Geriatric Distal Femur Fractures Treated with Arthroplasty Are Associated with Lower Mortality but Greater Costs Compared with Open Reduction and Internal Fixation at 30 Days

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Abstract

Distal femur fractures (DFFs) are common injuries with significant morbidity. Surgical options include open reduction and internal fixation (ORIF) with plates and/or intramedullary devices or a distal femur endoprosthesis (distal femur replacement [DFR]). A paucity of studies exist that compare the two modalities. The present study utilized a 1:2 propensity score match to compare 30-day outcomes of geriatric patients with DFFs who underwent an ORIF or DFR. The National Surgical Quality Improvement Program data from 2008 to 2019 were utilized to identify all patients who sustained a DFF and underwent either ORIF or DFR. This yielded 3,197 patients who underwent an ORIF versus 121 patients who underwent a DFR. A final sample of 363 patients (242 patients with ORIF vs. 121 with DFR) was obtained after a 1:2 propensity score match. Costs were obtained from the National Inpatient Sample database using multiple regression analysis and validated with a 7:3 train-test algorithm. Independent samples *t*-tests and chi-square analysis were conducted to assess cost and outcome differences, respectively. Patients who received a DFR had higher transfusion rates than ORIF ($p = 0.021$) and higher mean inpatient hospital costs ($p = 0.001$). Subgroup analysis for patients 80 years of age or older revealed higher 30-day unplanned readmission (0 vs. 18.2%; $p < 0.001$) and 30-day mortality (0 vs. 18.2%; $p < 0.001$) rates for patients undergoing ORIF compared with DFR. The total number of DFR cases needed to prevent one ORIF-related 30-day mortality for DFR for patients 80 years of age was 6 (95% confidence interval: 3.02–19.9). The mean hospital costs associated with preventing one case of death within 30 days from operation by undergoing DFR compared with ORIF was $176,021.39. Our results demonstrate higher rates of transfusion and increased inpatient costs among the DFR cohort compared with ORIF. However, we demonstrate lower rates of mortality for patients 80 years and older who underwent DFR versus ORIF. Future studies randomized controlled trials are necessary to validate the results of this study.

Keywords
- trauma
- knee
- DFR
- ORIF

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Fractures of the distal femur can result from low-energy trauma in the elderly and are becoming increasingly more prevalent as the population ages.[1,2] In the geriatric population, it is the second most common femur fracture after hip fractures.[3] Fragility fractures of the native distal femur have variable fracture patterns and high mortality rates in the elderly, commensurate to mortality rates seen in hip fractures.[4,5] In the elderly, distal femur fractures (DFFs) pose a challenge to treatment, especially with fracture comminution in poor bone quality.[6,7] Current fixation modes include open reduction and internal fixation (ORIF) with plates and/or intramedullary devices or distal femur replacement (DFR).[6–8]

Much of the present literature on distal femur endoprosthesis involves its use in the setting of periprosthetic fractures above total knee arthroplasties.[9–11] While the data examining the use of DFR in the treatment of native DFF remain limited,[12–15] the current literature suggests that ORIF and DFR are equally efficacious options for treating DFF, citing no difference in complication rates between the two treatments.[6–8,13] While arthroplasty is useful for preserving mobility and eliminating the risk of nonunion, failure after DFR may leave the patient with limited salvaged options.[7,14] In the geriatric population, another goal of treatment is to restore immediate postoperative weight-bearing and to allow early ambulation, which has encouraged surgeons to explore dual-implant ORIF techniques and DFR as alternative options.

It is well understood that early postoperative mobilization in the geriatric population after fragility fractures is paramount to optimizing outcomes. The purpose of this study was to compare 30-day outcomes and cost of care following ORIF versus DFR in patients with native DFF using a 1:2 propensity score matching algorithm in a national patient database setting. We hypothesized that due to early mobilization allowed following DFR, patients would have lower morbidity and mortality than patients who underwent ORIF.

