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Predictors of Intraoperative Fractures during Hemiarthroplasty for the Treatment of Fragility Hip Fractures

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Background: The aim of our study was to determine the rate and preoperative predictors of intraoperative fracture (IOF) during hip hemiarthroplasty (HA) in patients who have sustained a fragility hip fracture injury.

Methods: We reviewed 626 patients who underwent HA at our institution using the National Hip Fracture Database. Various patient- and surgery-related data including demographic information, cement usage, surgeon grade, time to surgery, and operative duration were collected. The metaphyseal diaphyseal index and modified canal bone ratio were measured on preoperative radiographs. We compared patients with and without IOF with respect to all variables collected. Multivariate regression modeling was used to identify significant preoperative risk factors for IOF.

Results: There was a 7% incidence of IOF in our cohort exclusively comprising of Vancouver A fractures. The majority of these complications were treated nonoperatively (52%). There was no statistically significant difference with respect to cement usage, surgeon grade, operative duration, time to surgery, and radiographic parameters collected. Increasing age was found to be the most significant preoperative risk factor for predicting IOF (p = 0.024, overall relative risk = 1.06).

Conclusions: Our identified predictor of increasing age is nonmodifiable and illustrates the importance of meticulous surgical technique in older patients. Furthermore, its independence from fixation methods or prosthesis design as a predictor of IOF may support using an uncemented prosthesis in patients at risk from cement implantation.

Keywords: *Hemiarthroplasty, Hip fractures, Femur neck fracture, Intraoperative fracture*

Hemiarthroplasty (HA) of the hip for fragility hip fractures can be inserted with cement or secured in the proximal femur with an uncemented press fit design. HA leads to functional recovery and decreases morbidity and mortality.[1-3] Intraoperative fracture (IOF) is a known complication associated with treatment using a HA for hip fractures. The ensuing problems of IOF include poor functional outcomes, increased surgical time, revision rates, morbidity and mortality.[4] Therefore, identifying factors that lead to IOF in HA is vital to help prevent its occurrence. In total hip replacements (THR) several studies have implicated female sex, metabolic bone disease, advancing age and sub optimal surgical technique as factors that contribute to IOF around the femur.[5-7]

Patients with intracapsular neck of femur fractures are generally frail with lower bone mineral density compared to patients in the elective population undergoing THR.[8,9] Measuring radiological parameters of the proximal femur has helped predict osteoporosis and bone mineral density.[10] Specific radiological parameters have also been shown to help predict IOF in patients receiving HA

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treatment.[11)]

Previous literature comparing older prosthesis designs have shown increased IOF rates in uncemented HA.[3)] By contrast, contemporary studies comparing modern prosthesis designs have shown variable IOF rates in cemented and uncemented HA designs.[11-13)] The aim of our case-control study was to determine potential risk factors, which may predispose to an IOF in patients undergoing HA for fragility hip fractures.

METHODS

We carried out a retrospective review of notes and radiographs for consecutive patients who underwent a HA for fragility intracapsular hip fractures over a 3-year period. Data was sourced from the National Hip Fracture Database of the United Kingdom in conjunction with the information governance team at Hull Royal Infirmary. We identified 626 consecutive patients who underwent HA using either an uncemented hydroxyapatite-coated Furlong H-A.C prosthesis or the Furlong cemented prosthesis (JRI, Sheffield, UK).

We excluded patients with incomplete data, pathological fractures, those deemed unfit for surgery by the anaesthetic team and those under the age of 50 with an intracapsular hip fracture due to high-energy trauma. Ultimately, 472 patients were available for analysis. We analysed our cohort with regard to the dependent variable of IOF in two groups. These included those who did not sustain an IOF (group 1) and those that did (group 2).

Initially during the study period an uncemented prosthesis design was favoured at our institution. This preference was changed during the course of the study to a cemented design following implementation of national hip fracture management guidelines. The decision to implant an uncemented prosthesis was still reserved for some patients. This was undertaken by a multidisciplinary team preceding surgery, which included the responsible surgical and anaesthetic teams. Patients with significant cardiovascular and respiratory comorbidities tended to be treated with an uncemented prosthesis in an attempt to help avert complications of cement implantation syndrome.

A modified Hardinge approach was used in all cases with stem implantation in line with the manufacturer's instructions using contemporary cementing techniques for cemented HA and bone preservation with press fit insertion for uncemented HA. A bipolar head corresponding to the femoral head size extracted was implanted in all cases.

