CANAL FILL RATIO IN HEMIARTHROPLASTY COMPARED TO TOTAL HIP ARTHROPLASTY: A CASE CONTROL STUDY

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ABSTRACT

Background: Cementless stems are commonly used in hemiarthroplasty (HA) for femoral neck fractures. Recent studies have reported increased risk of periprosthetic fracture with cementless stems compared to cemented HA. In elective total hip arthroplasty (THA), lower proximal canal fill ratios (CFR) of cementless stems have been associated with worse outcomes. The purpose of this study was to compare CFRs and complications following HA for femoral neck fracture compared to THA for arthritis. We hypothesized that HA would have lower CFRs.

Methods: 130 patients undergoing cementless hemiarthroplasty for femoral neck fracture were identified and matched by age, sex, and BMI to 328 patients undergoing elective cementless THA. Postoperative radiographs were independently evaluated by two investigators to determine Dorr femur type and CFR at four points. Interrater agreement was calculated for CFR and Dorr type. Complication rates were compared between HA and THA groups.

Results: Dorr type and CFR measurements showed strong agreement between investigators. Dorr type was similar between groups. Hemiarthroplasties had significantly lower CFR at each level, with the greatest difference at the lesser trochanter. Dorr C femurs had worse CFR, specifically in the HA group. Complications rates were similar between HA and THA.

Conclusion: Worse CFR in HA compared to THA further suggests that cemented stems should be considered in HA. Suboptimal CFR represents a potential cause of complications including periprosthetic fracture following HA.

Level of Evidence: III

Keywords: hemiarthroplasty, canal fill ratio, periprosthetic fractur

INTRODUCTION

Hip fracture is a serious medical condition in the elderly population with high morbidity and mortality which often leads to compromised mobility and significant associated healthcare expenses. In the US, it is estimated that the rate of hip fractures in recent years has increased due to a large aging population with increased risk factors for hip fractures such as osteoporosis.[1,2] Displaced unstable femoral neck fractures are of the greatest concern due to their delicate blood supply and typically require early surgical intervention to prevent further complications.[3] However, there is debate within the orthopedic community about the optimum surgical intervention for treating hip fractures in order to produce the best outcomes and minimize complications.

Common methods to treat femoral neck fractures include cannulated screw fixation and either cemented or cementless hemiarthroplasty (HA) or total hip arthroplasty (THA). Cannulated screws might seem preferable due to shorter operative times, but a growing body of evidence has shown that HA is associated with lower rates of reoperation and mortality, while leading to higher functional outcomes compared to screw fixation for intracapsular hip fractures.[4-7] Areas of controversy remain regarding choice of HA compared with THA[8-10] as well as choice of cemented implants versus cementless. Advantages of uncemented HA include shorter operative time, less blood loss, preservation of bone stock, potential for osseointegration, and theoretical lower rates of intraoperative cardiovascular collapse.[11] However, multiple recent studies have reported increased risk of periprosthetic fracture with cementless stems compared

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to cemented HA.[12-14] Patients thinner femoral cortices, as described by the Dorr classification, have been shown to be at increased risk for intraoperative fracture.[15,16]

There is little to no published data regarding the fit of the femoral prosthesis within the femoral canal in cementless HA and how fit confers to risk for periprosthetic fractures. A technique measuring canal fill described for elective THA has shown a relationship with radiographic complications, including subsidence.[17] The purpose of this study was to determine if canal fill after hemiarthroplasty for femoral neck fractures is suboptimal. The comparison group chosen was patients undergoing routine THA for osteoarthritis with cementless fixation. Although some authors have suggested that THA patients with severe osteoporosis should have cemented fixation, implant placement without cement is still in common usage.[18-20] We hypothesized that cementless HA for femoral neck fracture would be associated with lower CFRs compared to elective primary THA and that worse CFR could be an explanation for increased complication rates.