Materials and Methods

Database

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) was utilized to identify all patients between 2008 and 2019. Data in the ACS-NSQIP undergo rigorous quality checks from trained reviewers at more than 700 participating hospitals. Individuals included in the database are prospectively followed for 30 days following surgery. Data collected by these reviewers have been audited and previously employed in orthopaedic surgery research.[16–18]

Inclusion and Exclusion Criteria

The International Classification of Diseases, 9th Revision-Clinical Modification (ICD-9-CM) and 10th revision (ICD-10-CM) were used to identify all patients who sustained a DFF and were a minimum age of 18 years. These codes used are shown in ►**Supplementary Table S1**. Common Procedural Terminology (CPT) codes were used to identify surgical types. ORIF codes were identified as 27511, 27513, and 27514. DFR was identified as CPT codes 27442, 27443, 27445, and 27447. Exclusion criteria were patients with a diagnosis code of periprosthetic fracture (ICD-9-CM 996.4x; ICD-10-CM: M97.12, M97.11, T84.049). This yielded 3,318 cases (ORIF = 3,197 vs. DFR = 121).

Propensity Score Matching and Power Analysis

The analysis was powered to assess differences in rates of complications. Assuming a mild effect size of 0.2, our power analysis revealed a sample of 196 patients would be needed to achieve a power of 0.8. A nearest neighbor matching algorithm was executed for a 1:2 case–control match. Cases were matched to a control based on preoperative laboratory values, age, sex, race, ethnicity, American Society of Anesthesiologists physical status score, body mass index (BMI), Charlson comorbidity index, and various comorbidities (►**Fig. 1**). A standard mean difference of 0.1 was set as the threshold for adequate balance. This yielded a final sample size of 363 patients (ORIF = 242 and DFR = 121).

Estimating Hospital Cost

Data from the National Inpatient Sample (NIS) database were utilized to estimate costs. The NIS has been described in previous publications.[19] The NIS estimates 95% of all inpatient cases in the United States for a given year. A multivariate regression model with a 7:3 train-test cross-validation split was conducted to generate cost estimates. Input variables included year of surgery, length of stay, race, ethnicity, sex, age, and various comorbidities, including diabetes, congestive heart failure, chronic lung disease, obesity (BMI more than 30 kg/m^2), liver disease, and kidney failure. These variables can be found in both NIS and NSQIP databases. The costs were adjusted to 2019 U.S. dollars using the consumer price index reported by the U.S. Bureau of Labor Statistics (►**Table 1**).[20]

End Points and Statistics

The end points of interest included 30-day mortality, 30-day unplanned readmission, 30-day unplanned reoperation, 30-day major complication, 30-day minor complication, discharge disposition, and all tabulated complications within 30 days. Major complications were defined previously by Ottesen et al[21] and include: 30-day incidence of deep surgical site infection, sepsis, failure to wean from a ventilator within 48 hours, need for intubation, renal failure, thromboembolic event (deep vein thrombosis [DVT]/pulmonary embolism), cardiac arrest, myocardial infarction, and cerebrovascular accident (stroke). Minor complications included superficial surgical site infection, wound dehiscence, pneumonia, urinary tract infection, postoperative renal insufficiency, and need for transfusion. Missing variables were handled using a multiple imputation algorithm.[22] A Youden's index was calculated to identify age threshold in which patient was most at risk for postoperative complications. This age was used to conduct a subgroup comparative analysis between patients undergoing DFR and ORIF. A chi-square analysis or Fisher's exact test was conducted to compare categorical

