Anterior lag screw position and suboptimal reduction in lateral plain as predictors of failure in cephalomedullary nailing of intertrochanteric fractures

German Garabano (✉ ggarabano@hbritanico.com.ar)

British Hospital of Buenos Aires: Hospital Britanico de Buenos Aires <https://orcid.org/0000-0001-5936-0607>

Sebastian Pereira

Hospital Sirio-Libanes

Joaquin Rodriguez

British Hospital of Buenos Aires: Hospital Britanico de Buenos Aires

Cesar Angel Pesciallo

British Hospital of Buenos Aires: Hospital Britanico de Buenos Aires

Fernando Bidolegui

Hospital Sirio-Libanes

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Abstract

Background

Failed osteosynthesis of the proximal femur has a great impact on morbimortality, especially in elderly patients after hip fracture. The purpose of this study was to identify the variables associated with failure in intertrochanteric fractures treated with cephalomedullary nails.

Methods

We retrospectively analyzed 251 consecutive patients who underwent surgery between January 2016 and July 2019. Age, gender, fracture stability (AO/OTA), femoral neck angle (FNA), FNA difference with contralateral hip, lag screw position and tip-apex distance (TAD), union and failure rates were analyzed. Uni and multivariate logistic regression analyses were used to identify whether these variables were related to a risk of failure (cut-out, cut-through, and/or non-union).

Results

The failure rate was 9.56%: 7 non-union (2.78%), 10 cut-out (3.98%), and 7 cut-through cases (2.78%). Female sex ($p = 0.018$), $FNA < 125^\circ$ ($p = 0.0036$), FNA difference 7.5° with contralateral side in lateral view ($p = < 0.0001$), superior ($p = 0.01413$) - anterior ($p = < 0.0001$) lag screw position and $TAD > 25\text{mm}$ ($p = 0.0167$) were identified as risk factors for these complications in univariate logistic regression. Female gender (OR 12.92–95CI 1.39–1736; $p = 0.0196$), FNA difference in lateral view (OR 1.36–95CI 1.21–1.55; $p < 0.001$) and anterior screw position (OR 14.01 95CI 3.15–90.99; $p < 0.001$) were confirmed as independent predictors of failure in multivariate analysis.

Conclusion

This study confirmed female sex, malreduction in the lateral plane, and anterior screw position as independent predictors of failure. Every effort should be made to achieve an accurate reduction and proper implant positioning to improve failure rates.

Introduction

Despite implant evolution and improvements in the surgical techniques,

the fixation failure of proximal femur fracture remains high. Failed osteosynthesis of the proximal femur has a great impact on morbimortality, especially in elderly patients after a hip fracture, reported between 11% to 24 % in the first year after surgery [1, 2].

Cephalomedullary nails (CMN) are increasingly becoming the implants of choice to treat intertrochanteric fractures [2, 3]. Therefore, identifying predictors of failure is particularly relevant. Though much has been published regarding predictors of failure of extramedullary implants, [4–7] nail failure has not been extensively studied [8–11]. Since the biomechanical behavior of extramedullary implants differs from that of intramedullary implants, predictors of failure may also be different.

Multiple factors have been related to failure after intertrochanteric nailing: unstable fracture patterns [7, 9], suboptimal reduction [3, 11], superior lag screw placement on the femoral head [7, 10], tip to apex distance [3, 4, 8, 10], and poor bone quality [9, 12]. These parameters have been often discussed in the literature, however, conclusive evidence is still lacking.

The purpose of this study was to assess whether demographic variables, fracture stability, femoral neck angle, quality of reduction, screw positions on the femoral head, and tip to apex distance, alone or combined, are predictors of failure in intertrochanteric fractures treated with cephalomedullary nails.

Materials And Methods

We retrospectively analyzed the medical records of patients with intertrochanteric hip fractures operated in two centers between January 2016 and July 2019. The trauma database of each institution was reviewed to identify patients, using the corresponding codes with intertrochanteric hip fracture and surgical treatment with a cephalomedullary nail as search criteria. Subsequently, the data was collated with the medical records of the institutions to obtain precision data. This study was conducted after obtaining the approval of the Ethics Committee of both institutions.

