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ORIGINAL ARTICLE

Comparative analysis of the quality of the cement mantle in hip hemiarthroplasty after femoral neck fracture between three different surgical approaches: a single-center retrospective observational study

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Abstract

Purpose Achieving the initial stability of implants is necessary for hip hemiarthroplasty (HHA), especially in elderly patients, and this can be achieved with a cement mantle of quality. The direct anterior approach (DAA) for HHA lately has shown positive results. However, evidence is lacking of HHA in elderly patients with osteoporosis after femoral neck fracture (FNF). This study compares differences in cement mantle quality after HHA, its complications, radiological outcomes and functional status in elderly patients with FNF intervened through different approaches.

Methods A non-interventional, retrospective case–control study was conducted. 150 cases were selected based on the surgical approach (DAA, DLA and PLA) in a 1:1:1 proportion between 2018 and 2019. Under 75 years old suspicion or confirmation of a pathological fracture were excluded. Antibiotic-loaded cement was utilized. Cement preparation involved vacuum centrifugation and standard instructions for preparation canal and filling, and prosthesis placement were followed.

Results No statistically significant differences in cement mantle quality, radiological outcomes, and the majority of the postoperative complications and functional status considering the surgical approach ($p > 0.05$). However, the DAA was associated significantly with shorter hospital stays (8.3 days vs 11.3 and 13 days for DLA and PLA) a decrease in postoperative blood transfusion (22% vs 34% and 53%), and lower rate of loss of walking (8% vs 20% and 28.6%).

Conclusion The DAA for HHA in patients with FNF provides a high-quality cement mantle, similar to other approaches. Also, the DAA shows advantages like shorter hospital stays and lower transfusion rates in elderly patients.

Keywords Direct anterior approach · Cement mantle quality · Hemiarthroplasty · Femoral neck fracture · Elderly · Hip fracture

Introduction

Femoral neck fractures (FNF) in the elderly are generally managed through total hip arthroplasty (THA) or hip hemiarthroplasty (HHA). In both treatment strategies, the femoral stem can be either cemented or uncemented [1]. The cemented bipolar HHA is widely accepted as an effective method [2]. Among the multiple surgical approaches to perform an HHA, the most utilized are the direct lateral approach (DLA), posterolateral approach (PLA) and the direct anterior approach (DAA), which has increased its popularity worldwide in recent years [3].

The primary advantage of utilizing bone cement in HHA lies in its ability to achieve initial firm stability, irrespective of bone quality—an essential consideration in elderly patients [4]. Cement mantle quality is an important factor in

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the longevity of implants. Therefore, achieving an acceptable cement mantle becomes mandatory to prevent postoperative complications, especially in fragile patient populations [5].

The influence of using DAA to achieve an adequate cement mantle after an HHA has been seldomly studied in the literature, with great diversity of results [6]. Most of the evidence reported on the quality of the cement mantle obtained using DAA comes from studies where a THA is performed, and not exclusively as a treatment for FNF. Although many positive results have been published on the DAA for THA, evidence is scarce for the implantation of HHA in elderly patients with osteoporosis after a FNF using the DAA [7].

Therefore, the primary objective of this study is to compare the short-term outcomes of DAA, DLA and PLA in elderly patients with FNF, specifically analyzing differences in cement mantle quality after HHA. Secondary objectives include comparisons of blood loss, surgical time, intra and postoperative complications, other radiological parameters (such as stem orientation and femoral offset), re-operation rates, hospital length of stay, functional status postoperative, and mortality rates among the three surgical approaches.

Methods

Study design and participants

A non-interventional, retrospective case–control study was conducted at our Major Trauma Centre. Patients undergoing a cemented bipolar HHA performed by a Trauma and Orthopedics trainee under the direct supervision of a consultant between the 1st of January 2018 and the 31st of December 2019 after a displaced FNF were included. The exclusion criteria were patients < 75 years of age and suspicion or confirmation of a pathological fracture. All implants used were *Actinia*® (Implantcast GmbH, Germany) or *HMax*® (Lima Corporate, Italy).

