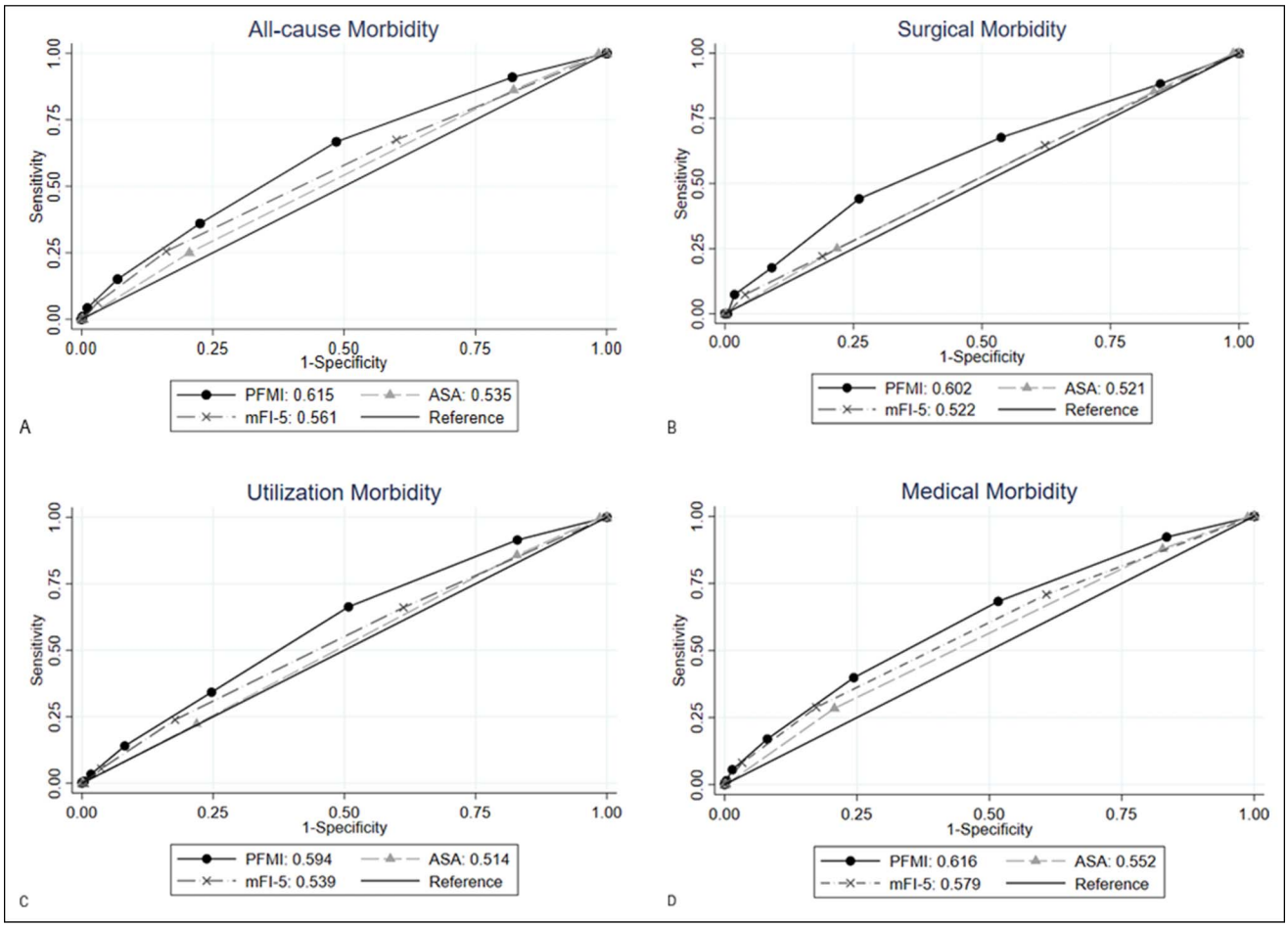
Morbidity	PFMI	ASA Score	mFI-5	*P*
All-cause	0.62[b]	0.54	0.56	<0.01
Surgical	0.60	0.52	0.52	0.11
Medical	0.62[a]	0.55	0.58	0.02
Utilization	0.59[b]	0.51	0.54	<0.01

ASA = American Society of Anesthesiologists; mFI-5, modified frailty index, NSQIP = National Surgical Quality Improvement Program, PFMI = Pathologic Fracture Mortality Index
[a]$P < 0.05$.
[b]$P < 0.005$.

completed pathologic fracture of a long bone secondary to disease states, such as myelomatous bone disease or metastatic disease. Patient demographics are presented in Table 4.

