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Proximal femoral replacement in the management of acute periprosthetic fractures of the hip: a competing risks survival analysis

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Abstract

To examine the mortality and implant survivorship of proximal femoral replacement (PFR), revision total hip arthroplasty (REV) and open reduction internal fixation (ORIF) in the treatment of acute periprosthetic fractures of the proximal femur, we retrospectively reviewed 97 consecutive acute periprosthetic proximal femoral fractures from 2000–2010. Three groups were defined: PFR (n=21), REV (n=19), and ORIF (n=57). Outcome measures were all-cause mortality, implant failure, and reoperation. Competing Risks survival analysis of overall mortality during the mean 35-month follow-up showed no statistical difference between the three groups (p=0.65; 12 and 60 month mortality for PFR: 37%, 45%; REV: 16%, 46%; ORIF: 14%, 100%). Implant survival was worse for the PFR group (p=0.03, 12 and 60-month implant failure rate for PFR: 5%, 39%; REV: 7%, 7%; ORIF 2%, 2%). We conclude that PFR as compared with REV or ORIF may have worse medium-term implant survival, primarily due to instability and dislocation.

Keywords

periprosthetic fracture; proximal femoral replacement; revision arthroplasty; proximal femur

Introduction

Periprosthetic fracture around proximal femoral implants is a difficult complication of hip arthroplasty. A rising incidence of this complication has been observed and is likely a result of increasing volume of primary and revision procedures, longer average patient lifespan, and increasing number of arthroplasty procedures in older patients.^{1–4} It is estimated to occur after 1% of primary total hip arthroplasty (THA) and 4% of revision total hip arthroplasty (RTHA) procedures.¹ Recent analysis from the Swedish Hip Registry has documented markedly increased perioperative and long-term mortality following

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periprosthetic proximal femur fracture compared with primary THA controls.⁵ The severity of periprosthetic fracture is determined by host and surgical factors. Although most commonly low energy,⁶ these injuries frequently occur in an aging population with osteoporotic bone, advanced osteolytic defects, and multiple prior hip operations. In addition, while modern implants have improved survivorship, their predominantly cementless design may have higher early rates of periprosthetic fracture.⁷ Revision stems may also be prone to stress shielding and proximal bone resorption.^{3,8}

Treatment paradigms for periprosthetic fracture around proximal femoral implants should be individualized based on patient functional demand, comorbidities, and patient expectations. However, the principles of obtaining a stable implant and achieving early mobilization are paramount in developing treatment strategy and improving outcomes.⁵ Important considerations in achieving these goals include fracture location, implant stability, and quality of the surrounding bone.^{8,9} Treatment options include most commonly, but are not limited to, open reduction with internal fixation and implant retention (ORIF), revision arthroplasty with supplemental fixation for fractures (REV), and modular endoprosthetic proximal femoral reconstruction (PFR). Although not a new implant technology, PFR in particular has emerged as an attractive treatment option for difficult fractures because it is technically straightforward, can be performed in an expeditious manner, and allows for immediate mobilization of the patient. There have been few reports on non-oncologic use of this implant, but in the existing studies there have been concerns regarding implant failure, especially due to instability.¹⁰⁻¹³

The purpose of this study was to examine the outcomes of PFR compared to the other most common treatment strategies for periprosthetic fractures of the proximal femur. Specifically, we sought to examine the implant survivorship, mortality, and complication profiles of PFR as compared with conventional revision surgery and ORIF in the treatment of this difficult problem. Based on our experience and existing reports¹⁰⁻¹³, we hypothesized that PFR is a viable, durable reconstructive option for difficult periprosthetic fractures around the proximal femur and may confer mortality benefit due to early mobilization and short operative times.

Patients and Methods

Study Design and Statistics

After obtaining approval from our institutional review board, we performed a retrospective analysis of 97 consecutive periprosthetic hip fractures treated at our center from 2000 to 2010. Inclusion criteria for the study included Vancouver grade A, B, or C periprosthetic fracture of the proximal femur around a primary or revision total or hemiarthroplasty femoral implant.¹⁴ In addition, the index operation for periprosthetic fracture took place at our institution without exception. Exclusion criteria in this study included antecedent surgical treatment prior to arrival at our institution and polytrauma including concomitant acetabular fracture.