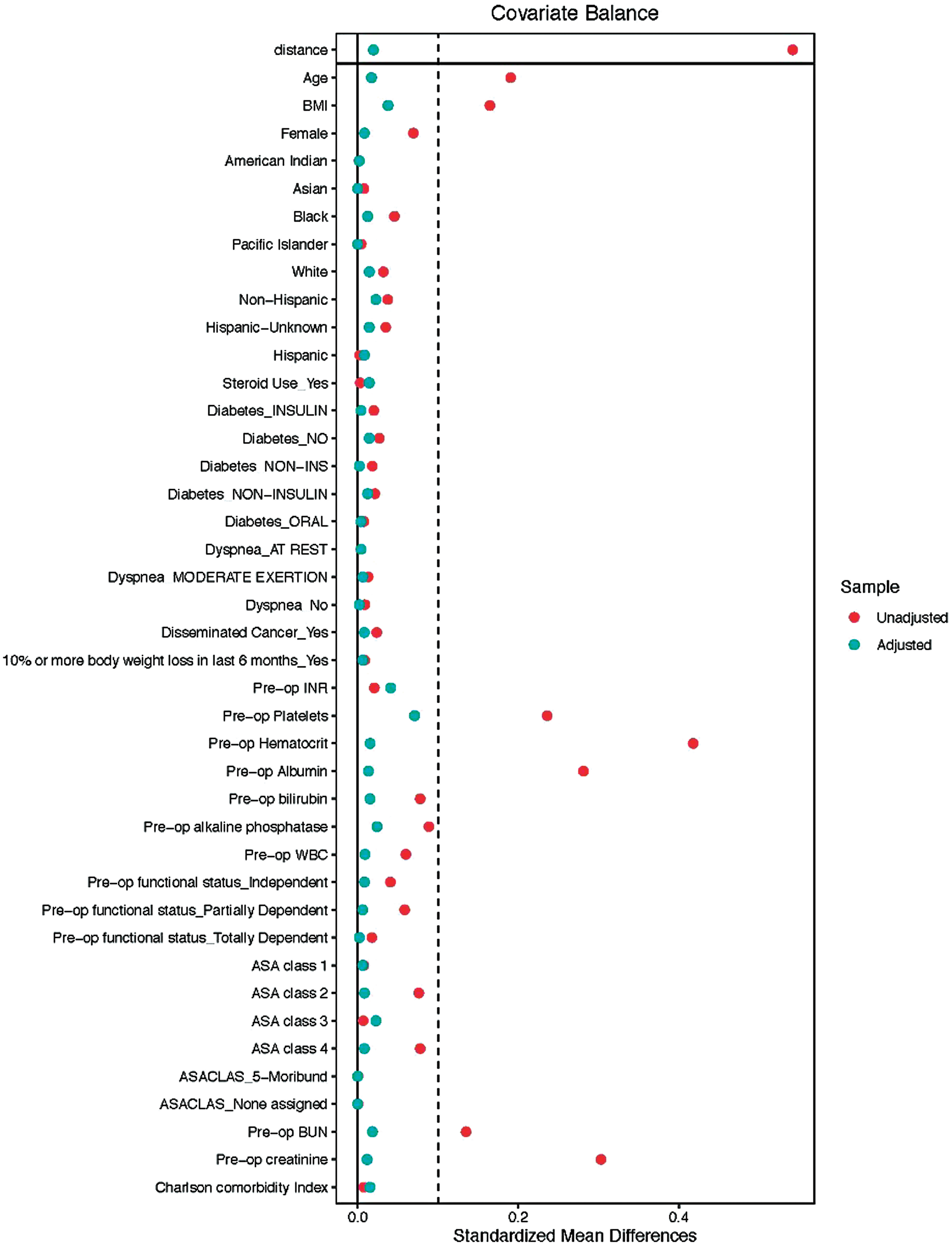

Fig. 1 Love plot demonstrating pre- and post match covariate balance.

Table 1 Inpatient cost estimation using data from the Nationwide Inpatient Sample database, root mean squared error = 12,622.44; mean absolute error = 7,548.665

	Beta	*p*-Value
Intercept	$26,475.40	<0.001
Female sex	−$1,585.64	<0.001
Age	−$49.80	<0.001
Patient has chronic lung disease	−$116.10	0.789
Patient has diabetes	−$690.45	0.08
Patient has liver failure	−$240.71	0.852
Abnormal weight loss before injury	$5,446.23	<0.001
Patient has renal failure	−$560.32	0.2532
Hospital length of stay	$2,504.09	<0.001
Underwent operative reduction and internal fixation (vs. endoprosthesis/arthroplasty)	− $13,956.42	<0.001

variables where appropriate. Independent samples *t*-tests were conducted to assess differences in continuous variables. An absolute risk reduction and number needed to prevent one 30-day mortality event was conducted with a 95% confidence interval (CI) reported.[23,24] A two-tailed *p*-value of 0.05 was set as the threshold for statistical significance. Statistical analysis was conducted in R 3.4.1 (Vienna, Austria).

