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Original Research

Who Is Treating Periprosthetic Femur Fractures? An Analysis of the Periprosthetic Research Consortium

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ABSTRACT

Background: Periprosthetic femur fractures (PPFFs) following total hip arthroplasty (THA) have increased in the past decade as the demand for primary surgery continues to grow. Although there is now more evidence to describe the treatment of Vancouver B fractures, there is still limited knowledge regarding factors that cause surgeons to perform either an open reduction and internal fixation (ORIF) or revision THA (rTHA). The purpose of this study was to determine what type of surgeons treat Vancouver B PPFFs at 11 major academic institutions and if there are trends in treatment decision-making regarding the use of ORIF or rTHA based on surgical training or patient factors.

Methods: This multicenter retrospective study evaluated patients surgically treated for Vancouver B PPFF after THA between 2014 and 2019. Patients from 11 academic centers located in the United States were included in this study. Surgical outcomes and patient demographics were evaluated based on surgeon training, surgical treatment type, and institution.

Results: Presence of Vancouver B2 (odds ratio [OR]: 0.02, $P < .001$) or B3 (OR: 0.04, $P < .001$) fractures were independent risk factors for treatment with rTHA. Treatment by a trauma (OR: 12.49, $P < .001$) or other-specified surgeon (OR: 13.63, $P < .001$) were independent risk factors for ORIF repair of Vancouver B fractures. There were no differences in outcomes based on surgeon subspecialty training.

Conclusions: This study showed the trends in surgeons who surgically manage Vancouver B fractures at 11 major academic institutions and highlighted that regardless of surgical training or surgical treatment type, postoperative outcomes following management of PPFF were similar.

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Introduction

Periprosthetic femur fractures (PPFFs) are a rare complication of total hip arthroplasty (THA) that have increased in the past decade as the demand for primary surgery continues to grow [1,2]. Previous research has postulated that the increase in PPFF may be due to the expanded indications for THA in younger and older patients as well as an increase in life expectancy, leading to more primary THA being performed in osteoporotic patients [3,4]. PPFF is 1 of the most serious complications of THA, with a previously reported incidence range of 1%-11% and a mortality of 11% [1,5]. In particular, the proportions of Vancouver B1, B2, and B3 fractures among PPFFs have been documented as 14.5%, 24.5%, and 9.2%, respectively [6].

Management of PPFFs frequently includes surgical intervention, and treatment strategy is most often determined based on the validated Vancouver classification system [7,8]. Specifically, Vancouver B fractures have been historically treated with open reduction and internal fixation (ORIF) to ensure stabilization or revision total hip arthroplasty (rTHA), which have been shown to improve mortality rates [9]. The use of ORIF and rTHA and surgical outcomes for Vancouver B subcategory fractures have been evaluated at several single institutions [10,11] and more recently by the Periprosthetic Research Consortium [12]. Further recommendations for the subcategories of Vancouver B fractures have been proposed [13]. However, adherence to these recommendations may differ among surgeons due to their training background and the hospital setting where PPFFs are treated. Surgical management historically has been performed by arthroplasty or trauma orthopaedic surgeons; however, there are no specified guidelines as to the allocation of treatment based on surgical training [14].

Previously, the Periprosthetic Research Consortium established a database with the collaboration of 11 centers in the United States to study the differences in reoperations after Vancouver B PPFF based on fracture characteristics, surgical treatment, and surgeon training. Specifically, the consortium found that patients with Vancouver B type and B3 subtype PPFFs who were treated by a non-arthroplasty-trained surgeon tended to have a higher risk of reoperation. Additionally, the use of ORIF or rTHA did not lead to an increased risk of reoperation [12].

Although there is now more evidence to describe the treatment of Vancouver B fractures, there is still limited knowledge regarding factors that cause surgeons to perform either an ORIF or rTHA. Additionally, information regarding whether PPFFs are predominantly treated by trauma or arthroplasty-trained surgeons at the institution or regional level is unknown. The purpose of this study was to (1) determine what type of surgeons treat Vancouver B PPFFs at 11 major academic institutions as well as (2) determine if there are trends in treatment decision-making regarding the use of ORIF or rTHA based on surgical training or patient factors.

Material and methods

This is a multicenter retrospective review of adult patients (>18 years old) who underwent treatment for PPFF after THA between 2014 and 2019. Patients from 11 academic centers located in the United States were included in this study. Institutional review board approval was obtained at each center prior to the commencement of this retrospective review. Patients were excluded if their postoperative follow-up was less than 6 months, unless they underwent a reoperation prior to 6 months of follow-up.

At each participating institution, patient demographics, surgical characteristics, postoperative outcome measurements, the number of surgeons treating PPFFs, and surgeon fellowship training were collected. Of the 11 centers included in this study, 3 were regionally located in the Northeast (Centers 1, 2, and 4), 5 were located in the South (Centers 3, 6, 7, 8, and 11), and 3 were located in the West region of the United States (Centers 5, 9, and 10). Six hundred one PPFFs were included in this study from the participating 11 institutions. Of those patients with fractures, 343 had 6 months of follow-up and were classified as Vancouver B fractures based on radiographic imaging review. Of patients with Vancouver B fractures, median ages between centers ranged from 69 to 82 years, and all centers had a higher proportion of females than males (Table 1).