Three treatment groups were identified depending on the index operation: Proximal femoral replacement (PFR, n=21), Revision arthroplasty (REV n=19), and open reduction internal

fixation (ORIF n=57). The three groups were analyzed in all cases with an intention-to-treat methodology despite occasional cases of crossover, for example failed ORIF which later went on to PFR. We recorded patient demographics and comorbidities (Table 1), original implant type, fracture grade according to the Vancouver classification of periprosthetic fracture of the proximal femur (Table 2),¹⁴ surgical treatment profiles, complication profiles (Tables 3, 4), and mortality. The principle outcome measure was implant failure, which was defined as need for reoperation and revision or resection of femoral or acetabular components for any reason. This definition referred to arthroplasty implants only, and not, for instance, revision of plates or screws. In addition, operations which retained the original implants such as polyethylene exchange or irrigation and debridement were not counted as implant failures but were recorded as re-operation events. A secondary outcome measure was death from all causes.

The PFR, REV, and ORIF groups were compared using analysis of variance for quantitative data, two-tailed chi-squared with Fisher exact test for categorical data, and Kaplan-Meier survival analysis incorporating log-rank statistic to compare survival curves (SPSS, IBM, Inc, Armonk, NY). Given the high incidences of two interacting outcome measures, death and implant failure, we also used competing risks survival analysis with the Gray test to compare cumulative incidence curves.^{15,16} This method accounts for interactions between outcome variables and analyzes their survivorship separately, thus overcoming bias and misleading overestimation effect sometimes present with Kaplan-Meier.

Operative Protocols

Indications for performing PFR included all fractures with a loose implant and poor surrounding proximal femoral bone stock (Vancouver B3, table 2, 24%). In addition, PFR was commonly performed for fractures with adequate bone stock and a loose implant (Vancouver B2, table 2, 57%) in cases where a subjective surgeon assessment of the risk/benefit profile for PFR was more favorable than that of revision arthroplasty based on reasons such as fracture difficulty or comminution, deconditioning and comorbidities of the host, or need for immediate mobilization with full weight bearing. Rarely, PFR was performed for A or B1 type fractures (table 2, 10% and 10%, respectively) in the face of a stable-appearing implant if there was extensive osteolysis, osteopenia, or if the host characteristics seemed to preclude healing based in the treating surgeon opinion. Indications for revision arthroplasty included those periprosthetic fractures with a loose stem (Vancouver type B2, table 2, 100%). Indications for ORIF included fractures with a stable stem either at the greater trochanter, around the stem, or well below it (Vancouver Ag, B1, and C, table 2, 5%, 81%, and 7%, respectively). 7% of the fractures treated with ORIF had a prosthetic stem loosen in the postoperative period and thus were classified retrospectively as Vancouver B2 variants although this was not recognized at the time of surgery.

Although this study involved three attending surgeons with different operative protocols, there are some generalizations which can be made. All surgeons contributing to this study use a direct lateral or anterolateral approach to the femur. At our institution specialized laboratory or aspiration studies to investigate occult infection are not routinely performed preoperatively in periprosthetic fracture patients unless the patient shows signs of sepsis on

presentation or there is some other sign which lowers the threshold of suspicion such as late spontaneous dislocation. We do however routinely send gram stain and intraoperative frozen section studies prior to implantation in any case where there is a question of infection or purulence discovered intraoperatively.

For PFR reconstructions specifically, two different techniques were used for abductor reconstruction: trochanteric slide with maintenance of continuity of the abductor-vastus lateralis complex on a wafer of the greater trochanter, or abductor reconstruction utilizing Dacron (Medi-Tech, Boston Scientific, Natick, MA) vascular grafts. Postoperative abduction bracing is infrequently used, being reserved only for a select portion of patients who undergo non-constrained total hip arthroplasty or where the abductors are reconstructed due to discontinuity with the vastus lateralis complex. Duration of bracing, when used, is typically 4–6 weeks. Patients undergoing bipolar hemiarthroplasty or constrained total hip arthroplasty procedures are typically not prescribed a postoperative abduction brace.