Patients aged > 65 years treated with short cephalomedullary nails were included. Exclusion criteria were previous surgery in the contralateral hip, pathological fractures, and lack of clinical/x-ray follow-up to assess fracture healing—whether due to death or loss to follow-up.

All patients were operated underwent minimally invasive surgery with intraoperative radioscopy on a traction table in a supine position. Closed reduction was attempted in all cases. The cephalomedullary nails utilized were made of steel, with an angle of 130°, a single cephalic lag screw to the head (no blade), and a single dynamic distal locking.

On the first postoperative day, all patients were allowed full-weight bearing with assistance, as tolerated, except no ambulatory patients.

Radiological examinations were performed before and after surgery, 6 weeks, and 3, 6, 9 and 12 months. X-ray examination included anteroposterior (AP) and lateral (L) views of the hips.

Age, gender, and side of fracture, were recorded. Preoperative AP and L X-ray views were reviewed to identify fracture stability according to AO/OTA classification (31.A1–31A2.1 were grouped as stable; and 31.A2.2 -A2.3 as unstable) [13].

Immediate postoperative X-rays were reviewed to assess femoral neck angle (FNA), reduction quality, lag screw position on the femoral head, and tip to apex distance (TAD).

FNA was measured in the operated and contralateral hip in the AP and L views and differences were calculated. The reduction quality was categorized according to a modification of the method developed by Baumgaertner et al. based on two criteria assessed on AP and L views [5]. FNA of 125–130° on AP and less than 20° of angulation on the L view was the first criterion. The second criteria were the presence of less than 4mm of displacement of any fragment in both views. If both criteria were met, the reduction was categorized as good, if only one or neither criteria were met the reduction was acceptable or poor, respectively.

For the lag screw position, the femoral head was divided into three regions on AP (inferior, center, superior) and L views (posterior, center, anterior) according to Cleveland's method [14]. For this, the placement of the tip of the lag screw in the femoral head was considered.

TAD was calculated according to the method described by Baumgaertner et al., according to which, a distance of $\leq 25\text{mm}$ is adequate [5].

These measurements were performed by two independent authors and discrepancies were resolved by the senior author.

Non-union was defined as the absence of bone callus at nine months after surgery and lack of radiographic healing progress in the last 3 months. Complications related to loss of fixation of cephalic screws in the femoral head (i.e. cut-through and cut-out) were also analyzed. Cut-out was defined as the extrusion of the screw from the superior cortex of the femoral head or neck and cut-through as the axial migration of the screw with joint penetration. On basis of nonunion, cut-out, and cut-through occurrence the study population was divided into two groups: failure and non-failure groups.

Statistical Analysis

A Student's t-test or Wilcoxon's test was used to compare continuous variables between failure and nonfailure groups, and a Chi-square or Fischer's test to analyze the relationship between categorical variables.

In order to analyze whether a variable exerted any influence on the incidence of complications, logistic regression analysis and selected the variables using a step-by-step method were applied. When assessed separately, due to the low frequency of each individual complication, Firth's logistic regression was used. Uni and multivariate logistic regression analysis results were presented as odds ratio (OR) for statistically significant variables. For the purposes of drawing statistical conclusions, a $p\text{-value} < 0.05$ was considered statistically significant. Statistical analysis was conducted using R Software (Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria).

Results

Out of the 289 patients examined initially, 251 with 251 fractures met inclusion criteria and were reviewed in this study. Thirty-eight were excluded (17 were lost to follow up, 5 died before fracture healing, 4 pathological fractures, 12 previous contralateral hip surgery).

Two hundred and nine were (83.26%) women. The mean age was 81.5 years (range 66–99). The left hip was affected in 134 (53.38%) cases. The mean follow-up 18.5 months (range 8–38). The union rate was 90.43% (227 hips) in an average period of 12 weeks (range 9–16). The remaining 24 fractures (9.56%) presented failures: 7 non-union (2.78%), 10 cut-outs (3.98%), and 7 cut-through (2.78%).