Regionally, 122 fractures were treated at northeastern centers, 118 were treated at southern centers, and 103 were treated at western centers. Of the Vancouver B fractures treated at northeastern centers, 82.8% were treated by an arthroplasty surgeon, while 81.4% and 64.1% fractures were treated by arthroplasty surgeons at southern and western centers, respectively. The highest proportion of patients receiving treatment by an arthroplasty surgeon at 1 center was 100%, while the highest proportion of patients receiving treatment by an orthopaedic trauma surgeon at 1 center was 44.4% (Table 1). Only 7 of the 11 centers had a Vancouver B3 fracture in their cohort. Across all centers, 105 surgeons were identified who treat PPFFs, of which 51.4% were arthroplasty surgeons, 40.9% were trauma surgeons, and 7.6% were other-trained surgeons. The majority of northeast and southern surgeons who treated PPFFs were arthroplasty-trained (55.1% and 55.2%, respectively), while western surgeons were primarily trauma-trained (Fig. 1). Across all centers, the average age of arthroplasty surgeons was 46.9 years, while the average age of trauma surgeons was 42.6 years. Additionally, the average years of experience of arthroplasty and trauma surgeons were 15.3 and 10.3 years, respectively.

Collected patient demographic data included age, sex, body mass index (BMI), smoking status, chronic kidney disease, peripheral vascular disease, diabetes mellitus, and preinjury ambulatory status. Data pertaining to surgical characteristics included the use of cementation vs press-fit during the primary THA. Outcome measurements included reoperation, nonunion, malunion, infection, instability, and postoperative ambulatory status following primary THA.

Surgical treatment types as well as outcomes of PPFF were also collected from participating centers. Treatment type was categorized as nonsurgical, ORIF, or rTHA with or without ORIF. Similar to Toci et al., revision arthroplasty with internal fixation components were considered to be rTHA, while surgical treatment with plate, screw, and/or cerclage cable fixation with no revision of the femoral stem component was considered ORIF [12]. Additionally, orthopaedic surgeons at each institution reviewed radiographic images prior to ORIF, rTHA, or nonsurgical treatment to classify each PPFF based on the Vancouver scale (A, B1, B2, B3, or C) [15,16].

To assess the influence of surgical training on PPFF treatment, surgeons were classified as arthroplasty, orthopaedic trauma, or other. An arthroplasty specialist was defined as a surgeon who completed an adult reconstruction fellowship or routinely performed more than 200 total joint arthroplasties per year [12]. Orthopaedic trauma specialists were defined as surgeons who completed an orthopaedic trauma fellowship. If a surgeon completed both an orthopaedic trauma and adult reconstruction fellowship, they were considered to be an arthroplasty surgeon for the purposes of this

Table 1
Center-specific information regarding demographics, Vancouver B periprosthetic fracture classification, and treatment by arthroplasty, trauma, or other orthopaedic surgeons.