Results

Demographics and Follow-up

For the entire series of 97 patients, mean patient age at fracture was 72. There was no significant difference between the three groups with regard to age, gender, BMI, or medical comorbidities with the exception chronic pulmonary disease, which was more prevalent in the PFR group (Table 1). The distribution of our patient population according to the Vancouver classification of periprosthetic fractures¹⁴ is outlined in table 2. The PFR group had a significantly greater proportion of Vancouver grade B3 fractures than the other two groups, whereas the REV group was comprised entirely of B2 fractures and the ORIF group had a preponderance of B1 fractures. Original implant prior to fracture was primary total hip arthroplasty (THA) in 79% of the series, bipolar hemiarthroplasty in 9%, revision total hip arthroplasty in 7%, and other in 5%. Average age of original implant prior to fracture was 9.0 years and there was no statistically significant difference in this parameter between PFR, REV, or ORIF groups ($p=0.45$). Average time from injury to index operation was 5 days. Operative times were not statistically different between the three groups (172 min. vs. 162 min. vs. 168 min, $p=0.92$).

Follow-up data were recorded differently depending on the outcome variable. For the implant failure endpoint, clinical documentation from in-person office examinations was required. We did not use a minimum follow-up period and the overall mean follow-up was 16.3 months (PFR 15.2 months, REV 18.0 months, ORIF 15.9 months). 15 total patients were lost to follow up at an average of 2.0 months after surgery (PFR, 3 patients, REV, 5 patients, ORIF, 7 patients). The reason for loss of follow-up was not able to be determined from the medical record in 10 cases; the other 5 patients resumed care with a surgeon outside our system. Conversely, for the all-cause mortality endpoint, follow-up data were recorded using the United States Social Security Death Index (SSDI), an accurate, verified measure of death data in the United States. Follow-up intervals for death using this database were a minimum of 12 months and a mean 40 months (PFR 34 months, REV 45 months, ORIF 41 months). There was no loss to follow-up.

Implant Survival

Overall raw implant survival in the entire series was 97% (95% CI 91%–99%) at 12 months and 84% (95% CI 75%–90%) at 60 months. Using Kaplan Meier log-rank analysis, PFR implant survival with arthroplasty implant revision as endpoint was 94.4% at 12 months (Standard error 5.4%) and 31.5% at 60 months (Standard error 18.3%), and was significantly worse than the REV or ORIF groups (figure 3, $p=0.03$). This result was generally upheld by using Competing Risks survival analysis (figure 4, $p=0.03$), although implant survival with revision as the endpoint was 95.0% at 12 months and 61.0% at 60 months using this alternate analysis.

The PFR group was comprised of 38% bipolar, 33% constrained, and 29% non-constrained PFR prostheses. The group had 5 total implant failures defined by need for revision or resection of femoral or acetabular implants. The etiology of the implant failure in this group was instability in 3 patients, and infection in 2. One of the 5 patients had concomitant infection and dislocation. For the three that dislocated, 2 did so despite constrained polyethylene liners and one dislocated with a standard non-constrained configuration. The average time to failure in these 5 patients was 37 months (Standard deviation, 21 months). In the REV group, the one observed implant failure was due to persistent infection requiring explant and staged revision. In the ORIF group, the one implant failure was due to nonunion at the fracture site requiring resection of the implants and conversion to PFR. There were no cases of aseptic loosening or arthroplasty implant fracture as an etiology for failure.

Mortality

For the entire series, mean time to death ($n=33$, 34%) from index surgery was 38 months. Overall raw patient survival in the entire series was 80% (95% CI 71%–87%) at 12 months and 31% (95% CI 23%–41%) at 60 months (Figure 1). Based on chi squared analysis, there was no statistically significant difference between the PFR, REV, and ORIF groups with regard to 12-month mortality (38% vs. 16% vs. 16%, $p=0.11$). Kaplan-Meier log-rank analysis of all-cause patient mortality during the mean 35 month follow-up also showed no difference between the three groups (Figure 2, $p=0.52$). Competing Risks survival analysis using the Gray test for cumulative incidence curve comparison also demonstrated no statistically significant difference in cumulative incidence of death from all causes (Figure 5, $p=0.65$).