The comparative analysis between failure (n: 24) and non-failures (n: 227) groups showed that mean age was similar in both groups (i.e. 81 years old). (Table 1)

Table 1
Descriptive comparison between non-failure and failure groups.

	Total n = 251	Non-Failure (n = 227, 90.4%)	Failure (n = 24, 9.6%)	p-value
Age <i>mean</i>	81.5	81.5	81.4	0.8220
Gender, <i>n (%)</i>	209 (83.3)	185 (81.5)	24 (100.0)	0.0181
Female	42 (16.3)	42 (18.5)	0 (0.0)	
Male				
Fracture <i>n (%)</i>	102 (40.6)	92 (40.5)	10 (41.7)	0.9999
Stable	149 (59.4)	135 (59.5)	14 (58.3)	
Unstable				
Reduction quality <i>n - (%)</i>	120 (100)	114 (95)	6 (5)	0.0478
Good	97 (100)	84 (86.6)	13 (13.4)	
Acceptable	34 (100)	29 (85.3)	5 (14.7)	
Poor				
FNA <i>Mean (SD)</i>	128.9 ± 6.1°	129.1 ± 6.0°	126.4 ± 6.6°	0.0632
FNA ≥125° <i>n (%)</i>	206 (82.1)	192 (84.6)	14 (58.3)	0.0036
FNA difference	3 (3)	3 (3)	4.5 (5.25)	0.0758
Median (IR)	0 (5)	0 (5)	7.5 (10)	< 0.0001
AP				
L				
Lag Screw placement <i>AP n-%</i>	51 (20.32)	45 (19.82)	6 (25)	0.01413
Inferior	183 (72.91)	170 (74.89)	13 (54.17)	
Center	17 (6.77)	12 (5.29)	5 (20.83)	
Superior				

FNA: femoral neck angle; **FNA difference** *L view*: angulation difference with unaffected hip; **TAD:** tip-apex distance; **AP:** antero-posterior view; **L:** lateral view; **CI:** confidence interval

	Total n = 251	Non-Failure (n = 227, 90.4%)	Failure (n = 24, 9.6%)	p-value
Lag Screw Placement _{L n-%}	46 (18.33)	44 (19.38)	2 (8.33)	<0.0001
Posterior	173 (68.92)	164 (72.25)	19 (37.50)	
Center	32 (12.75)	19 (8.37)	13 (54.17)	
Anterior				
TAD _{mean (SD)}	22.7 (5.6)	22.5 (5.4)	24.9 (7.2)	0.1258
TAD > 25mm _{n (%)}	77 (30.7)	64 (28.2)	13 (54.2)	0.0167
FNA: femoral neck angle; FNA difference_{L view}: angulation difference with unaffected hip; TAD: tip-apex distance; AP: antero-posterior view; L: lateral view; CI: confidence interval				

Regarding sex, there were more female patients in both groups. However, it should be noted that all patients in the failure group were women (p = 0.0181).

The distribution of fracture type (stable - unstable) was similar in both groups. Approximately 60% of fractures were classified as unstable in each group.

The failure rate increased significantly as reduction quality decreased. The 5%, 13.40%, and 14.70% of those rated with good, acceptable, or poor reductions respectively presented complications (p = 0.0478).

The mean FNA was $128.9 \pm 6.1^\circ$ for both groups (range 113–152). When analyzed separately, the mean FNA ($126.4 \pm 6.6^\circ$) was lower in the failure group as compared to non-failure group ($129.1 \pm 6.0^\circ$). This difference was not statistically significant (p = 0.0631). When classifying patients by FNA, the percentage of patients with $FNA \geq 125^\circ$ was higher in the non-failures group: 192 (84.6%) vs 14 (58.3%) (p = 0.0036).