Variable	Center 1 (N = 41)	Center 2 (N = 40)	Center 3 (N = 11)	Center 4 (N = 41)	Center 5 (N = 18)	Center 6 (N = 32)	Center 7 (N = 5)	Center 8 (N = 16)	Center 9 (N = 63)	Center 10 (N = 22)	Center 11 (N = 54)
Arthroplasty	38 (92.7%)	33 (82.5%)	9 (81.8%)	30 (73.2%)	10 (55.6%)	30 (93.8%)	2 (40.0%)	16 (100%)	39 (61.9%)	17 (77.3%)	39 (72.2%)
Other	3 (7.30%)	5 (12.5%)	2 (18.2%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (20.0%)	0 (0.00%)	7 (11.1%)	3 (13.6%)	15 (27.8%)
Orthopaedic trauma	0 (0.00%)	2 (5.00%)	0 (0.00%)	11 (26.8%)	8 (44.4%)	2 (6.2%)	2 (40.0 %)	0 (0.00%)	17 (27.0%)	2 (9.10%)	0 (0.00%)
Age	69.1 (11.1)	74.8 (10.6)	69.8 (14.7)	72.9 (10.5)	70.7 (10.2)	72.2 (10.7)	45.4 (15.4)	80.2 (10.0)	77.1 (13.0)	72.4 (20.9)	74.6 (10.6)
Sex: female	31 (75.6%)	31 (77.5%)	6 (54.5%)	25 (61.0%)	14 (77.8%)	22 (68.8%)	4 (80.0%)	10 (62.5%)	36 (57.1%)	13 (59.1%)	43 (79.6%)
BMI	27.4 (6.51)	28.0 (5.18)	26.1 (5.57)	29.7 (5.75)	28.4 (6.58)	29.1 (6.42)	24.7 (1.95)	25.9 (8.45)	27.0 (5.69)	27.6 (5.98)	28.7 (6.89)
Smoking:											
Nonsmoker	18 (43.9%)	38 (95.0%)	11 (100%)	38 (92.7%)	15 (83.3%)	23 (71.9%)	3 (60.0%)	16 (100%)	57 (90.5%)	20 (90.9%)	49 (90.7%)
Smoker	23 (56.1%)	2 (5.00%)	0 (0.00%)	3 (7.32%)	3 (16.7%)	9 (28.1%)	2 (40.0%)	0 (0.00%)	6 (9.52%)	2 (9.09%)	5 (9.26%)
CKD	1 (2.44%)	3 (7.50%)	1 (9.09%)	7 (17.1%)	2 (11.1%)	2 (6.25%)	0 (0.00%)	1 (6.25%)	13 (20.6%)	2 (9.09%)	14 (25.9%)
PVD	3 (7.32%)	4 (10.0%)	2 (18.2%)	3 (7.32%)	1 (5.56%)	1 (3.12%)	2 (40.0%)	1 (6.25%)	13 (20.6%)	3 (13.6%)	9 (16.7%)
Diabetes	2 (4.88%)	3 (7.50%)	2 (18.2%)	8 (19.5%)	2 (11.1%)	5 (15.6%)	2 (40.0%)	3 (18.8%)	16 (25.4%)	3 (13.6%)	16 (29.6%)
Vancouver:											
B1	1 (2.44%)	4 (10.0%)	1 (9.09%)	9 (22.0%)	5 (27.8%)	7 (21.9%)	3 (60.0%)	3 (18.8%)	19 (30.2%)	7 (31.8%)	6 (11.1%)
B2	40 (97.6%)	35 (87.5%)	10 (90.9%)	29 (70.7%)	12 (66.7%)	21 (65.6%)	2 (40.0%)	9 (56.2%)	39 (61.9%)	13 (59.1%)	48 (88.9%)
B3	0 (0.00%)	1 (2.50%)	0 (0.00%)	3 (7.32%)	1 (5.56%)	4 (12.5%)	0 (0.00%)	4 (25.0%)	5 (7.94%)	2 (9.09%)	0 (0.00%)
Cement-primary	1 (2.44%)	3 (7.69%)	2 (18.2%)	1 (2.44%)	3 (16.7%)	0 (0.00%)	0 (0.00%)	6 (37.5%)	0 (0.00%)	0 (0.00%)	3 (5.56%)

Data are presented as N (%).
CKD, chronic kidney disease; PVD, peripheral vascular disease.

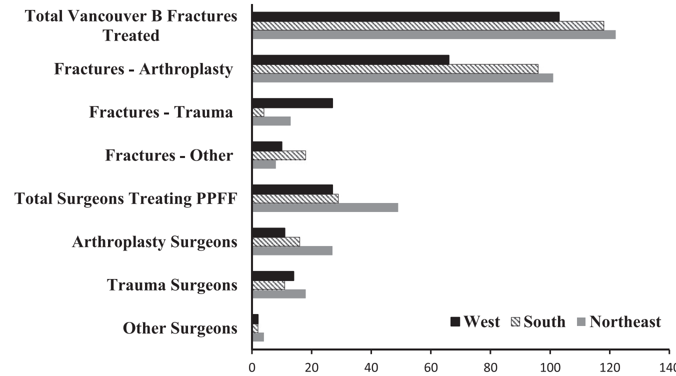

Figure 1. Vancouver B fractures and surgeon training by geographic region.

study, as all these surgeons performed at least 200 TJAs per year. Of the 11 centers included, 10 reported having at least 1 trauma surgeon who treats PPFFs. The 10 centers also described their protocol, which involved the trauma team directing PPFF patients to the subspecialty/subspecialist selected by the trauma team, with 1 center permitting the on-call physician to refer the patient to the subspecialty/subspecialist chosen by the on-call physician.

Surgeon fellowship training information was evaluated collectively as well as at the individual center level. Subgroup analysis for outcome measurements and surgical characteristics was performed for patients who underwent ORIF or rTHA after primary THA. Additionally, analysis was also performed to evaluate surgical characteristics for patients treated by arthroplasty, trauma, or other orthopaedic surgeons. Multivariate logistic regression analyses were performed for patients with Vancouver B fractures undergoing ORIF as opposed to rTHA for reoperation. Independent variables used in the multivariate logistic regression analyses included surgeon type (arthroplasty, trauma, or other) and patient demographics (age, sex, BMI, smoking status [current or nonsmoker], chronic kidney disease, peripheral vascular disease, and diabetes status). A P value of < .05 was considered statistically significant for all statistical analyses. All analyses were performed using RStudio Version 4.0.2 (Boston, MA).