Complications

The overall raw complication rate for the entire series with regard to summary non-death complications was 34% (95% CI 25%–44%). Based on Chi squared analysis, there were no detected statistical differences in summary non-death complications between the PFR, REV, and ORIF groups (table 3, 29% vs. 44% vs. 32%, $p=0.80$). The PFR and REV groups trended towards higher infection rates than the ORIF group (19% vs. 16% vs. 4%, $p=0.06$), but the ORIF group carried a 12% nonunion rate compared to 0% in the REV group ($p=0.10$), and a re-fracture rate of 9% compared to 5% in the REV group and 0% in the PFR group ($p=0.32$). The PFR group, compared with the REV and ORIF groups, had a higher rate of arthroplasty implant revision (24% vs. 5% vs. 2%, $p=0.004$), and had a trend towards higher dislocation (19% vs. 5% vs. 4%, $p=0.06$). There was no statistically significant

difference in the need for return to the OR for any reason (38% vs. 16% vs. 19%, $p=0.15$). In the PFR and REV groups, all returns to the OR which were not implant failure-related were irrigation and debridement procedures for wound drainage with implant retention. In the ORIF group, returns to the OR not related to arthroplasty implant failure were for re-fracture in 4 patients, and nonunion in 7 patients. In the ORIF group, re-fracture and nonunion were addressed surgically with revision ORIF in 5 patients, revision long-stem arthroplasty in 2 patients, and PFR in 4 patients. Of the 5 total PFR implants used for patients with failed ORIF, 4 were uncomplicated and one patient experienced implant failure (25%) related to instability requiring revision PFR. When we examined all PFR implants performed for any reason in a non-intention-to-treat methodology ($N=26$), we found a dislocation rate of 23% at an average of 18 months (Standard deviation, 22 months) from index operation. We observed a bimodal time distribution with some instability occurring early (range 2–9 months), and some instability occurring late (range 37–54 months). 66% of dislocation events occurring with standard, non-constrained polyethylene constructs, and 33% occurring despite constrained constructs.

Discussion

In treating difficult periprosthetic fractures around proximal femoral implants, we found that PFR as compared with REV or ORIF has no significant difference in short and medium-term patient mortality but does have worse medium-term implant survival related to late instability and infection. Incidence of summary non-death complications was statistically similar between the three groups, but complications which lead to implant revision such as dislocation and infection may be higher in the PFR group.

Using Competing Risks (CR) analysis in this study did not change the overall findings but did alter the survival estimates at any given time point. CR survival analysis is a statistical tool which is important to consider when performing research involving survivorship which may have two or more co-dependent outcome variables.^{15–19} Conversely, conventional Kaplan Meier (KM) analysis requires *independence* of all outcome variables. If KM is used to analyze a given outcome such as implant survival, there must not be any other appreciable interacting outcomes (such as death). For example, in a KM curve of implant survival, death may not be independent from implant failure due to known or unknown patient, injury, or treatment-related factors. Additionally, in KM analysis death would be treated the same way as a loss to follow-up (censored), thereby creating overestimation bias of those implant failure events that *have* occurred. If many deaths occur over time, this bias effect would grow larger and larger. This was the case in our study. While PFR implant survival was similar using KM and CR calculations at 12 months (94.4% vs 95.0%), the KM calculation of implant survival was far lower than that of CR at 60 months (31.5% vs. 61.0%). Because of competing risks, the KM calculation gives an overestimate of implant failure, which gets worse over time. Thus, the CR calculation is probably a more accurate estimation of the true survival rate in the general population as estimated by our limited sample.

The chief limitations of this study are the retrospective nature of the analysis, small sample size, and the possibility of selection bias amongst groups which are heterogeneous and have different indications for treatment. We have attempted to control group heterogeneity by

measuring many patient-related variables which are presented in table 1. We detected few differences between groups with the exception being chronic pulmonary disease, which was higher in the PFR group. Overall, the fracture characteristics and treatment indications for each of the three groups are admittedly different and thus ORIF and REV are not true control groups for the PFR treatment. However, we feel the group comparisons are still useful since there are clinical scenarios where several of these different treatments could reasonably be used. Other limitations of the study include lack of quantification of bone quality or the effects of tribocorrosion, lack of detailed data on acetabular reconstruction parameters, and heterogeneity of acetabular resurfacing in the PFR group.