The FNA difference with the contralateral hip was higher in AP measures in the failure group (4.5° vs 3.0° ; p = 0.0758). In L view the median difference was 7.5° for the failures group and 0° for non-failures, this difference was significant (p < 0.0001). (Fig. 1)

According to Cleveland's zones, the most frequent positioning of the lag screw in the non-failures group was center-center (51.5%), and superior-center (33.3%) in the failure group. Figure 2 shows the distribution of each zone and failure rate. According to the 3 positions of each view, the Superior zone in AP and Anterior in L views were related whit failures (p < 0.0001 and p 0.01413, respectively).

The mean TAD was 22.7 ± 5.6 mm for both groups (range 7–45). When analyzed separately, mean TAD was larger in patients with failures, though differences were not statistically significant (p = 0.1258). When classified by TAD, 64 (28.2%) patients in the non-failures group had TAD > 25mm, while in the

failure group 13 (54.2%) patients had TAD > 25 mm. Such difference was statistically significant ($p = 0.0167$).

Variables with $p < 0.05$ were included in the univariate analysis. According to the logistic regression model, the following variables showed increased failure risk: female gender, FNA < 125°, FNA difference in lateral view, TAD > 25mm, and superior in AP, and anterior in L views of lag screw position. (Table 2)

Table 2
Univariant logistic regression.

	Odds ratio	95% CI for OR	<i>p</i> -value
Gender Female	11.22	1.51–1435.07	0.0112
FNA (< 125° vs ≥125°)	3.93	1.61–9.35	0.0031
FNA difference _{L view}	1.28	1.16–1.43	< 0.001
Reduction quality	2.81	1.09–7.97	0.0520
Good vs Acceptable	3.28	0.94–11.08	
Poor vs good			
TAD (> 25mm vs ≤ 25 mm)	2.94	1.29–7.14	0.0110
Lag Screw Position _(AP)	5.56	1.76–17.08	0.0150
Superior vs Center	3.13	0.82–11.11	
Superior vs Inferior			
Lag Screw Position _(L)	1.03	0.28–5.52	< 0.001
Center vs Posterior	12.32	3.32–67.38	
Anterior vs Center			
FNA: femoral neck angle; FNA difference _{L view} : angulation difference with contralateral hip; AP: antero-posterior view; L: lateral view; CI: confidence interval			

When the multivariate logistic regression model was adjusted, gender female, FNA difference in lateral view, and anterior screw position had a significant influence on the chance of failure. (Table 3)

Table 3
Multivariant logistic regression analysis.

	OR	(95% CI for OR)	<i>p</i> -value
Gender Female	12.92	1.39–1736.99	0.0196
FNA difference _{Lat view}	1.36	1.21–1.55	< 0.001
Lag Screw Position	0.63	0.14–3.79	< 0.001
Center vs Posterior	14.01	3.15–90.99	
Anterior vs Center			
FNA: femoral neck angle; FNA difference_{L view}: angulation difference with contralateral hip; TAD: tip-apex distance; AP: antero-posterior view; L: lateral view; CI: confidence interval			

Discussion

Proximal femur osteosynthesis failures after hip fracture can occur due to patient-dependent and patient-independent factors. Many authors have attempted to identify risk factors for mechanical proximal femur fixation failure [5–7, 9, 15, 16].

Reduction quality has been pointed as a possible predictor of failure after proximal femur fixation with CMN [15, 16]. In this study was observed that de failure rate increased significantly as reduction quality decreased. Like Kasighar et al. we didn't find a significant risk increase in regression logistic model, related to reduction according to Baumgaertner method and failure [17]. Subjective assessment based on interpretation and the wide range (< 20° difference in lateral view) included in Baumgaertner's criteria could influence those results. In contrast, Murena et al. demonstrated in a multivariate analysis that poor reduction quality was significantly correlated with cut-out failure [15].

Varus reduction has been mentioned as a risk factor for cut-out/failure as it exerts a greater force on the interface between the screw and the femoral head and limits screw placement to a position above the femoral head [17–19]. Ciuffo et al. reported a significant difference in failure with varus malreduction > 5°, compared with the contralateral hip [19]. The analysis of our data shows that FNA < 125° were a risk factors for failure in univariate regression.