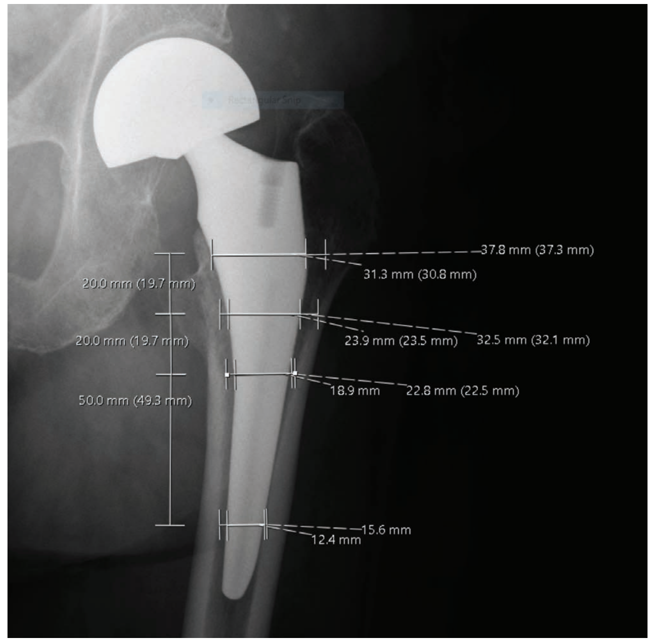

Figure 1. CFR calculated at the lesser trochanter (LT) as 23.9/32.5 = 73.5%; the LT +2 cm as 31.3/37.8 = 82.8%; the LT -2 cm as 18.9/22.5 = 84.0%; and the LT -7 cm as 12.4/15.6 = 79.5.

METHODS

Population and Data

Following institutional review board approval, 130 patients undergoing cementless HA for femoral neck fracture between January 2010 and November 2020 were identified. A power analysis was conducted, determining that this cohort size would allow for at least 90% power to detect differences in canal fill ratio. Procedures were performed by one of 27 surgeons in a large orthopaedic practice with multiple locations throughout a metropolitan region. Patients were propensity matched by age, sex, and body mass index (BMI) to 328 patients undergoing cementless primary elective THA for osteoarthritis. Revisions and primaries using revision-type implants were excluded. Stem type was recorded based on the classification system described by Khanuja et al.[21]

Postoperative radiographs were independently evaluated by two investigators (SK and JH) to determine Dorr femur type and canal fill ratio (CFR). CFR was calculated by dividing the diameter of the femoral stem by the intramedullary canal diameter at four points as described by D'Ambrosio: the level of the lesser trochanter (LT), the LT + 2 cm, LT -2 cm, and LT -7 cm.[22] An example CFR calculation is shown in Figure 1. Charlson Comorbidity Index (CCI) was recorded for each patient. The electronic medical record was queried to identify 90-day complications, 90-day readmissions, and reoperations on the same hip for any reason.

Table 1. Demographics of Hemiarthroplasty and Total Hip Arthroplasty Groups

	Hemiarthroplasty (n=130)	THA (n=328)	P value
Age	79.8 +/- 10.7	79.1 +/- 10.1	0.344
Sex			0.06
Male	29.2%	36.0%	
Female	70.8%	64.0%	
Race			0.626
White (Non-Hispanic)	86.2%	84.1%	
Black	6.1%	8.8%	
Other	7.7%	7.1%	
BMI	25.2 +/- 5.6	25.5 +/- 4.4	0.160
Charlson Comorbidity Index	1.76 +/- 3.0	0.7 +/- 1.1	0.711
Stem			<0.001
Type 1	76.2%	96.4%	
Type 2	16.9%	2.7%	
Type 3	6.9%	0.9%	

Reported as mean +/- standard deviation or percentage. P values from Mann Whitney, Chi square, or Fisher exact tests.

Statistical Methods

Interrater reliability was calculated for CFR using intraclass correlation coefficients (ICC) and for Dorr classification using Fleiss's Kappa. Continuous variables were compared between groups using Mann-Whitney tests. Nonparametric data was reported as median and interquartile range (IQR). Categorical variables were analyzed with chi square or Fisher exact tests and reported as percentages. For Dorr classification, THA and HA femur types were compared using a pairwise comparison or proportions using the average proportion of classification by each reviewer. For CFR, average measurement values between reviewers were used to compare HA to THA. Multiple comparison testing was used to compare CFR between different Dorr types in patients where reviewers agreed on Dorr type. Logistic regression was used to investigate association of the CFR with complications. An alpha of 0.05 was used for all statistical tests. All statistical analyses and calculations were performed using R software (Foundation for Statistical computing, Vienna, Austria).

RESULTS

Demographics

Mean age of patients undergoing hemiarthroplasty for femoral neck fracture was 79.8 +/- 10.7 years compared to 79.1 +/- 10.1 years in matched patients undergoing elective primary THA (p=0.461). The majority of patients undergoing HA were female (70.8%) and white (86.2%). Age, sex, BMI, and race were statistically similar between groups (Table 1). Median CCI was also similar between groups. Type 1 stems (single wedge) were used for the majority of cases in both groups; however, the frequency of type 2 (double wedge, metaphyseal filling) and type 3 stems (tapered) was higher for HA than for THA (Table 1).[21]

Dorr Classification and Canal Fill Ratio

Classification of femur Dorr type showed strong agreement between reviewers (Table 2). Based on pairwise comparisons with Bonferroni correction, Dorr types showed no significant differences between THA and HA (Table 3). Type B femurs were more common in both groups, followed by type A then type C.