Our implant survivorship with revision as the endpoint was worse than prior published reports. A recent series described 48 non-oncologic PFR procedures with a minimum and mean follow up times of 24 months and 37 months respectively.¹⁰ Compared with our series, implant survivorship was slightly worse at 12 months (87%) but better at 60 months (73%). Other comparable series describing non-oncologic PFR survivorship are uncommon but have reported implant survivorship from 87% to 100% over a mean follow-up period ranging from 16–60 months.^{11,20–22} Unfortunately, the majority of these series feature very small numbers of patients have extremely short follow-up periods and thus are difficult to interpret. The literature describing the use of PFR in the oncologic setting is more robust and the largest series which exclude cases of revision for local recurrence describe implant survivorship in the range of 81% to 90% at 60 months.^{23–26} In their series of 86 bipolar endoprostheses performed for oncologic indications, Bernthal et al report 10 and 20 year survivorship of 84% and 56% respectively.²⁵ However, translating results from reconstructions in the oncology literature to those in the trauma or reconstructive literature is extremely difficult because of very high patient mortality related to oncologic disease. As in our study, death and implant failure are competing risks, and for the reasons already stated, Kaplan Meier is an inadequate estimate of implant survival in the presence of high mortality. In addition, most oncology patients do not share the same medical comorbidities, multiplicity of surgical events, and age related disability with patients with periprosthetic fractures. This renders apt comparison dubious at best.

Patient mortality has been described infrequently for non-oncologic patients with periprosthetic fractures who undergo PFR. In one of the largest series of PFR performed for non-oncologic periprosthetic fracture, the authors reported 6% mortality at 24 months and 12% mortality over the entire study period.¹⁰ Our mortality rate was significantly higher, although our series was composed exclusively of patients undergoing acute periprosthetic fracture care, without contribution of other indications for surgery such as staged infected or loose arthroplasty prostheses as in the above study. In addition, although the above study does not document medical comorbidities, our study cohort had relatively high rates of baseline cardiac (42%), pulmonary (20%), and diabetic disease (20%). As such, our short and long-term all-cause mortality could be expected to be somewhat higher. It is interesting that we found no difference in overall mortality between the PFR, REV, or ORIF groups. This would seem to indicate either a lack of power to resolve a difference or the possibility that the drivers of mortality are more related to host characteristics and the general systemic insult of immobilization and surgery than to the type of surgery itself.

Overall complication rates were high in our series, which is consistent with prior reports.^{10,11,27,28} Since the complications to which patients are exposed are different depending on the treatment, we chose to construct a composite metric of all non-death complications as shown in Table 3. There were no differences between groups, indicating that periprosthetic fractures of the proximal femur in patients with our series' typical host profile are at high risk for complication based on the injury or the patient comorbidities themselves, regardless of surgical treatment. However, it was interesting to note the trend towards higher dislocation rates in the PFR group. This may be partially due to use of non-constrained prostheses. Standard, non-constrained polyethylene liners were used in approximately one-third of our PFR series. Indeed, over two thirds of our total PFR dislocation events occurred with a standard, non-constrained polyethylene liner. Other explanations for the higher dislocation rate in the PFR group include a theoretically higher rate of abductor dysfunction after a more extensive surgical dissection, need to disrupt the capsule circumferentially at the time of femoral resection, and technical challenges involved in recreating length and offset without bony proximal femoral landmarks. The bimodal time frame of instability events from index surgery suggests a mixed etiology for instability, with component malposition most likely for early dislocations and muscle wasting/deconditioning, neurologic decline, or polyethylene wear most likely responsible for late dislocations. With regard to differences in infection between groups, it was not surprising that infection rates in the REV and PFR groups trended toward being higher than the ORIF group. The most likely explanation for this observation is more extensive soft tissue dissection or the use of more extensive non-biologic materials.