Results

The 1:2 matching algorithm revealed a good balance between the DFR (treatment) and ORIF (control) cohorts (**►Fig. 1**). The resulting sample had a mean age of 69.62 years (standard deviation = 14.21 years) and a sex distribution of 83.7% female and 16.3% male. The sample revealed no statistical difference between the groups in postoperative diagnosis ICD-9-CM ($p = 0.253$) and ICD-10-CM ($p = 0.212$) codes. There was a significant difference in mean total hospital costs ($p < 0.001$). Patients with DFR had a mean total hospital cost of $46,323 ± $17,022 and a mean inpatient hospital per day cost of $7,515 ± $5,242), whereas patients undergoing ORIF had a mean total hospital cost of $20,849 ± $35,021 and a mean inpatient hospital per day costs of $4,123 ± $1,182 (**►Table 2**).

Patients undergoing DFR in our sample population had higher transfusion rates than patients undergoing ORIF (57.0 vs. 44.2%; $p = 0.021$; **►Table 2**). There were no statistical differences in 30-day rates of pneumonia, DVT requiring therapy, septic shock, renal complications, urinary infection, surgical site infections, need for intubation, pulmonary embolism, cardiac arrest, minor complications, major complications, death within 30 days of mortality, 30-day unplanned readmission, and 30-day unplanned reoperation (**►Table 2**). There were no differences in discharge destination between the groups ($p = 0.399$).

A subgroup analysis was conducted for our patient sample of patients 80 years of age and older (DFR $n = 21$; ORIF $n = 33$) (**►Table 3**). There was no difference between ICD-9-CM ($p = 0.078$) and ICD-10-CM ($p = 0.092$) coding between the two groups. Similarly, there were no differences in mean age (86.70 ± 1.36 vs. 87.05 ± 1.28; $p = 0.349$), mean BMI (26.35 ± 6.18 vs. 27.72 ± 6.92 kg/m^2; $p = 0.450$), sex ($p = 0.236$), race ($p = 0.802$), and Charlson comorbidity index ($p = 0.346$). Postoperatively, there were no differences in rates of discharge destination between the groups ($p = 0.264$). The DFR group demonstrated a lower 30-day unplanned readmission rate (0 vs. 18.2%, $p = 0.038$) and a lower 30-day mortality rate (0 vs. 18.2%, $p = 0.038$) than ORIF. The causes for 30-day readmission included cerebrovascular accident ($n = 1$), pneumonia ($n = 1$), pulmonary embolism ($n = 1$), urinary tract infection ($n = 1$), pain ($n = 1$), and fracture of operative extremity ($n = 1$). All readmitted patients eventually expired within 30 days from the index operation. The absolute risk reduction for 30-day mortality for patients in this age cohort undergoing DFR was 18.8% (95% CI: 5.02–31.34%).

Discussion

The present study examined how patients fared after native DFFs nationally and found that patients who underwent DFR had higher rates of postoperative transfusions. Furthermore, the average inpatient cost of DFR was more than twice as much compared with ORIF. In the subset of patients (**►Table 3**) 80 years of age, DFR resulted in lower rates of 30-day mortality compared with ORIF.

The appropriate surgical management continues to Garner-wide debate for patients who sustain DFFs.[6,7,10,15,25] Much of the current literature examines the efficacy of treatment strategies at restoring baseline functional status, especially in the elderly population who experience high morbidity and mortality rates after sustaining DFF.[6,7,10,15,25,26] This study adds to the literature by demonstrating lower 30-day readmission and mortality rates after DFR than ORIF. However, long-term outcomes in this patient population remain limited and were beyond the scope of our study. Myers et al demonstrated a 1-year mortality rate of 13.4% in an elderly cohort of both native and periprosthetic DFFs. They noted a significant negative impact on mortality when surgery was delayed more than 2 days.[27] The authors noted that this rate is lower than established mortality rates after geriatric hip fractures, which are typically allowed to weight-bearing immediately, and hence questioned whether postoperative weight-bearing affected outcomes after DFF.