The FNA difference with the contralateral hip in lateral view showed a difference of 7.5° between failure and non-failure groups. This was found associated with an increased risk of failure in univariate and confirmed in multivariate regression analyses. Perhaps, this result could help to design a new method to assess the quality of reduction, and the reason why in our series, the Baumgaertner method failed to demonstrated increased risk between quality of reduction and failure.

Baumgaertner et al. defined TAD and recommended values below 25mm to avoid cut-out of dynamic hip screws (DHS) after fixation of trochanteric fractures [5]. Even though some authors validate the use of

TAD in intramedullary implants [4–6], others have pointed out the need to redefine it due to biomechanical differences [17]. Although there is a consensus about the predictor value of TAD, there is a lack of consensus on the ideal cut-off value. Nikoloski et al. state that the TAD should be between 20 and 30 mm [20], Kraus et al. <30 mm [21], and Geller et al. [8], recommends TAD < 25 mm to reduce the risk of cutting. Although the analysis of our data shows that a TAD > 25 mm was significantly associated with failure, this was not identified as an independent risk factor in the multivariate regression analysis.

Seven (2.77%) patients in our series presented cut-through. This shows that this type of failure is not exclusive to helical blade fixation as some authors initially pointed out [11, 16, 17]. In a biomechanical study, Weil et al. showed that this type of failure might occur both with helical blades and screws [22]. Theories about the origin of this type of failure include osteoporosis, TAD less than 20mm, and failure of the blade/screw sliding mechanism [19].

There is a lack of consensus regarding the ideal position of the screw in the femoral head. While center position on lateral view is generally accepted, on the AP view some support a center position [5] and others an inferior position [17]. Yoo et al. [16] reported greater cut-out with posterior screw positioning, while Baumgaertner reported in anterior positioning [5]. In our analysis, we found a significant increase of risk between superior and anterior screw positions.

In this study, the age, side of fracture, and AO fracture classification were not found to be related to failure fixation. Unlike many authors, we were unable to prove a direct relationship between stable and unstable fracture pattern (AO/OTA classification) and failure of osteosynthesis in our series [17,23]. Finally, we found a statistical association between the female gender and the possibility of failure. Like Caruso et al. we believe that the higher index of osteoporosis in female patients combined with age (mean 81.5 years) may account for these results [12]. However, the large confidence interval presented, lead to us a cautions interpretation.

This study has some limitations. First those inherent to retrospective studies. Second, although our failure rate is similar to those reported in the literature, there are a few failures in our study. This may present the opportunity for a beta-type error in variables that did not reach significance. Third, the lack of analysis of other variables that have been suggested as predictors of failure in the treatment of intertrochanteric fractures with CMN (i.e. osteoporosis, body mass index). The strengths are the detailed X-ray evaluation and thorough statistical analysis. It also highlights the relevance of adequate lateral plane reduction, which has not been as thoroughly evaluated as varus/valgus alignment.

Conclusion

This study identified three main predictors of failure after cephalomedullary nailing of intertrochanteric hip fractures: female sex, malreduction in the lateral plane, and anterior position of the lag screw on the femoral head. These results suggest that the surgeon should do his best effort to achieve an anatomical reduction and proper implant positioning.

Declarations

Funding: This work has not received funding.

Conflicts of interest: The authors declare that they have no conflict of interest.

Ethics approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to participate: Informed consent was obtained from all individual participants included in the study.

Consent for publication: Not applicable

Availability of data and material: All data generated and analyzed during this study are included in this article and are available from the corresponding author on reasonable request.

Code availability: not applicable

Author contributions: All authors made substantial contributions to the design of the study; to the acquisition, analysis, and interpretation of the data; to the intellectual content by means of the critical revision of the manuscript; Finally, everyone approved the final version to be published.

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Figures

Figure 1

Frequency of lag screw position and distribution according to Cleveland zones. Total number and percentages of each zone in the femoral head. Failure rates in bold.

Figure 2

a-c. Unstable trochanteric hip fracture fixed with short cephalomedullary nail. Superior lag screw placement on the femoral head and poor reduction in lateral view (16°). d-e. Three-month postoperative X-ray views shows cephalic screw cut-out.