In summary, for PFR used to treat acute periprosthetic fractures of the proximal femur, we did not detect a mortality or operative-time benefit and did observe increased implant failure in the medium-term. Periprosthetic fracture of the proximal femur is a difficult problem with high associated mortality, and should be managed according to host characteristics, implant stability, and bone quality for the best outcomes. In certain situations, PFR may be the only reasonable reconstructive modality, as available bone stock may be so deficient as to preclude other reconstructive techniques. This was often the case in our study. Nevertheless, because it is technically straightforward to perform and allows early mobilization, PFR also remains one option for dealing with difficult proximal femoral fractures where implants are found to be loose and bone quality is preserved. Based on our findings, enthusiasm for expanded use of PFR in this setting should be tempered. When we do use PFR implants, we currently recommend use of constrained liners or bipolar heads where applicable, as instability constituted the majority of our implant-related complications. Although we do not commonly use bracing in the postoperative period, it remains another option when attempting to address this problem. Careful attention must also be paid to abductor reconstruction, with meticulous maintenance of the abductor-vastus lateralis sleeve or use of synthetic reconstruction as described in our methods. Finally, since the results of this retrospective study are meant to generate hypotheses for further testing only, additional prospective, long-term studies are required to fully evaluate the survivorship and role of PFR in treating periprosthetic fractures of the proximal femur.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Total Study Group Mortality: Patient Mortality as Endpoint

Figure 2.
Kaplan Meier Patient Survival: Patient Mortality as Endpoint **Log rank p value= 0.52**

Figure 3.

Kaplan Meier Implant Survival: Implant Revision as Endpoint **Log rank p value= 0.03**

Figure 4.
Competing Risks Implant Failure: Implant Revision as Endpoint **Gray test p value = 0.03**

Figure 5.
Competing Risks Patient Mortality: Patient Mortality as Endpoint **Gray test p value = 0.65**

Table 1

Study Group Demographics and Medical Comorbidities

	PFR	REV	ORIF	p Value
Male	43%	42%	40%	0.36
Female	57%	58%	60%	0.36
Age at Fracture *	75	72	76	0.53
Cardiac Disease	43%	37%	44%	0.80
Chronic Pulmonary Disease	38%	16%	16%	0.05
Chronic Steroid Use	19%	5%	7%	0.26
Prior Unrelated Oncologic History	29%	26%	14%	0.19
Peripheral Vascular Disease	19%	5%	11%	0.42
Renal Disease	19%	5%	5%	0.16
Diabetes	19%	21%	21%	0.94
Chronic Bisphosphonate Use	10%	11%	4%	0.46
Dementia	19%	5%	18%	0.38
Immunosuppression	5%	5%	0%	0.25
Smoking	19%	16%	9%	0.49
BMI **	26.9	27.8	27.6	0.90

* Means reported. Standard deviations: PFR, 15.8, REV, 14.5, ORIF, 13.1

** Means reported. Standard Deviations: PFR, 7.6, REV, 6.1, ORIF, 6.1

Table 2

Vancouver Classification of Periprosthetic Fractures by Treatment Group

Vancouver Periprosthetic Fracture Grade	Description	PER	REV	ORIF	p Value
A _g	Greater trochanteric fracture, stable stem	10%	0%	5%	0.42
B ₁	Fracture around or just below stem; stable implant	10%	0%	81%	<0.0001
B ₂	Fracture around or just below stem; unstable implant	57%	100%	7%	<0.0001
B ₃	Fracture around or just below stem, unstable implant and poor surrounding bone stock	24%	0%	0%	<0.0001
C	Fracture well below tip of stem	0%	0%	7%	0.21

Table 3

Summary Non-Death Complications: Entire Study Group

Entire Series: Summary Non Death Complications	34%
Pulmonary Embolus	1%
Deep Venous Thrombosis	3%
Myocardial Infarction	1%
Infection Requiring Debridement	9%
Hematoma Requiring Debridement	3%
Re-fracture	6%
Non-Union	7%
Knee or Hip Contracture	2%
Dislocation	7%
Nerve Palsy	2%

Table 4

Major Complications by Treatment Group

	PFR	REV	ORIF	p value PFR/REV/ORIF comparison	p value PFR/REV comparison
1-Year Mortality	38%	16%	16%	0.11	
Reoperation (any reason)	38%	16%	19%	0.15	0.16
Revision Arthroplasty after Index	24%	5%	2%	0.004	0.19
Infection	19%	16%	4%	0.06	0.99
Dislocation	19%	5%	4%	0.06	0.35
All Non-Death Complications	29%	42%	33%	0.80	