Early mobilization and functional rehabilitation principles are highly emphasized after most orthopaedic injuries. In the geriatric hip fracture literature, Heiden et al[28] revealed higher rates of 30-day mortality in patients who were unable to ambulate by postoperative day 3 compared with patients who mobilized within the first 3 days. In a prior comparative study, Hart et al[7] demonstrated similar reoperation and mortality rates at 1 year between DFR and ORIF in a geriatric population. The ORIF group, however, had an 18% rate of

Table 2 Comparison of costs and outcomes between match group of patients with distal femur fractures who underwent DFR versus ORIF

	DFR ($n = 121$)	ORIF ($n = 242$)	p-value
Mean inflation adjusted inpatient hospital costs (stdev)	**$46,322.54 ($17,022.12)**	**$20,848.74 ($35,021.23)**	**<0.001**
Mean inflation adjusted inpatient hospital costs er hospital day (stdev)	**$7,515.02 ($5,241.56)**	**$4,123.32 ($1,182.27)**	**<0.001**
Median length of stay (interquartile range)	**6.5 (5)**	**5.0 (4)**	**<0.001**
Pneumonia	2.5% (3)	11 (4.5%)	0.335
DVT requiring therapy	6.6% (8)	2.9% (7)	0.268
Septic shock	1.7% (2)	2.1% (5)	0.787
Renal complications	0.8% (1)	0.8% (2)	0.999
Urinary infections	2.5% (3)	5.0% (12)	0.263
Surgical site infection	0.8% (1)	1.2% (3)	0.722
Need for intubation	3.3% (4)	1.2% (3)	0.177
Received at least one transfusion	**57.0% (69)**	**44.2% (107)**	**0.021**
Pulmonary embolism	4.1% (5)	2.1% (5)	0.257
Cardiac arrest	0.8%(1)	0.4% (1)	0.616
Minor complications	5.0% (6)	10.3% (25)	0.084
Major complications	5.8% (7)	4.5% (11)	0.608
Death within 30 d	5.0% (6)	5.4% (13)	0.868
30-d unplanned readmission	8.3% (10)	7.4% (18)	0.781
30-d reoperation	3.3% (4)	2.9% (7)	0.829
Discharge destination			
Not recorded	3.3% (4)	5.4% (13)	0.399
Against medical advice	0.8% (1)	0% (0)	
Expired	3.3% (4)	1.7% (4)	
Home	23.1% (28)	22.7% (55)	
Hospice	0% (0)	0% (2)	
Rehabilitation	20.7% (25)	19.8% (48)	
Separate acute care	0% (0)	2.1% (5)	
Skilled care not home	48.8% (59)	47.5% (115)	

Abbreviations: DFR, distal femur replacement; DVT, deep vein thrombosis; ORIF, open reduction and internal fixation; stdev, standard deviation. Bold indicate *p*-values less than 0.05.

nonunion and a 25% rate of remaining wheelchair bound.[7] These data underscore that early mobilization principles should also apply to DFF.

The exposure necessary during surgery in addition to required bony resection can carry a biological cost to the zone of injury greater than that of ORIF, which may explain the increased transfusions in the postoperative setting. This, along with the cost of the implant, further contributes to the overall cost burden of treatment, which are important factors to consider, as cost containment has an increasing role in surgical decision-making.[29,30] Correspondingly, surgical implants and ORIF techniques have also continued to evolve.[2] Periarticular locking plates and retrograde intramedullary nailing provide minimally invasive techniques that minimize soft tissue stripping, blood loss, and operative duration.[31,32] Dual implant constructs are also gaining popularity as surgeons seek to improve fixation strength to allow for early weight-bearing. Despite these advances, many authors have argued that older patients with poor bone quality would be better candidates for DFR.[7,8,12,13,26,33] Furthermore, highly comminuted fractures not amenable to fixation are also indicated for DFR as high rates of nonunion and malunion have been demonstrated after ORIF.[12–15,26]

Our study revealed increased costs associated with patients undergoing DFR when compared with ORIF for DFF. Similar studies report similar findings with much of the cost difference associated with implant costs. Caines et al[34] performed a retrospective cohort study entailing 39 patients with DFFs (OTA/AO 33C fractures) who either underwent DFR or ORIF. The authors increased direct implant costs between the groups, with a mean implant cost of $11,403 in the DFR group and $2,066 in the ORIF group ($p = < 0.01$). After all attributable hospitalization costs were analyzed, the total cost of providing index surgical care was

Table 3 Subgroup analysis of patient 80 years of age or older: comparison of costs and outcomes between match group of patients with distal femur fractures who underwent DFR versus ORIF