Patients were categorized into three groups based on the surgical approach employed (DAA, DLA and PLA). The surgical approach performed on each patient was decided based on the patient's characteristics and the surgeon's preference and experience. In total, 50 cases of patients where the DAA approach was used and that fulfilled the eligible criteria for the study were identified. The selection of 50 controls for DLA and PLA were selected chronologically during the time frame of the study.

Cement mantle quality was set as the primary outcome, and it was evaluated according to the four-grade Barrack's classification [8]. Grade A ("white-out") was defined as perfect canal filling and absence of radiolucency in the cement–bone interface. Grade B indicates radiolucency up to 50% of the cement–bone interface; while, Grade C indicates radiolucency in 50 – 99%. Grade D is characterized by 100% radiolucency in the cement–bone interface or the absence of cement distal to the tip of the stem tip. Cement mantle quality was evaluated on immediate postoperative radiographs and was classified twice by two independent and skilled Orthopedic Surgeons. In case of classification discrepancy, a Senior Orthopedic Surgeon provided the final classification. Additionally, the patients were classified as "Acceptable Barrack" when they had a Grade A or B cement mantle quality, or as "Unacceptable Barrack" when they were classified as C or D grade.

Other radiology parameters studied were limb length discrepancy (LLD), stem coronal alignment and femoral offset, which were obtained using the *TraumaCad*® system (Voyant Health, Petah Tikva, Israel).

Data collection

Data on age, gender, American Society of Anesthesiologists (ASA) score, physical function class, blood transfusion, intra and postoperative complications, hospital length of stay, mobility recovery post-surgery, re-operation rates and mortality were collected from hospital medical records. A minimum follow-up of 12 months was maintained.

Cementing technique

Following our institution's evidence-based protocol for HHA [9], all procedures used antibiotic-laden cement according to the surgeon's preference, either *Copal*® (Biomet Merck, Darmstadt, Germany) or *Vancogenx*® (Tecres Spa, Sommacampagna, Verona, Italy). Cement preparation involved vacuum centrifugation, with femoral canal preparation including the insertion of a cement restrictor and pulsatile lavage. Following canal preparation, cement was retrogradely inserted and pressurized (fourth-generation cementing technique). Finally, the prosthesis was manually inserted and impacted into its desired position.

Statistical analysis

Means and standard deviation (SD) were calculated for continuous variables; whereas, categorical variables were reported as frequencies and percentages. Normality was tested using the Shapiro–Wilk test. Groups were compared using the χ^2 test or Fisher's exact test for categorical variables, as appropriate to the normality test. Continuous variables were evaluated with the ANOVA test or the one-way Kruskal–Wallis test, as appropriate. All p values were two-tailed. A p value < 0.05 was considered statistically significant. Statistical analysis was performed using *Stata*® v.14.0 software (StataCorp. College Station, TX, USA).

Table 1 Patient demographics, comorbidities and previous functional status by study groups

Baseline characteristics	DAA ($n=50$)	DLA ($n=50$)	PLA ($n=50$)	p value
Age (years), mean (SD)	85.4 (6.55)	86.5 (6.52)	86.6 (5.46)	0.579
Female, n (%)	30 (60)	37 (74)	39 (70)	0.116
Previous ambulatory status, n (%)				0.762
Ambulatory	47 (94)	46 (92)	45 (90)	
Non-Ambulatory	3 (6)	4 (8)	5 (10)	
Previous ambulatory assistive device use, n (%)				0.239
Yes	35 (70	37 (80)	40 (80)	
No	15 (30)	13 (20)	10 (20)	
ASA Score, n (%)				0.901
I	0 (0)	0 (0)	0 (0)	
II	11 (22)	11 (22)	9 (21)	
III	33 (66)	35 (70)	37 (70)	
IV	6 (12)	4 (8)	4 (9)	
Body mass index, mean (range)	28.2 (18.2–33.7)	27.9 (17.2–34.2)	28.5 (17.9–33.7)	0.364
Time to surgery (hours), mean (range)	49.5 (4–137)	50.6 (4–190)	52.5 (3–165)	0.701