We collected patient-related, surgery-related and radiographic data for our cohort. Patient-related data included age, sex, and fracture type as determined by the Vancouver classification.[14)] With respect to surgery-related data, we recorded the grade of surgeon undertaking the procedure, use of cement, the time to surgery from presentation with injury, and the operative duration.

Radiographic parameters were measured on DICOM images using the IMPAX 6 AGFA radiographic software (Agfa Healthcare, Mortsel, Belgium) by two independent assessors. These included the metaphyseal diaphyseal index (MDI) score and the modified Yeung's canal bone ratio (CBR)[11)] as demonstrated in Fig. 1. Both MDI score and CBR have previously been shown to help predict IOF in patients undergoing uncemented HA.[11)]

All categorical variables were analyzed using the chi-square or Fisher exact test, while the independent-samples Mann-Whitney test was used for continuous variables when comparing the two groups in univariate analysis. All variables that met criteria for inclusion in univariate analysis ($p < 0.15$)[15)] were then included in a Cox regression model using backward selection to identify the significant

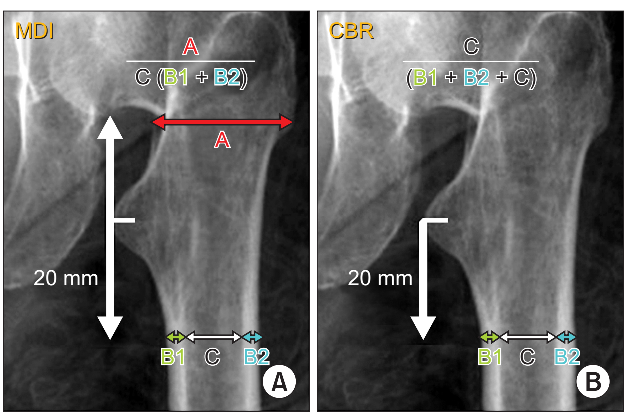

Fig. 1. Description of calculation of metaphyseal diaphyseal index (MDI) score (A) and modified canal bone ratio (CBR) (B).

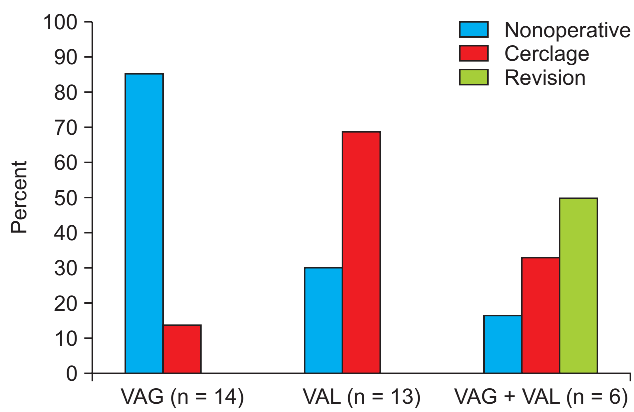

Fig. 2. Treatment for intraoperative fractures in the cohort (n = 33). VAG: Vancouver A greater trochanter fracture, VAL: Vancouver A lesser trochanter fracture.

preoperative predictors of IOF. SPSS ver. 20.0 (IBM Corp., Armonk, NY, USA) was used to perform the analyses.

RESULTS

A total of 472 patients were included in this study. Of them, 33 patients (7%) sustained an IOF (group 2). All patients in group 2 sustained a Vancouver A fracture with the majority affecting the greater trochanter of which most were treated nonoperatively (Fig. 2). A statistically significant difference was found with respect to age between the two groups ($p = 0.024$). Patients were older in group 2 as compared to group 1 with mean ages of 84.0 years and 80.4 years (range, 54 to 105 years), respectively. There was no statistical difference with respect to sex distribution between the two groups. All patient-related data collected is summarized in Table 1.