In total, 25 patients (16%) experienced medical morbidity, 14 (9%) experienced surgical morbidity, and 62 (39%) experienced utilization morbidity, with a pooled morbidity incidence of 70 patients (44%) in our cohort. When used to risk stratify for all-cause, medical, surgical, and utilization morbidities, the PFMI surpassed the 0.6 threshold to serve as a predictive tool, resulting in AUCs of 0.68, 0.62, 0.64, and 0.69, respectively. In predicting all-cause morbidity, the AUCs of the mCCI, ASA, and mFI-5 were 0.52, 0.57, and 0.61, respectively.

Figure 1



Graphs showing A, all-cause, (**B**) surgical, (**C**) utilization, and (**D**) medical morbidity receiver operating characteristic curves (2005 to 2020).

Table 3. Area Under the Receiver Operating Characteristic Curve (NSQIP 2005 to 2012)

Morbidity	PFMI	mCCI	ASA Score	mFI-5	*P*
All-cause	0.66[a]	0.54	0.53	0.54	0.01
Surgical	0.66[a]	0.48	0.63	0.58	0.05
Medical	0.61[a]	0.55	0.47	0.48	0.03
Utilization	0.64	0.56	0.56	0.55	0.19

ASA = American Society of Anesthesiology, mCCI = modified CCI, mFI-5 = modified Frailty Index, NSQIP = National Surgical Quality Improvement Program, PFMI = Pathologic Fracture Mortality Index.
[a]$P < 0.05$.

Table 4. Characteristics of Institutional Cohort (N = 159)

Variable		n	Percentage of Cohort (%)
Age	Mean (IQR)	63.1 (56-74)	
Sex	Female	76	47.8
	Male	83	52.2
Fracture location	Femur	117	74
	Humerus	37	23
	Radius	1	0.6
	Tibia	2	1.2
	Ulna	1	0.6
Pulmonary disease	Yes	21	13.2
	No	138	86.8
Preoperative anemia	Yes	123	77.3
	No	36	22.6
Preoperative hypoalbuminemia	< 3.5 mg/dL	55	34.6
	≥3.5 mg/dL	104	65.4
Alkaline phosphatase	>150 U/L	53	33.3
	<150 U/L	106	66.7
Weight loss	Yes	37	23.3
	No	122	76.7
WBC count	>12,000	17	10.7
	<12,000	142	89.3
Dependence for daily living	Dependent	18	11.3
	Independent	141	88.7
INR	>1.1	23	14.5
	≤1.1	136	85.5
Thrombocytopenia	≤ 150K/μL	32	20.1
	> 150K/μL	127	79.9
BUN	≥ 28 mg/dL	23	14.5
	< 28 mg/dL	136	85.5

BUN = blood urea nitrogen, IQR = interquartile range, INR = international normalized ratio, WBC = white blood cell

The PFMI outperformed all three of these indices (P = 0.02) in our institutional cohort. A higher PFMI score was associated with increased risk of postoperative morbidity. A per-point increase in the PFMI score was associated with increased odds of all-cause morbidity (OR, 1.30; 95% confidence interval [CI], 1.12 to 1.51; $P < 0.001$), medical morbidity (OR, 1.19; 95% CI, 1.03 to 1.40; $P = 0.046$), and utilization morbidity (OR, 1.32; 95% CI, 1.14 to 1.52; $P < 0.001$) but was not associated with surgical morbidity in our sample size (Table 5).

Discussion

Surgical fixation of pathologic fractures is associated with a high rate of postoperative morbidity. Improved methods of morbidity risk stratification are necessary for patients undergoing orthopaedic surgery for established or impending pathologic fracture. In this study, we assessed the efficacy of the PFMI in predicting risk of 30-day postoperative morbidity after pathologic fracture fixation in patients with metastatic or myelomatous osseous disease. We then compared its predictive accuracy with that of multiple commonly used risk stratification tools. Notably, despite having a lower AUC than anticipated, the PFMI was still moderately more accurate than the mCCI, mFI-5, and ASA scores in predicting 30-day postoperative all-cause, medical, and surgical morbidity in the 2005 to 2012 cohort and all-cause, medical, and utilization morbidity in the 2005 to 2020 cohort. These findings largely validated our initial hypothesis and present an opportunity to augment current risk stratification methods in oncologic musculoskeletal surgery.