There was strong agreement between reviewers of the measured canal fill ratios (ICC >0.7) at the level of the lesser trochanter, 2 cm above the lesser trochanter, and 2 cm below the lesser trochanter. There was moderate to strong agreement (ICC 0.674) between reviewers 7 cm below the lesser trochanter. Using mean CFR between reviewers, the canal fill was significantly greater for THA compared to HA at each level (Table 3). This difference was greatest at the level of the lesser trochanter, with a median CFR of 0.86 compared to 0.71 (p<0.001). The difference was smallest 7 cm below the greater trochanter, although the difference was still significant (median 0.85 versus 0.79, p<0.001). Effect size was moderate to large at all levels.

Dorr classification A versus C was also significantly associated with CFR (tables 4 and 5) at the level of LT -2 cm (0.89 vs 0.86, p=0.049) (Figure 2). While statistically significant, the slight difference for THA was likely

Table 2. Agreement Between Reviewers for Dorr Classification and CFR

	Agreement Index	P value or 95% Confidence Interval	Agreement Strength
Dorr Femur Type			
Type A	0.804	p<0.001	Strong
Type B	0.852	p<0.001	Strong
Type C	0.775	p<0.001	Strong
Canal Fill Ratio			
LT + 2 cm	0.720	95% CI: 0.586 – 0.803	Strong
Lesser trochanter	0.826	95% CI: 0.731 – 0.869	Strong
LT – 2 cm	0.778	95% CI: 0.725 – 0.820	Strong
LT – 7 cm	0.674	95% CI: 0.674 – 0.721	Moderate/ Strong

Agreement indices were Fleiss' Kappa for Dorr type and Intraclass Correlation Coefficients for CFR.

Table 3. Dorr Type and CFR in Hemiarthroplasty and THA

	Hemiarthroplasty	THA	Effect Size	P value
Dorr Femur Type				
Type A	28.1%	22.9%		0.399
Type B	49.6	62.3%		0.070
Type C	22.3%	14.2%		0.173
Canal Fill Ratio				
LT + 2 cm	0.66 +/- 0.10	0.74 +/- 0.06	0.98	<0.001
Lesser trochanter	0.71 +/- 0.16	0.86 +/- 0.07	1.12	<0.001
LT – 2 cm	0.76 +/- 0.13	0.87 +/- 0.07	1.06	<0.001
LT – 7 cm	0.79 +/- 0.13	0.85 +/- 0.10	0.53	<0.001

Reported as percentage or mean +/- standard deviation. P values from proportions test (Dorr type) and t tests (CFR).

Table 4. CFR by Dorr Type for THA

	Dorr A	Dorr B	Dorr C	P value
LT + 2 cm	0.73 [0.69, 0.77]	0.74 [0.70;0.77]	0.75 [0.68;0.80]	0.559
Lesser trochanter	0.86 [0.82, 0.90]	0.88 [0.84;0.91]	0.88 [0.81;0.92]	0.219
LT – 2 cm	0.89 [0.86, 0.92]	0.88 [0.84;0.93]	0.86 [0.81;0.92]	0.192
LT – 7 cm	0.88 [0.82, 0.92]	0.87 [0.81;0.92]	0.84 [0.80;0.91]	0.284

Reported as median [25th percentile; 75th percentile].

Table 5. CFR by Dorr Type for HA

	Dorr A	Dorr B	Dorr C	P value
LT + 2 cm	0.67 (0.09)	0.66 (0.09)	0.67 (0.09)	0.793
Lesser trochanter	0.85 [0.68;0.90]	0.73 [0.58;0.85]	0.67 [0.60;0.81]	0.018
LT – 2 cm	0.87 [0.77;0.91]	0.79 [0.71;0.84]	0.75 [0.58;0.79]	<0.001
LT – 7 cm	0.89 [0.82;0.95]	0.80 [0.72;0.89]	0.74 [0.62;0.80]	<0.001

Reported as mean +/- standard deviation or median [25th percentile; 75th percentile].

clinically insignificant. HA showed decreasing CFR from Dorr A to Dorr B to Dorr C at the lesser trochanter and below (table 5). The greatest differences were found between Dorr A and Dorr C femurs, with lower CFRs at the levels of the LT (0.85 vs 0.67, p=0.022), the LT -2 cm (0.87 vs 0.75, p=0.001), and the LT -7 cm (0.89 vs 0.74, p<0.001) (Figure 3).