There was no statistical difference in terms of surgeon seniority between the two groups ($p = 0.19$). More than 80% of cases in both groups were undertaken by a

Table 1. Comparison of Group 1 and Group 2

Variable	No intraoperative fracture (group 1, n = 439)	Intraoperative fracture (group 2, n = 33)	*p*-value
Incidence (%)	93	7	-
Patient-related data			
Type of fracture (Vancouver)			-
A (GT)	-	14 (42.4)	
A (LT)	-	13 (39.4)	
A (GT + LT)	-	6 (18.2)	
B	-	0	
C	-	0	
Age (yr)	80.4 (54–101)	84.0 (63–105)	0.024*
Sex			0.132*
Female	118 (26.9)	23 (69.7)	
Male	321 (73.1)	10 (30.3)	
Surgery-related data			
Surgeon grade			0.19
Consultant	111 (25.3)	8 (24.2)	
Associate specialist	25 (5.7)	5 (15.2)	
Registrar	302 (68.8)	20 (60.6)	
Senior house officer	1 (0.2)	0	
Operative duration (min)	97 (46–222)	116 (55–192)	0.001
Time to operation (hr)	36 (1–430)	41 (6–205)	0.80
Cement use	139 (31.7)	10 (30.3)	0.87
Radiographic data			
MDI	21.4 (4.1–84.9)	24.3 (8.4–49.1)	0.147*
CBR	0.74 (0.4–0.9)	0.72 (0.6–0.9)	0.29

Values are presented as number (%) or mean (range).
GT: greater trochanter, LT: lesser trochanter, MDI: metaphyseal diaphyseal index, CBR: canal bone ratio.
*Variables entered into univariate regression analysis.

middle grade trainee or a consultant. The overall mean time to surgery for our cohort was 36 hours. The mean time to surgery was not different between the two groups ($p = 0.80$). We found significantly higher operative duration in group 2 as compared to group 1 (mean duration, 116 vs. 97 minutes; $p = 0.001$). Out of the 472 patients in this cohort, there were 323 uncemented and 149 cemented HAs. There was no difference in the proportion of cemented HA between the two groups ($p = 0.87$). The rate of IOF in cemented HA was 6.7% in comparison to 7.1% in uncemented HA.

Table 1 summarises the findings with regards to radiographic parameters between the two groups. Interestingly, there was no statistical difference in the mean MDI and CBR between the two groups ($p = 0.147$ and $p = 0.29$, respectively).

After univariate analysis, all eligible parameters were entered into the Cox regression model including age ($p = 0.024$), sex (0.132) and MDI (0.147). Increasing age was the only factor that was found to be significant for predicting IOF ($p = 0.024$; overall relative risk = 1.06; 95% confidence interval, 1.01 to 1.12).

DISCUSSION

Our study has demonstrated an IOF rate of 7% associated with hip HA procedures. The most significant preoperative determinant, contributing to the risk of IOF, was increasing age. Interestingly, we did not find the usage of an uncemented prosthesis, surgeon grade or proximal femoral morphology indices to have any significant impact on the risk of developing an IOF.

The 7% incidence of IOF using a contemporary uncemented prosthesis design is comparable to that of others.[2,11-13,16] In comparison to previous studies using the JRI uncemented hydroxyapatite-coated prosthesis,[11,17,18] our IOF rate compares favourably. We attribute this to the longstanding experience and training in implanting the uncemented JRI HA prosthesis at our institution. Most of the fractures in our cohort were around the femoral metaphysis (Vancouver A). Barlas et al.,[17] in their cohort of 273 hip fractures treated using the JRI furlong H-A.C. prosthesis, demonstrated an IOF rate of 10.3%. Similarly, they also showed that Vancouver A was the only type of IOF sustained. The authors postulated that the lack of flexibility in tailoring femoral prosthesis sizes for relatively narrow femoral canals would be the causative factor in sustaining IOF. This resulted in the development of further sizes in the inventory of the prosthesis in question. In our study, we used this more contemporary version of the same prosthesis design, which may have curtailed the risk of IOF.

The JRI furlong H-A.C. prosthesis uses a proximally loading design. Such designs have led to Vancouver A IOFs as compared to more distally loading stems, which are commonly associated with Vancouver B fractures.[19] The metaphyseal portions of the femora are predisposed to hoop stresses generated from initial mechanical fixation using a proximally loading prosthesis. In the elective population, these stresses help in implant fixation whereas in the osteoporotic patient, these stresses may be too great leading to fractures around the metaphyseal portion.[11] Undisplaced Vancouver A IOFs are largely stable and most authors would support nonsurgical management.[19] The management strategy in our cohort agrees with these recommendations (Fig. 2).