Patients with pathologic fractures related to skeletal malignancy generally have poor short-term prognoses. Median survival after pathologic fracture fixation has been reported to be as low as 3 to 4 months, and the rate of 1-year postoperative survival ranges from 27% to 51%.[23-26] Orthopaedic surgery can play a critical role in the short-term palliation of pain and disability in these patients. Substantial pain reduction has been observed as early as 2 weeks after pathologic fracture fixation,[23] and functional gains are generally observed after at least 6 weeks postoperatively.[8] However, morbidity during the early postsurgical period can diminish quality of life and interfere with recovery. Furthermore, both minor and major complications related to surgical intervention are associated with markedly lower odds of survival at 30 days and 1 year postoperatively.[9,12] Patients at high risk of short-term complications, particularly those with limited expected survival, may therefore be less likely to benefit from surgery. Given the notable ramifications of postoperative morbidity, surgeons must be able to identify high-risk patients to ensure appropriate patient selection and facilitate preoperative patient counseling.

A morbidity risk assessment tool is the next step in refining patient care in musculoskeletal tumor surgery. Notably, the Musculoskeletal Tumor Society and the American Academy of Orthopaedic Surgeons recently collaborated to develop the MsTR.[24] The MsTR is a prospectively collected repository of longitudinal, outcomes-based data focused on bone and soft-tissue tumors intended to facilitate systems-level research and clinical decision making. With the introduction of the Metastatic Bone Disease module of the MsTR, opportunities may exist to better compare outcomes among surgical techniques. However, the limitations of risk stratification among these patients with metastatic disease who already meet the ASA $\geq$ III and CCI $\geq$ 6 criteria challenge the ability to reliably compare clinical outcomes. The PFMI is uniquely positioned to address this deficiency specific to the MsTR and to appropriately risk-stratify patients undergoing evaluation by an orthopaedic oncologic surgeon for pathologic fracture fixation.

The PFMI has previously exhibited superior stratification of 30-day postsurgical mortality risk among patients with osseous metastatic disease when compared

Table 5. Pathologic Fracture Mortality Index (PFMI) Area Under the Receiver Operating Characteristic Curve (Institutional Cohort)

Morbidity	AUC	Morbidity Risk: OR (95% CI)	*P*
All-cause	0.68	1.30 (1.13-1.51)	<0.01
Surgical	0.64	1.21 (0.98-1.49)	0.08
Medical	0.62	1.19 (1.03-1.40)	0.05
Utilization	0.69	1.32 (1.14-1.52)	<0.01

AUC = area under the receiver operating characteristic curve, CI = confidence interval, PFMI = Pathologic Fracture Mortality Index

with the ASA and mFI-5 scores.[16] In this study, the PFMI, similarly yet modestly, outperformed these tools and the mCCI when predicting the risk of various forms of 30-day postoperative morbidity after pathologic fracture fixation. However, its predictive accuracy fell short of achieving the desired AUC threshold of ≥0.7 across all forms of morbidity. Modifications to the PFMI scoring criteria, such as consideration of fracture characteristics, may improve its prognostic ability related to postoperative complications. For example, multiple studies have shown that patients with completed pathologic fractures experience greater rates of morbidity after surgery than those with impending fractures.[10,12,25] Furthermore, surgery on the lower extremity has been linked to higher complication risk than upper extremity surgery, possibly because of relatively more complex and lengthier operations, which often require longer hospital stays and more intense postoperative rehabilitation.[12] Factoring in these dichotomous, objective, and easily accessible variables may improve performance while adding minimal complexity to the risk calculation. Maximizing simplicity is critical because an advantage of the PFMI is its relative ease of use because each of its current components is typically collected during standard preoperative evaluation.[16] Additional improvements to the PFMI may also be identified through investigations using the MsTR.