Table 2 Post-operative radiological outcomes in the three study groups

Outcome	DAA ($n=50$)	DLA ($n=50$)	PLA ($n=50$)	p value
Barrack, n (%)				0.118
A	11 (22)	17 (34)	10 (20)	
B	21 (42)	20 (40)	17 (34)	
C	15 (30)	8 (16)	11 (22)	
D	3 (6)	5 (10)	12 (24)	
Dichotomic Barrack, n (%)				0.253
Acceptable	32 (64)	37 (74)	27 (57)	
Unacceptable	18 (36)	13 (26)	23 (43)	
LLLD (mm), mean (SD)	6.28 (5.75)	5.08 (5.02)	5.48 (4.23)	0.539
FO difference (mm), mean (SD)	5.58 (5.76)	6.08 (5.98)	7.36 (6.32)	0.151
Coronal alignment difference (mm), mean (SD)	1.99 (1.58)	1.84 (2.77	2.4 (2.1)	0.102

Results

A total of 150 patients were included in the present study, with each group (DAA, DLA and PLA) comprising 50 patients. Patient demographic characteristics, comorbidities and previous functional status are shown in Table 1. All three groups presented a similar time from diagnosis of FNF to surgery, with no statistical differences found, as shown in Table 1. Post-operative radiological outcomes are presented in Table 2. An "unacceptable Barrack" was identified in 18 patients (36%) in the DAA group, 13 patients (26.5%) in the DLA group and 23 patients (43%) in the PLA group. However, there were no statistically significant differences between the groups ($p=0.253$). Substantial agreement was observed in interobserver reliability, with Cohen's kappa coefficient of 0.760 for the Barrack classification and 0.794 for the Dichotomic Barrack (Table 3). Furthermore, no statistically significant differences were detected in terms of cement mantle quality, LLD, stem coronal alignment, or femoral offset between the groups ($p>0.05$).

Table 3 Inter-observer reliability for Barrack classifications

	Cohen's Kappa	SD	95% CI	
			Lower	Upper
Barrack (A, B, C, D)	0.760	0.036	0.690	0.829
Dichotomic Barrack (Acceptable, Unacceptable)	0.794	0.052	0.691	0.896

150 subjects and 2 raters. Confidence intervals are asymptotic. If there are only 2 levels, weighted kappa is equal to unweighted kappa

$p < 0.01$

The mean follow-up was 12.42 months, with no statistical differences between in each group as shown in Table 4. Mean operation time was 90.2 ± 14.4 min for the DAA group; 89.8 ± 19.6 min for the DLA group and 93.1 ± 21.6 for the PLA group ($p = 0.681$). There was a statistically significant difference ($p = 0.05$) in the need of transfusion of red cell concentrates between groups: 11 patients (22%) in DAA group; 17 patients (34%) in DLA group and 26 (53%) in PLA group ($p < 0.05$).

Significant differences ($p = 0.025$) in hospital length of stay were observed, favoring the DAA group: 8.38 days ± 4.03 in DAA group; 11.3 days ± 7.55 in DLA group and 13 ± 12.5 in PLA group ($p < 0.05$). Post-operative complications and final functional status are summarized in Table 4. Nursing homes were required for 32 (64%) patients in the DAA group; 36 (72%) patients in the DLA and 28 (62%) patients in the PLA group ($p = 0.555$). When comparing final functional status, 8.5% of previous ambulatory patients became non-ambulatory in the DAA group, 21% in the DLA group and 28% of the patients from the PLA group became non-ambulatory, which was a statistically significant difference ($p = 0.03$) between groups, favoring the DAA group. Figure 1 detail the non-ambulatory status previous to the FNF and after the surgery in the three study groups.