Results

Surgeon training

Patients operated on by trauma surgeons were the oldest (79.0 vs 73.0 for arthroplasty and 71.5 for others, $P = .035$). Arthroplasty surgeons performed the highest rate of rTHA (89.0% vs 36.4% for trauma specialists and 58.3% for others, $P < .001$), and orthopaedic trauma surgeons operated on the highest proportion of Vancouver B1 PPFFs (50.0% vs 13.3% for arthroplasty and 22.2% for others, $P < .001$). There was not a significant difference in outcomes such as rate of reoperation, nonunion, malunion, infection, instability, or postoperative ambulatory status based on surgeon subspecialty training (Table 2).

Treatment type

Of 343 Vancouver B PPFFs treated operatively, 72 (21.0%) were treated with ORIF alone, while 271 (79.0%) were treated with rTHA with or without ORIF. Patients who underwent rTHA were most often performed by an arthroplasty surgeon (86.3%) in comparison to only 40.3% of ORIF surgeries ($P < .001$). Additionally, Vancouver B2 fractures were more commonly treated with rTHA (88.2%), while B1 fractures were treated with ORIF (69.4%, $P < .001$). There were no

Table 2
Surgical characteristics based on surgeon training.

Variable	Arthroplasty	Other	Trauma	*P*-value
	n = 263	n = 36	n = 44	
Treatment:				<.001[a]
ORIF	29 (11.0%)	15 (41.7%)	28 (63.6%)	
Revision THA	234 (89.0%)	21 (58.3%)	16 (36.4%)	
Vancouver:				<.001[a]
B1	35 (13.3%)	8 (22.2%)	22 (50.0%)	
B2	212 (80.6%)	28 (77.8%)	18 (40.9%)	
B3	16 (6.08%)	0 (0.00%)	4 (9.09%)	
Cemented primary:	14 (7.25%)	2 (6.90%)	3 (12.0%)	.570
Reoperation:	50 (19.0%)	9 (25.0%)	14 (31.8%)	.134
Nonunion:	14 (6.33%)	4 (11.1%)	3 (8.57%)	.463
Malunion:	14 (6.33%)	4 (11.1%)	3 (8.57%)	.505
Infection:	23 (10.3%)	5 (13.9%)	5 (14.3%)	.631
Instability:	22 (9.69%)	2 (5.56%)	4 (11.4%)	.659
Ambulatory at 3 months postoperatively:	214 (89.9%)	29 (82.9%)	31 (86.1%)	.341
Ambulatory at 6 months postoperatively:	207 (95.4%)	29 (96.7%)	28 (93.3%)	.872

[a] Indicates statistical significance ($P < .05$). Data are presented as N (%).

Table 4
Surgical characteristics based on treatment type.

Variable	ORIF	Revision THA	*P*-value
	N = 72	N = 271	
Surgeon type:			<.001[a]
Arthroplasty	29 (40.3%)	234 (86.3%)	
Other	15 (20.8%)	21 (7.75%)	
Trauma	28 (38.9%)	16 (5.90%)	
Vancouver:			<.001[a]
B1	50 (69.4%)	15 (5.54%)	
B2	19 (26.4%)	239 (88.2%)	
B3	3 (4.17%)	17 (6.27%)	
Cemented primary:	1 (2.27%)	18 (8.87%)	.211
Reoperation:	18 (25.0%)	55 (20.3%)	.481
Nonunion:	9 (15.0%)	12 (5.17%)	.020[a]
Malunion:	1 (1.67%)	10 (4.33%)	.470
Infection:	10 (16.4%)	23 (9.87%)	.227
Instability:	1 (1.67%)	27 (11.3%)	.041[a]
Ambulatory at 3 months postoperatively:	47 (73.4%)	227 (92.7%)	<.001[a]
Ambulatory at 6 months postoperatively:	53 (93.0%)	211 (95.9%)	.314

[a] Indicates statistical significance ($P < .05$). Data are presented as N (%).

other significant differences in demographics between Vancouver B fracture patients who received surgical repair with either rTHA or ORIF. (Table 3). There was a higher rate of instability in the rTHA group (11.3% vs 1.67%, $P = .041$) and a higher rate of nonunion in the ORIF group (15.0% vs 5.17%, $P = .020$). Those treated with rTHA were more likely to be ambulatory at the 3-month postoperative timepoint (92.7% vs 73.4%, $P < .001$). There was not a significant difference in reoperation rate based on treatment type (Table 4).

Regression analysis

Having either a Vancouver B2 or B3 were significant independent risk factors for treatment with rTHA (odds ratio [OR]: 0.02, $P < .001$, and OR: 0.04, $P < .001$, respectively). Treatment by a trauma or other-specified surgeon was also an independent risk factor for ORIF repair of Vancouver B fractures (OR: 12.49, $P < .001$, and OR: 13.63, $P < .001$, respectively). Demographic factors such as age, sex, BMI, smoking status, chronic kidney disease, peripheral vascular disease, or diabetes were not found to be independent factors in receiving treatment with rTHA or ORIF (Table 5).

Table 3
Surgical treatment characteristics.