Existing morbidity prediction tools, such as the ASA score, CCI, and mFI-5, are limited in their ability to stratify oncologic patients based on the risk of short-term complications after orthopaedic surgery. These indices have not been sufficiently validated in patients undergoing surgical stabilization of pathologic fracture and cannot reliably predict morbidity on a timescale that is appropriate for patients with oncologic diagnoses. For example, an increased ASA score, particularly a score of ≥ III, has been described as a risk factor of complications after orthopaedic procedures.[26,27] However, the ASA system may be inconsistently applied in the oncologic orthopaedic population. For instance, in a retrospective series of 434 patients with peripheral skeletal metastases studied by Bonnevialle et al,[28] just 27% of patients were given an ASA score of ≥ III. By contrast, 83% of patients in our NSQIP cohort were classified as ASA IV or higher, describing a patient with an incapacitating disease that is a constant life threat. Because ASA III denotes a patient with severe systemic disease that is not life-threatening, it would be reasonable to argue that advanced metastatic disease resulting in a completed or impending pathologic fracture necessitates at least an ASA III. It is unclear how nearly 75% of patients in the study by Bonnevialle were classified as ASA II or lower despite having skeletal metastases, unless a disproportionate percentage were in remission, but this discrepancy with our findings suggests that the ASA system may not be uniformly applied in this patient population. Furthermore, the potential for inter-rater variability when assigning ASA scores has been acknowledged in the literature.[29] The poor performance of the ASA score in our study further underscores its inherent shortcomings for prediction in this patient population.

Similarly, the CCI has limited utility for postoperative morbidity risk stratification among patients with skeletal lesions. Unlike the subjective assessment used by the ASA score, the CCI is an objective, standardized model that generates a weighted score for patients based on existing comorbidities.[30] This complex morbidity index is widely used to predict complication risk associated with orthopaedic surgery.[13,31] The mCCI, a validated adaptation of the CCI used for NSQIP analysis, has also been predictive of postoperative complications in patients operated on for spinal tumors.[32,33] However, no previous study has validated its use among patients undergoing fixation of long bones secondary to malignancy. In our cohort, the mCCI failed (AUC < 0.6) to predict any form of postoperative morbidity. One explanation for the poor discriminative ability of the mCCI in this population is that a diagnosis of metastatic carcinoma alone automatically raises the score to a high-risk category.[34] Therefore, all patients in this population are designated as high risk, which restricts any additional, more granular risk stratification. For effective stratification of morbidity risk in patients with advanced cancer, the CCI must undergo modifications to its scoring weights or be replaced by a more targeted predictive model. The mFI-5 is an alternative predictive model that assesses morbidity and mortality risk based on objective differences in patients' physiologic reserves. This risk assessment tool has proven to be an effective predictor of postoperative morbidity in patients undergoing nononcologic spinal surgery and distal radius fracture fixation.[35,36] However, using the NSQIP database to study outcomes in 2,170 patients undergoing surgical resection of spinal tumors, Lakomkin et al found no association between mFI-5 scores and risk of postoperative adverse events. Furthermore, the mFI-5 has never been used to predict postoperative complications after pathologic fracture fixation, and our data suggest that it may be inferior in predicting 30-day postoperative morbidity risk in this patient cohort.

The strengths of this investigation include the generalizability of its findings owing to its use of a large,

multinational data set; validation in an external institutional cohort with comparable results; and use of specific laboratory cutoff values in calculating the PFMI score. However, this study has some limitations. First, NSQIP collects data only within a 30-day postoperative period, which prohibits assessment of medium-term and long-term surgical outcomes. It is also possible that missing or incorrectly coded information in NSQIP could have affected calculations of predictive ability. Furthermore, our characterization of postoperative morbidity was robust but not exhaustive, so the true morbidity burden after pathologic fracture fixation is likely underestimated by this study. Moreover, the PFMI can signal increased risk of general categories of morbidity after surgery (eg, medical, surgical, and utilization) but cannot currently predict the likelihood of specific complications or differentiate between major and minor complications.[37] In addition, data from the institutional cohort are subject to possible selection bias associated with a retrospective chart review. Future investigation and prospective studies are needed to assess adverse outcome risk beyond the 30-day postoperative window, as well as complications not accounted for in this study.

Conclusion

The findings of this study demonstrate that the PFMI modestly outperforms other commonly used comorbidity indices in predicting early postoperative morbidity among patients undergoing pathologic fracture fixation due to metastatic or myelomatous bone disease. In our institutional cohort, the PFMI was an independent predictor of all-cause, medical, and utilization morbidity. Expanding the PFMI to include both morbidity and mortality risk assessment may further enhance its utility in guiding preoperative decision making as well as patient and family counseling. The PFMI represents a promising alternative to established risk stratification tools and may serve as a valuable addition to the MsTR module for use in patients being evaluated by musculoskeletal tumor surgeons. In addition, the PFMI may prove to be useful in future clinical studies analyzing patient outcomes after surgical intervention for pathologic fracture. Additional investigations are warranted to augment the predictive capacity of the PFMI. Optimizing preoperative risk assessment in patients with oncologic diagnoses is paramount to facilitating perioperative management and risk-standardized outcome assessment.

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