Complications

At least 90-day follow-up was obtained for 89.3% of the THA group and 76.9% of the HA group. Ninety-day total complication and readmission rates were similar between groups, as shown in Table 6. Complications occurred in 4.6% of patients undergoing THA, and 3.5% of patients were readmitted. 8.5% of patients undergoing HA experienced a complication, and 1.5% were readmitted. Complications in the THA group included periprosthetic fracture, instability, prosthetic joint infection, persistent wound drainage, seroma, venous thromboembolism, syncope, and urinary tract infection (UTI), and two mortalities. Complications in the HA group included periprosthetic fracture, prosthetic joint infection, instability, pneumonia requiring intensive care, and UTI, and six mortalities. The combined fracture/dislocation rates were similar between groups (THA 0.9% versus HA 1.5%, p=0.625). There was a significantly higher 90-day mortality rate in the HA group (4.6% versus 0.6%, p=0.008). Logistic regression did not demonstrate increased complication rates based on worse CFR.

Six patients (1.8%) in the THA group underwent reoperation. Reasons included periprosthetic fracture, revision for dislocation, revision for prosthetic joint infection, and irrigation and debridement for wound infection. Two patients (1.5%) in the HA group required additional surgery for prosthetic joint infection and periprosthetic fracture.

DISCUSSION

The most significant finding of this study was that canal fill ratio was significantly lower for patients undergoing cementless hemiarthroplasty compared to THA in a matched cohort, and this was demonstrated with strong interrater agreement. This finding occurred despite similar percentages of Dorr A, B, and C type femurs that were also classified with strong interrater agreement. Additionally, we found that Dorr type was associated with CFR to a greater extent in HA than THA. We did not demonstrate significant differences in complication

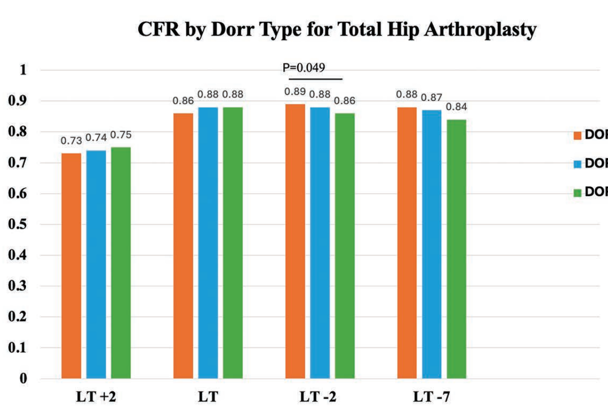

Figure 2. CFR by Dorr Type for Total Hip Arthroplasty.

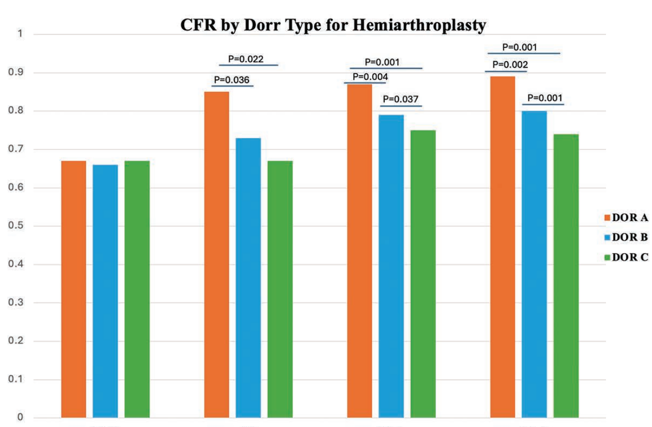

Figure 3. CFR by Dorr Type for Total Hemiarthroplasty.

Table 6. Complications and Readmissions

	Hemiarthroplasty	THA	P value
Total Complications	8.5%	4.6%	0.162
Fracture or Dislocation	1.5%	0.9%	0.625
Readmission	1.5%	3.4%	0.367
Reoperation	1.5%	1.8%	0.999
90-day mortality	4.6%	0.6%	0.008

P value from Fisher exact tests.

or readmission rates between the groups. Periprosthetic fractures, dislocations, and reoperations all occurred at similar rates, although mortality was higher in patients undergoing hemiarthroplasty.