Variable	Total data	Revision THA	ORIF	*P*-value
	N = 343	N = 271	N = 72	
Age:	73.3 (12.8)	73.1 (11.5)	74.0 (16.8)	.156
Sex:				.961
Female	235 (68.5%)	185 (68.3%)	50 (69.4%)	
Male	108 (31.5%)	86 (31.7%)	22 (30.6%)	
BMI (range)	27.9 (6.22)	28.1 (6.39)	27.2 (5.49)	.305
Smoking status:				.987
No	288 (84.0%)	227 (83.8%)	61 (84.7%)	
Yes	55 (16.0%)	44 (16.2%)	11 (15.3%)	
CKD:	46 (13.4%)	34 (12.5%)	12 (16.7%)	.473
PVD:	42 (12.2%)	32 (11.8%)	10 (13.9%)	.782
Diabetes:	62 (18.1%)	45 (16.6%)	17 (23.6%)	.230

Data are presented as N (standard deviation) and N (%).
CKD, chronic kidney disease; PVD, peripheral vascular disease.

Discussion

PPFFs around THA are becoming increasingly more prevalent [2]. We evaluated the institution-specific and overall allocation patterns for surgical treatment of Vancouver B fractures at 11 diverse institutions, as well as treatment decision-making based on surgical training and patient factors. Overall, the number of patients treated for Vancouver B fractures substantially varied among the centers included in this study. Across all regions of the United States, the majority of surgeries for Vancouver B fractures were performed by an arthroplasty surgeon, although centers from the western region of the United States included the largest cohort of patients treated by a trauma surgeon. Furthermore, 10 of the 11 centers stated their PPFF management protocol consisted of the orthopaedic on-call team referring patients to the subspecialist of the on-call team's choice. While the reasoning for this regional trend is not fully understood, it is possibly due to the increasing number of arthroplasty surgeons practicing in comparison to orthopaedic trauma surgeons in the United States [17], the average number of completed applications for arthroplasty fellowship is nearly double that of trauma fellowship [18], and additional insight regarding triage methodology at the participating centers.

Surgical training background was determined to influence the surgical strategy selected for managing Vancouver B fractures, as bivariate and multivariate analyses both demonstrated that trauma surgeons were more likely to perform ORIF in comparison to arthroplasty and other surgeons. Additionally, arthroplasty surgeons performed significantly more rTHA than ORIF for all subgroup fracture types evaluated. Previous research has demonstrated a training-based trend for primary femoral neck fractures and periprosthetic femoral fractures following total knee arthroplasty [14,19]. Furthermore, Perry et al. demonstrated that 10 of 11 patients with Vancouver B2 fractures at a single trauma center treated by a fellowship-trained arthroplasty surgeon were managed with rTHA [10]. This further supports our findings that arthroplasty surgeons are more likely to perform revision surgery, while trauma surgeons perform fixation. Although the differences in surgical procedure type were significant between surgeons with various training backgrounds, the reoperation rates, postoperative ambulation, and rates of complications were comparable, therefore indicating similar outcomes. As this study only included major

Table 5
Multivariate logistic regression for receiving treatment with open reduction and internal fixation (ORIF) in Vancouver B fractures.

Variable	Estimate	*P*-value	Odds ratio	Lower 95	Upper 95
Surgeon type:					
Arthroplasty	Reference				
Other	2.52	<.001[a]	12.49	4.30	37.73
Trauma	2.61	<.001[a]	13.63	4.78	41.44
Vancouver:					
B1	Reference				
B2	−3.97	<.001[a]	0.02	0.01	0.05
B3	−3.24	<.001[a]	0.04	0.01	0.18
Age	−0.01	.712	0.99	0.96	1.03
Male	−0.17	.682	0.84	0.36	1.90
BMI	−0.04	.224	0.96	0.89	1.02
Smoker	0.23	.690	1.26	0.39	3.75
CKD	0.15	.805	1.16	0.33	3.79
PVD	0.28	.630	1.33	0.41	4.12
Diabetes	−0.43	.456	0.65	0.21	1.95

CKD, chronic kidney disease; PVD, peripheral vascular disease.
[a] Indicates statistical significance ($P < .05$).

academic centers, the level of fellowship training and resources available may be substantially different from those in community hospitals and other hospital systems. Therefore, the outcomes demonstrated in this multicenter cohort study may not be generalizable to all hospital systems. However, this information does suggest that in hospital systems with limited availability of either highly skilled trauma or arthroplasty surgeons, outcomes can be expected to be similar regardless of the surgical subspecialty training.