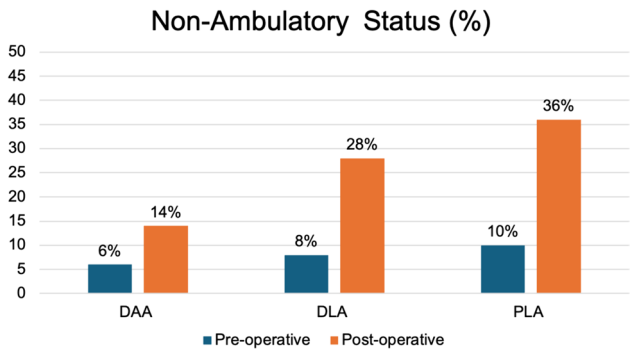

Fig. 1 Non-Ambulatory status pre-operative and post-operatively in the three study groups

Discussion

We found no statistically significant differences concerning cement mantle quality and other radiological outcomes between the three groups. The DAA was associated with a shorter hospital stay, a decrease in postoperative blood transfusion and a higher rate of maintaining the patient's previous functional status. DAA muscle sparing nature can be the reason behind the association with less need for blood transfusion, shorter hospital stays and better functional outcomes while maintaining no difference in cement mantle quality or radiological parameters.

The main advantage of using a cemented femoral stem is its ability to achieve good initial stability regardless of the patient's bone quality [4]. This early stability of the implant is crucial as early stem migration has been reported as a predictor of early aseptic loosening and the need for early revision surgery [10]. In patients older than 75 years –like our cohort– the variability in initial stability greatly favors the cemented femoral stems, as demonstrated by Tanzer et al. which found that early revision (1 month) is 9.14 times more likely in cementless stems than in cemented ones [11]. Thus, a good cementing technique contributes to the longevity of

Table 4 Post-operative complications and final functional status in the three study groups

Outcome	DAA ($n = 50$)	DLA ($n = 50$)	PLA ($n = 50$)	p value
Red cell concentrates transfusion (number of patients), *n* (%)	11 (22)	17 (34)	26 (53)	0.005*
Length of stay (days), mean (SD)	8.38 (4.03)	11.3 (7.55)	13 (12.5)	0.005**
Wound complication, *n* (%)	3 (6)	2 (4)	2 (4)	0.861
Acute PJI, *n* (%)	2 (4)	2 (4)	3 (6)	0.861
Dislocation, *n* (%)	1 (2)	2 (4)	3 (6)	0.594
Femoral cortex perforation, *n* (%)	0 (0)	0 (0)	1 (2)	0.349
Periprosthetic fracture, *n* (%)	0 (0)	0 (0)	1(2)	0.349
Revision surgery, *n* (%)	3 (6)	4 (8)	5 (10)	0.762
Final ambulatory status, *n* (%)				0.412
Ambulatory	43 (86)	36 (72)	32 (64)	
Non-Ambulatory	7 (14)	14 (28)	18 (24)	
Loss of walking, *n* (%)[1]	4 (8%)	10 (20%)	14 (28.6%)	0.031*
Follow-up (months), mean (range)	12.26 (12–17)	12.40 (12–19)	12.60 (12–20)	0.537

* $p < 0.05$; ** $p < 0.01$

[1]It is calculated as the difference between the Ambulatory Pre-operative and Post-operative non-ambulatory patients, and corresponds to the percentage of patients who previously walked and stopped doing so after the episode

the prosthesis [4]. Nonetheless, the initial thickness and homogeneity of the cement mantle, as well as the presence of deficiencies, are critical in the aseptic loosening process [12]. In this sense, have been observed of osteolytic lesions around well-fixed stems with cement mantle defects [13]. Late-onset aseptic loosening –which is more characteristic of cemented stems—may represent fatigue failure at the bone–cement interface, and this interface is weaker with reduced cement interdigitation that can be observed as radiolucent lines on the radiographs [10]. One aspect of the DAA previously questioned is the surgeon's ability to adequately approach the femoral canal [14], consequently altering the ability to achieve a high-quality cement mantle. Nonetheless we found no difference in cement mantle quality which concur with results reported by Kenanidis et al. [6] which demonstrate in a series of 116 undergoing a primary THA that DAA can provide an uncompromised view to the femur that enables correct implantation of a straight femoral stem and high-quality cement mantle even in elderly patients, their results were Barrack A cementation in 39.25%, B in 53.0%, and C in 7.75% of anteroposterior radiographs.