Urgent surgical intervention within 48 hours has been shown to reduce morbidity and mortality following femoral neck fractures.[23] Hemiarthroplasty is often preferred for displaced fractures, especially in elderly patients, and has a lower perceived difficulty compared to THA.[24] Cementless hemiarthroplasty specifically has the advantage of shorter operative times and blood loss, which can be critical when dealing with elderly patients often presenting with multiple medical comorbidities.[25] A recent meta-analysis by Fenelon et al. showed higher mortality within two days of cemented HA compared to uncemented HA, but no difference at seven days, thirty days, or one year following surgery.[26] In a randomized trial, Taylor et al. described a higher rate of implant related complications following cementless hemiarthroplasties.[27] They noted significantly increased rates of subsidence, intraoperative fracture, and postoperative periprosthetic fracture. They found cementless HA operative times to be slightly shorter but observed no differences in blood loss, length of stay, or postoperative pain. Langslet et al. similarly described a higher rate of postoperative periprosthetic fractures following cementless HA, but also found significantly higher Harris hip scores at 5 years postoperatively.[13] Our data may provide an anatomical basis for this finding and supports the recommendation that cemented fixation should be considered for HA.

As HA is generally performed on a more urgent basis compared to THA, surgeon experience may contribute to the ability to achieve optimal implant fit. While it has been shown that hemiarthroplasty can be safely performed regardless of surgeon volume,[28] our theory is that less experienced arthroplasty surgeons may provide at least a partial explanation for lower canal fill rations in these patients.[29] However, our study was not designed to evaluate this, since all patients were operated on by specialized arthroplasty surgeons with extensive experience in placing implants. In fact, our group of 27 arthroplasty surgeons still demonstrated inferior CFR's as compared to the matched cohort of total joint patients.

Analysis of implant type between the two groups demonstrated some important differences. Interestingly, in spite of a higher rate of type 2 metaphyseal filling stems used in the hemiarthroplasty group, canal fill was still lower at all levels. Rattanaprichavej et al. recently found that Dorr B and C femurs had a higher rate of subsidence following THA, noting that a higher CFR at 2 cm below the lesser trochanter was protective against subsidence.[30] When looking at patients with periprosthetic fracture following THA, Bigard et. found that Dorr C femurs conferred a greater risk, although canal fill was not significantly associated with fracture.[31] Our study found that Dorr C femurs in hemiarthroplasty had significantly worse canal fill at multiple levels compared to Dorr A. These findings suggest that Dorr C femurs along with poor CFR may contribute to periprosthetic fracture risk. Surgeons might be tempted in these cases to use a larger stem, but this must be balanced with the risk for intraoperative fracture when trying to place a larger stem in a Dorr C femur. This study was not powered to determine whether a more canal filling stem type would be advantageous.

CFR is a topic that remains relatively unstudied in the current literature, especially relating to hemiarthroplasty. Only a single study by Lo et al. has reported on CFR in HA, finding that lower CFR was associated with increase rates of subsidence in bipolar HAs at 12 weeks follow-up.[32] They acknowledged this subsidence as an important risk factor for complications, although excluded patients with early periprosthetic fracture from analysis. To our knowledge, our study is the first to compare CFR of HA to THA. These findings demonstrated that although the fit of femoral prosthesis in cementless HA was less than THA, it did not correlate with an increased risk of periprosthetic fracture or any other type of complication. While our study demonstrated differences in CFR between HA and THA and the association of Dorr type on CFR, it was likely underpowered to detect statistically significant differences in complications such as dislocation or periprosthetic fracture.

Limitations of our study include the retrospective nature and limited follow up of our patients. As hemiarthroplasties are generally performed urgently, it is possible that postoperative complications may have arisen that presented to an outside hospital limiting accurate tracking of complications. We found a lower rate of complications in this cohort than commonly described in the literature, which suggests that complications likely occurred in patients lost to follow-up.[33-35] As discussed, our cohort was powered to detect differences in CFR but not events such as periprosthetic fracture and dislocation. Utilization of data only from arthroplasty surgeons also limited our ability to interpret results for surgeons in general practice. Our a priori decision to propensity matches the patients for age also biased the results since the average THA patient is younger than that for HA. However, the fact that a matched group of osteoarthritic THA patients showed improved canal fill, indicates that there is something clearly different about patients undergoing HA for fracture.

CONCLUSION

Patients who undergo cementless HA for femoral neck fractures have inferior canal fill ratios compared to routine THA patients. This suggests that the mechanism for increased periprosthetic fractures in these patients may be suboptimal canal fill. Given that CFR rates are concerningly low post cementless HA, when interpreted in the context of previously published data, our findings further strengthen the rationale for utilizing cemented fixation in the setting of HA post hip fracture. Future research is necessary to determine whether these trends can be reversed utilizing alternative stem designs that are able to achieve improved canal fill and large studies will be necessary for adequate power to show direct relationship to periprosthetic fracture.

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