There were no demographic factors to predict which patients received treatment with either ORIF or rTHA except for preoperative radiographic Vancouver classification. Both bivariate and multivariate analyses demonstrated Vancouver B2 and B3 fractures were more likely to be surgically reconstructed using rTHA in lieu of ORIF. Overall, the average BMI in both surgical treatment cohorts was less than 30, but BMI was not shown to be a predictor of ORIF or rTHA. It is likely arthroplasty surgeons may be more comfortable treating patients with a BMI over 40 using a revision procedure, while trauma surgeons may elect to treat with ORIF. However, due to the multicenter nature of this study, our results did not provide granular detail on the relationship between BMI and treatment in obese patients. Additionally, Vancouver B fractures treated with rTHA had lower nonunion rates and earlier postoperative ambulation, while those treated with ORIF resulted in decreased instability compared to rTHA. In a systematic review by González-Martín et al., which reviewed 856 patients with Vancouver B2 fractures, 57.6% were treated with rTHA and functional testing, and first-year mortality results were similar between ORIF and rTHA management. However, ORIF allowed for shorter operative time, less need for transfusion, fewer complications, lower reoperation rate, and shorter length of stay [20]. Additionally, a meta-analysis by Haider et al. consisting of 1132 patients with either Vancouver B2 or B3 fractures showed 84.8% of cases were treated with rTHA, while functional outcomes, mortality rates, and overall complication rates did not differ between the rTHA and ORIF cohorts [21]. There is no consensus in the current literature or in our study in regard to functional outcomes and complications to support a superior approach to treating Vancouver B2 or B3 fractures; however, it is clear that the most common treatment used was rTHA. It is possible this finding is due to the recommendations previously supported by the authors of the Vancouver classification on Vancouver B fracture treatment as well as comfortability regarding technique surgeons have based on fellowship training [16].

Our study also demonstrated Vancouver B1 fractures were more likely to be treated with ORIF in comparison to rTHA. The original PPFF treatment guidelines by Duncan and Masri in 1995 recommended B1 fractures be treated with ORIF due to their stable stem [16,20]. B1 fractures have previously been treated conservatively; however, if nondisplaced, it has been suggested that surgical management is best when the patient is an appropriate candidate for surgery [1,22]. Additionally, in an observational retrospective study by Roche-Albero et al., 37 patients with B1 fractures were shown to be appropriately treated with ORIF, as this technique allowed for good results even in elderly patients or those with poor bone quality [23]. A cross-sectional survey of both trauma and arthroplasty surgeons also showed ORIF to be the most preferred management technique, with only 2.3% of respondents preferring nonoperative management [24]. However, in a retrospective study by Efird et al., there was no difference in 1-year mortality, union rate, or return to preinjury ambulatory status in select nonoperative and operative patients with B1 fractures [25]. Our findings support the original recommendations and cross-sectional survey study data; however, there is still discussion as to the appropriate management of B1 fractures among surgeons for select patients such as those with minimally displaced fractures and partial remaining distal fixation.

There are several limitations to this study. First, across all centers, patients with a PPFF were retrospectively identified, and therefore, as with all retrospective studies, there is the risk of sampling bias. Each center included in the study was responsible for the collection of patient data, and differences in data extraction, completeness of data, and fracture type classification may have occurred. Second, the participating centers primarily consisted of adult reconstruction-trained surgeons, and therefore the regional treatment trends demonstrated in this study may not be generalizable or reflect the practices in other centers throughout the United States. Lower extremity PPFFs have been shown to be treated predominantly in large and urban teaching hospitals, with the majority of patients managed at their presenting hospital without transfer to a tertiary care center [26,27]. However, to our knowledge, there is no prior research assessing PPFF management that describes hospital demographics regarding surgeon fellowship training. It is likely other centers primarily consist of trauma fellowship-trained surgeons who treat Vancouver B fractures. Third, because the majority of surgeons included in this study were arthroplasty-trained, there was possibly further selection bias to treat marginal Vancouver B1 and B2 fractures with rTHA in lieu of ORIF due to surgeon comfort level. Fourth, classification of fractures was performed using preoperative imaging, and previous research has shown intraoperative classification may be more accurate [28,29]. Additionally, while preoperative imaging was utilized for diagnosis, further imaging information pertaining to stem position and fracture assessment was not available from all participating centers. Future research should include additional preoperative and postoperative radiographic characteristics to further assess outcomes of Vancouver B fracture surgical management. Fifth, indications for primary THA and mechanism of injury-causing PPFF were not collected in this study, which may further affect revision treatment decision-making. Finally, many patients with less than 6-month follow-up were excluded from our analysis, and therefore this may have resulted in fewer patients with excellent outcomes necessitating shorter follow-up.

Conclusions

Our study evaluated 1 of the largest cohorts of Vancouver B PPFFs. Surgical treatment for Vancouver B fractures was predominantly treated by arthroplasty surgeons at all centers. Arthroplasty surgeons most commonly performed rTHA, and orthopaedic trauma surgeons had the highest rate of choosing ORIF.

rTHA was more likely used to treat B2 and B3 fractures and resulted in lower nonunion rates and earlier postoperative ambulation for all Vancouver B features in comparison to those treated by ORIF. Additionally, ORIF was used more for the management of B1 fractures and resulted in increased stability for all Vancouver B fractures compared to rTHA. Overall, this study showed the trends in surgeons who surgically manage Vancouver B fractures at 11 major academic institutions and highlighted that regardless of surgical training or surgical treatment type, postoperative outcomes following management of PPFF were similar.