Most patients in our cohort presented in the eighth decade of their life. This is in agreement with the mean age of patients in the national hip fracture database.[20] Although not statistically significant, there was a higher proportion of female patients who sustained an IOF as compared to those that did not. These findings agree with those of others who have investigated fracture complications associated with HA surgery[11] and may be attributable to the relatively earlier onset of osteoporosis in comparison to men, owing to postmenopausal changes.[21,22]

Anecdotally it may be considered that surgical inexperience may be a determinant of complications both intra- and postoperatively in hip fracture surgery. However, this has not been borne out in recent literature. A contemporary registry level study has demonstrated no difference in postoperative dislocation rates associated with hip fracture surgery between those that had completed training and those that did not.[23] We found that surgeon seniority did not have an impact on the occurrence of an IOF in our cohort. Similarly, the findings of Kendrick et al.[24] also demonstrated no difference in IOF rates with respect to surgeon grade.

One of the fundamental rationales for recommending the use of a cemented HA in hip fracture patients, in the current English national guidelines,[25] has been the concern of an increased risk of IOF using an uncemented prosthesis. The majority of the evidence base for this rationale has been on comparative studies of older prosthesis designs such as the Austin Moore and Thompsons.[3] In contrast, our study has shown no difference when comparing contemporary uncemented and cemented designs with respect to IOF. This is in agreement with recent prospective studies which also compare contemporary cemented and uncemented HA prostheses.[12,16]

Several radiographic parameters have been used as a predictor of IOF.[11,26] It has been postulated that such measures may be considered a surrogate marker of the degree of osteoporosis. Yeung et al.[10] investigated the use of the CBR and other radiographic parameters in determining the presence of osteoporosis. Their study showed a strong correlation between dual-energy X-ray absorptiometry measured T scores and CBR in cadaveric femora. The CBR had the best overall performance in diagnosing osteoporosis.[10] Similarly, Dorr's classification also highlights the degree of osteoporosis in proximal femora. Type A, B, and C are in order of increasing osteoporosis.[27] Nash and Harris[26] found Dorr type B and C were associated with a higher rate of IOFs in comparison to Dorr type A. We found no difference in MDI score and modified CBR between patients that sustained an IOF to those that did not. This is in contrast to the findings of Chana et al.[11] who only measured the modified CBR and MDI scores for patients who underwent uncemented implantation. Perhaps a subgroup analysis of only uncemented HA in our cohort would have yielded results similar to Chana et al.[11] Our study did not differentiate between uncemented and cemented prostheses with regards to MDI and CBR, as we hypothesised that the process of femoral canal preparation in both may predispose to significant stresses leading to an IOF. This rationale is supported by the work of Jasty et al.[28] who demonstrated similar cortical stresses when comparing implantation of cemented stems to that of uncemented press fit designs in a study using cadaveric femora.

Univariate analysis identified three variables, which were eligible for inclusion into our multivariate cox model. Of these, an increasing age was found to be the strongest predictor of IOF during HA with a relative risk of 1.06. Interestingly, this was independent of the type of fixation or prosthesis design used. Increasing age alters bone morphology and reduces bone mineral density with structural and cellular compromise.[26] This may make proximal femora less favourable for rasp preparation and subsequent implant fixation. Perhaps this explains our finding of increasing age being the strongest preoperative determinant of an IOF. While there is paucity of information on the impact of age on IOFs in the setting of hip fracture surgery, it has certainly been shown to be a determinant of IOFs in the elective setting during THR surgery.[29]

Our study was limited by its retrospective design but data was collected and verified from multiple sources with incomplete data being excluded. Data regarding comorbidities and medications were not collected. Therefore, patients such as those on steroids or with established osteoporosis were not accounted for. This certainly could have confounded IOF rates. There were no formal criteria for the choice of an uncemented or cemented prosthesis. However, we would argue that the choice for an uncemented prosthesis was generally in the more frail patients. Any other approach, which may have accounted for the frailty of patients, would perhaps have made the choice for an uncemented prosthesis appear protective with respect to IOF and thereby introducing bias in favour of an uncemented approach. It is yet unclear as to whether accepting the risk of IOF in implanting an uncemented prosthesis in order to avert the potential problems relating to cement use in frail elderly patients yields any long-term benefit.

IOFs are inherently an iatrogenic complication. Interestingly, in our study this is not related to surgical experience. Our identified predictor of increasing age is a nonmodifiable risk factor and perhaps illustrates the importance of meticulous surgical technique in patients that are older and hence frailer. Furthermore, its independence from fixation methods or prosthesis design as a predictor for IOF may well support the notion of using an uncemented prosthesis in patients that may be at increased risk of complications from cement implantation.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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