Barrack B cementation is the most prevalent in studies utilizing different types of implant and approaches [6] which coincide with the results obtained in our series. Furthermore, comparing our results with previously published series such as Schuroff et al. [15] that reports 5.8% type A, 53, 5% type B, 31.4% type C, and 9.3% type D cementation according to Barrack in 86 hips operated by a PLA, similar to ours despite all of them being THA and the majority being primary THA. Other previously published series have superior cementation results compared to our series, like Ek and Choong [16] that report 45.7 type A, 46% type B, and 8% type C cement mantles, although less than 5% of the patients in the series underwent a THA for an FNF. To the best of our knowledge, our series is the only one reporting cement mantle quality according to Barrack's Classification exclusively for HHA in patients with FNF utilizing different surgical approaches.

Barrack classification has been proven to have a limited interobserver agreement [17]. We tried to minimize that downfall by having two members of the team review all the radiographs twice, and having a senior orthopedic surgeon designate the classification in cases where an intra-observer or interobserver disagreement was found.

The shorter hospital stays, and reduced blood transfusions associated with the DAA also concur with multiple previous studies. Skowronek et al. [18] demonstrated a reduced hospitalization and blood loss with DAA compared to PLA. Carlson et al. [19] also found shorter hospital stay with DDA compared to DLA. Yang et al. [20] found in a meta-analysis that DAA in THA was associated with reduced blood loss, faster rehabilitation and no significant differences in complications including dislocation compared to the PLA approach which are similar to our results. In a gait analysis comparing DAA vs DLA in THA conducted by Mayr et al. [21] found that functional recovery in the DAA is likely to occur earlier than DLA and is still observable at 12 weeks postoperative, evidence that further substantiates the claim that DAA can lead to a faster rehabilitation. DLA provides excellent exposure to the proximal femur but requires partial dissection of the *gluteus medius*, which can cause loss of abductor muscle strength leading to Trendelenburg gate and reduced mobility [22]. Patients in the DAA group were more likely to maintain their previous ambulatory status after an FNF, and the degree of postoperative mobilization after a FNF has been shown to have social implications such as nursing home requirements [2].

In contrast to previous reported findings, we did not encounter a statistically significant number of dislocations in the PLA group probably because of our low statistical power [23].

Faggiani et al. [24] found no difference in number of transfusions, surgical time and perioperative complications when comparing DAA to DLA in HHA in patients with FNF. Likewise, Auffarth et al. [25] found that the outcome after a HHA was not influenced by the selection between DAA and DLA. Van der Sijp et al. [23] found in a meta-analysis comparing DLA, DAA and PLA that the PLA for HHA in patients with FNF poses an increased risk of dislocation and re-operation compared to the lateral and anterior approaches without providing an evident advantage, considering it an inferior approach to HHA and suggesting its routine use for fracture related HHA should be questioned.

Our study has certain limitations such as being a small retrospective cohort evaluation with limited follow-up. A heterogeneous group participated in the surgical procedures in terms of experience and sub-specialities of consultants. Another limitation is that we did not evaluate cement mantle thickness in the different Gruen zones. Although the use of tranexamic acid intraoperatively for HHA is routine in our practice, there are patients in whom its use is contraindicated and therefore do not receive this medication. Unfortunately, the record of this last data is irregular in the clinical history, so there is a possible bias regarding the need for blood transfusion differences between groups. Nevertheless, we believe that the value of this paper resides in the novelty of studying the influence of the surgical approach in cement quality exclusively on the elderly population undergoing HHA for an FNF.

Conclusion

The DAA for HHA in patients with FNF is a valid alternative that although can be technically more challenging, has no disadvantages regarding the ability to obtain a high-quality cement mantle. Additionally, DAA can provide some

advantages like shorter hospital stays and reduced transfusion rate in elderly patients with FNF.

Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. No funds, grants, or other support was received.

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