Conflicts of interest

S. C. Mears has stock options in Delta Ortho LLC; is an editorial board member of the Journal of the American Geriatrics Society and SAGE; and is a board/committee member of Fragility Fracture Network. A. Saxena is a paid consultant for Corin USA; has stock options in Parvizi Surgical Innovations; receives research support from United Orthopaedics; is an editorial board member of the Journal of Arthroplasty, Journal of Bone and Joint Surgery—American, and Journal of the American Academy of Orthopaedic Surgeons; and is a board/committee member of the Eastern Orthopaedic Association, American Association of Hip and Knee Surgeons, American Board of Orthopaedic Surgery, Inc., and AAOS. J. B. Stambough receives royalties from Signature Orthopaedics; is a CurveBeam speaker; is a paid consultant for Smith & Nephew and Medacta; is an editorial board member of the Journal of Arthroplasty; and is a board/committee member of the American Association of Hip and Knee Surgeons and the American Joint Replacement Registry (AJRR). P. M. Lichstein is a board/committee member of the American Association of Hip and Knee Surgeons. J. R. Martin is a paid consultant for DePuy and A Johnson & Johnson Company. The other author declares no potential conflicts of interest.

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CRediT authorship contribution statement

Nicholas B. Pohl: Writing — original draft, Investigation, Formal analysis, Data curation. **Arjun Saxena:** Writing — review & editing, Methodology, Investigation, Formal analysis, Data curation. **Jeffrey B. Stambough:** Writing — review & editing, Methodology, Investigation, Formal analysis, Data curation. **John Ryan Martin:** Writing — review & editing, Methodology, Investigation, Formal analysis, Data curation. **Simon C. Mears:** Writing — review & editing, Methodology, Investigation, Formal analysis, Data curation. **Paul M. Lichstein:** Writing — review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

References

[1] Mondanelli N, Troiano E, Facchini A, Ghezzi R, Di Meglio M, Nuvoli N, et al. Treatment algorithm of periprosthetic femoral fracturens. Geriatr Orthop Surg Rehabil 2022;13:21514593221097608. https://doi.org/10.1177/21514593221097608.

[2] Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89:780—5. https://doi.org/10.2106/jbjs.F.00222.

[3] Abdel MP, Cottino U, Mabry TM. Management of periprosthetic femoral fractures following total hip arthroplasty: a review. Int Orthop 2015;39:2005—10. https://doi.org/10.1007/s00264-015-2979-0.

[4] Maradit KH, Larson DR, Crowson CS, Kremers WK, Washington RE, Steiner CA, et al. Prevalence of total hip and knee replacement in the United States. J Bone Joint Surg Am 2015;97:1386—97. https://doi.org/10.2106/jbjs.N.01141.

[5] Bhattacharyya T, Chang D, Meigs JB, Estok 2nd DM, Malchau H. Mortality after periprosthetic fracture of the femur. J Bone Joint Surg Am 2007;89:2658—62. https://doi.org/10.2106/jbjs.F.01538.

[6] Abdel MP, Watts CD, Houdek MT, Lewallen DG, Berry DJ. Epidemiology of periprosthetic fracture of the femur in 32 644 primary total hip arthroplasties: a 40-year experience. Bone Joint J 2016;98-b:461—7. https://doi.org/10.1302/0301-620x.98b4.37201.

[7] Naqvi GA, Baig SA, Awan N. Interobserver and intraobserver reliability and validity of the vancouver classification system of periprosthetic femoral fractures after hip arthroplasty. J Arthroplasty 2012;27:1047—50. https://doi.org/10.1016/j.arth.2011.11.021.

[8] Lee S, Kagan R, Wang L, Doung YC. Reliability and validity of the vancouver classification in periprosthetic fractures around cementless femoral stems. J Arthroplasty 2019;34:S277—81. https://doi.org/10.1016/j.arth.2019.02.062.

[9] Ricci WM. Periprosthetic femur fractures. J Orthop Trauma 2015;29:130—7. https://doi.org/10.1097/bot.0000000000000282.

[10] Perry M, Rivera JL, Wesolowski M, Eikani C, Lack W, Cohen J, et al. Treatment of vancouver b2 femur fractures with open reduction internal fixation versus revision arthroplasty. Cureus 2023;15:e38614. https://doi.org/10.7759/cureus.38614.

[11] Spina M, Scalvi A. Vancouver b2 periprosthetic femoral fractures: a comparative study of stem revision versus internal fixation with plate. Eur J Orthop Surg Traumatol 2018;28:1133—42. https://doi.org/10.1007/s00590-018-2181-3.

[12] Toci GR, Stambough JB, Martin JR, Mears SC, Saxena A, Lichstein PM. Effect of fracture type, treatment, and surgeon training on reoperation after vancouver b periprosthetic femur fractures. J Arthroplasty 2023;38:1864—8. https://doi.org/10.1016/j.arth.2023.03.024.