	DFR ($n = 21$)	ORIF ($n = 33$)	*p*-Value
Mean inflation adjusted inpatient hospital costs (stdev)	**$45,800.20 ($18,598.44)**	**$16,463.31 ($52,112.63)**	**0.017**
Mean inflation adjusted inpatient hospital costs per hospital day (stdev)	$7,119.06 ($4,635.16)	$3,735.98 ($549.76)	<**0.001**
Pneumonia	4.8% (1)	12.1% (4)	0.363
DVT requiring therapy	9.5% (2)	6.1% (2)	0.636
Urinary infections	0% (0)	9.1% (3)	0.155
Need for intubation	4.8% (1)	0% (0)	0.206
Received at least one transfusion	66.7% (14)	51.5% (17)	0.272
Pulmonary embolism	9.5% (2)	6.1% (2)	0.636
Minor complications	4.8% (1)	21.2% (7)	0.097
Major complications	4.8% (1)	3.0% (1)	0.743
Death within 30 d	**0% (0)**	**6 (18.2%)**	**0.038**
30-d unplanned readmission	**0% (0)**	**6 (18.2%)**	**0.038**
30-d reoperation	4.8% (1)	0% (0)	0.206
Discharge destination			
Not recorded	0% (0)	6.1% (2)	0.264
Against medical advice	4.8% (1)	0% (0)	
Expired	0% (0)	6.1% (2)	
Home	14.3% (3)	12.1% (4)	
Hospice	0% (0)	6.1% (2)	
Rehabilitation	9.5% (2)	21.2% (7)	
Skilled care not home	71.4% (15)	48.5% (16)	

Abbreviations: DFR, distal femur replacement; DVT, deep vein thrombosis; ORIF, open reduction and internal fixation; stdev, standard deviation. Bold indicate *p*-values less than 0.05.

also significantly different, with a mean DFR cost of $61,259, compared with $44,491 in the ORIF group ($p = 0.05$). Brodke et al[35] conducted a systematic review entailing 37 observational studies and 1 randomized controlled trial to compare costs for patients with DFF who underwent either a DFR or ORIF. The authors performed a Markov decision analysis model wherein total costs were estimated by combining facility costs with surgeon fees. Facility costs were obtained from the Healthcare Cost and Utilization Project's online query system using 2017 data. The authors reported higher costs associated with DFR (mean estimate = $65,536; $63,790–$67,619) when compared with ORIF (mean estimate = $25,556; $24,230–$27,257).

The present study is inherently limited by its retrospective design, which eliminates the ability to determine the causality of the findings. This study design also allows for confounding factors within the data that cannot be accounted for in the analysis. We attempted to mitigate this bias by utilizing a propensity score matching algorithm by matching multiple patient-specific and preoperative laboratory variables to identify an adequate control. In our study, we observed that DFR incurred significantly higher costs when compared with ORIF. This disparity can be attributed, at least in part, to variations in implant expenses,[36] with DFR being notably more expensive. However, it is important to note that we encountered a limitation in our analysis, as we could not disaggregate overall care costs, which hindered our ability to identify specific factors contributing to variations in care expenses. A further limitation is that fracture types could not be classified. This was mitigated by using ICD-9 and ICD-10 coding as a surrogate for fracture morphology to ensure similarities between the groups. Nonetheless, we note that fracture morphology, BMI, and preexisting arthritis can play a role in surgeon decision-making between proceeding with DFR versus ORIF. We elected not to include periprosthetic DFFs in our study given concerns of added heterogeneity and inability to adequately match periprosthetic DFFs for an adequate analysis. As such, our results cannot be extrapolated for patients with periprosthetic femur fractures. Finally, using a national database, as the source of data, prevents monitoring the quality of data reporting provided by other institutions; however, both the Healthcare Cost and Utilization Project, Nationwide Inpatient Database, and ACS-NSQIP database have published their rigor of data collection and outcomes monitoring, thus minimizing this concern.[37]

Conclusion

In conclusion, patients who underwent DFR for DFFs in the current study had higher postoperative transfusion rates and greater inpatient costs than ORIF. Nevertheless, DFR should be considered in patients 80 years of age, as this group demonstrated lower 30-day readmission and mortality rates than ORIF. While the study contributes to understanding treatment outcomes after DFF, a prospective clinical trial is necessary to compare ORIF and DFR for comminuted, intra-articular fractures in the elderly to optimize their outcomes.

Conflict of Interest

None declared.

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