[13] Schwarzkopf R, Oni JK, Marwin SE. Total hip arthroplasty periprosthetic femoral fractures: a review of classification and current treatment. Bull Hosp Jt Dis (2013) 2013;71:68—78.

[14] Van Rysselberghe NL, Campbell ST, Goodnough LH, Amanatullah DF, Gardner MJ, Bishop JA. To fix or revise: differences in periprosthetic distal femur fracture management between trauma and arthroplasty surgeons. J Am Acad Orthop Surg 2022;30:e17—24. https://doi.org/10.5435/jaaos-d-20-00968.

[15] Gaski GE, Scully SP. In brief: classifications in brief: vancouver classification of postoperative periprosthetic femur fractures. Clin Orthop Relat Res 2011;469:1507—10. https://doi.org/10.1007/s11999-010-1532-0.

[16] Duncan CP, Masri BA. Fractures of the femur after hip replacement. Instr Course Lect 1995;44:293—304.

[17] Oreluk H, Cherf J. Orthopaedic workforce trends: census data show shifting patterns of practice. AAOS Now; 2015.

[18] Ruddell JH, Eltorai AEM, DePasse JM, Kuris EO, Gil JA, Cho DK, et al. Trends in the orthopaedic surgery subspecialty fellowship match: assessment of 2010 to 2017 applicant and program data. J Bone Joint Surg Am 2018;100:e139. https://doi.org/10.2106/jbjs.18.00323.

[19] Stambough JB, Nunley RM, Spraggs-Hughes AG, Gardner MJ, Ricci WM, McAndrew CM. Clinical practice guidelines in action: differences in femoral neck fracture management by trauma and arthroplasty training. J Am Acad Orthop Surg 2019;27:287—94. https://doi.org/10.5435/jaaos-d-17-00760.

[20] González-Martín D, Hernández-Castillejo LE, Herrera-Pérez M, Pais-Brito JL, González-Casamayor S, Garrido-Miguel M. Osteosynthesis versus revision arthroplasty in vancouver b2 periprosthetic hip fractures: a systematic review and meta-analysis. Eur J Trauma Emerg Surg 2023;49:87—106. https://doi.org/10.1007/s00068-022-02032-8.

[21] Haider T, Hanna P, Mohamadi A, Merchan N, McNichol M, Wixted JJ, et al. Revision arthroplasty versus open reduction and internal fixation of vancouver type-b2 and b3 periprosthetic femoral fractures. JBJS Rev 2021;9:e21.00008. https://doi.org/10.2106/jbjs.Rvw.21.00008.

[22] Lee YK, Kim JT, Kim KC, Ha YC, Koo KH. Conservative treatment for minimally displaced type b periprosthetic femoral fractures. J Arthroplasty 2017;32:3529—32. https://doi.org/10.1016/j.arth.2017.05.057.

[23] Roche-Albero A, Mateo-Agudo J, Martín-Hernández C, Arnaudas-Casanueva M, Gil-Albarova J. Osteosynthesis in vancouver type b1 periprosthetic fractures. Injury 2021;52:2451—8. https://doi.org/10.1016/j.injury.2021.03.023.

[24] Bates BD, Walmsley DW, Vicente MR, Kuzyk PR, Nauth A, Waddell JP, et al. An international, cross-sectional survey of the management of vancouver type b1 periprosthetic femoral fractures around total hip arthroplasties. Injury 2018;49:364—9. https://doi.org/10.1016/j.injury.2017.10.034.

[25] Efird WM, Boyd ED, Schottel PC, Nelms NJ, Blankstein M. Outcomes of non-operatively treated vancouver b1 fractures: is failure common? J Arthroplasty 2023;38:S431—7. https://doi.org/10.1016/j.arth.2023.03.069.

[26] Pagani NR, Varady NH, Chen AF, Rajaee SS, Kavolus JJ. Nationwide analysis of lower extremity periprosthetic fractures. J Arthroplasty 2021;36:317—24. https://doi.org/10.1016/j.arth.2020.07.050.

[27] Chaharbakhshi E, Schmitt D, Brown NM. The added burden of transfer status in patients undergoing surgery after sustaining a periprosthetic fracture of the hip or knee. Cureus 2021;13:e16805. https://doi.org/10.7759/cureus.16805.

[28] Pavone V, de Cristo C, Di Stefano A, Costarella L, Testa G, Sessa G. Periprosthetic femoral fractures after total hip arthroplasty: an algorithm of treatment. Injury 2019;50:S45—51. https://doi.org/10.1016/j.injury.2019.01.044.

[29] Cinotti G, Sinno E, Fornara G, LaTorre G, Giannicola G. Plain films are not accurate in planning internal fixation in vancouver type b1 periprosthetic femoral fractures and in distinguishing between subtypes b1 and b2. Injury 2021;52:1592—6. https://doi.org/10.1016/j.injury.2020.12.013.