Predictors of cut-out after cephalomedullary nail fixation of pertrochanteric fractures: a retrospective study of 813 patients

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Abstract

Background Cut-out is the most common mechanical complication of the osteosynthesis of pertrochanteric fractures. This complication determines a significant increase in morbidity in elderly patient. Cut-out is defined as the varus collapse of the femoral head–neck fragment with the extrusion of the cephalic screw. Surgical treatment of cut-out might lead to further complications, longer rehabilitation, increased social burden and healthcare system costs. The aim of the study is to identify the predictors of cut-out to prevent its occurrence.

Materials and methods Study population included all patients affected by extracapsular fracture of the proximal femur who were admitted and treated with short cephalomedullary nailing at the Cattinara Hospital-ASUITS of Trieste between 2009 and 2014. A retrospective analysis of clinical and radiographic data was carried out and cut-out cases recorded. The data collected on the study population were analyzed to find an eventual correlation with the occurrence of cut-out. The independent variables were age, gender, side of the fracture, ASA class, Evans classification, nailing system, quality of reduction, TAD, CalTAD, and Parker ratio.

Results The study population counted 813 cases, with an F:M ratio of 4:1 and a mean age of 84.7 years. The cut-out was recorded in 18 cases (2.2%). There was no statistically significant association between cut-out and age, sex, side of fracture, ASA class, and nailing system. The Evans classification, the quality of reduction, the TAD, the CalTAD, and the Parker's ratio demonstrated a significant correlation at univariate analysis with cut-out. The results of multivariate analysis confirmed that TAD, Parker AP, and quality of reduction were independently significantly correlated to cut-out.

Conclusion The results of the present study demonstrate that good quality of reduction and correct position of the lag screw are likely to decrease the risk of cut-out complication. A nomogram for cut-out prediction is proposed for clinical validation.

Keywords Pertrochanteric fractures · Fragility fractures · Cephalomedullary nailing · Cut-out · Mechanical failure · Predictors · Nomogram

Introduction

Fractures of the proximal femur are matter of debate in the literature because of their high incidence and prevalence and their social and economic burden. Hip fractures occur in 90% of cases in elderly patients (over 65) affected by osteoporosis, being one of the most relevant causes of mortality and morbidity in the geriatric population [1].

Beneath proximal femur fractures, pertrochanteric fractures have increased significantly in incidence during the last few decades [1]. Their prevalence reaches about 50% of hip fractures [2].

Cephalomedullary (CM) nail fixation has become popular for the treatment of pertrochanteric fractures, increasing from 3% of all cases in 1999 to 67% in 2006 in the United States [2].

Nowadays, it is one of the most commonly used surgical techniques for the treatment of these fractures, especially in unstable fracture patterns [1]. Despite technical evolution, mortality and morbidity caused by these fractures are still

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matter of concern. The mortality rate for unstable fractures in the first year after surgery is reported to be between 11 and 27% [5]. Nonetheless, mechanical complications are the most common causes of morbidity after these fractures, with cut-out being the most relevant [5].

Cut-out is defined as a varus collapse of the neck-shaft angle leading to extrusion of the cephalic screw [2] (Fig. 1). In a large study on 3066 hip fractures, a prevalence of cut-out of 1.85% was reported [2]. Nonetheless, other studies reported a prevalence up to 16.5% [1]. Furthermore, cut-out usually occurs in elderly people with several comorbidities. In these patients, surgical treatment of cut-out increases the risk of further complications and leads to longer rehabilitation and hospitalization. Therefore surgeons may opt for a relatively "quick" treatment as the cephalic screw exchange, with high risk of new failure and multiple subsequent operations reported in literature [6].

Several authors [2, 5, 7, 8] were able to demonstrate a significant association of different variables with cut-out. Anyway, conclusive evidence is still lacking in particular regarding the role of quality of fracture reduction. Moreover, some parameters were recently introduced in the literature and still need to be fully validated

Aim

The aim of the study is to define the predictors of cut-out in the present population, to prevent its occurrence.

Materials and methods

The patients admitted to the Cattinara Hospital-ASUITS of Trieste (Italy) Orthopaedics and Traumatology Unit for extracapsular fracture of the proximal femur between January 2009 and December 2014 were selected for the study. Patients aged > 65 years treated with short CM nail were all included in the present study. Exclusion criteria were pathologic fractures, follow-up < 3 months, and previous surgery in the contralateral hip.

Surgical treatment was performed under fluoroscopic control with the patient lying on a radiolucent traction table. Closed reduction was attempted before surgery in all cases. Osteosynthesis was performed using different single cephalic screw CM nailing systems. For distal locking, a single screw was inserted using the targeting device in all cases.

On the first day post-op, the patient was introduced to rehabilitative program including early weight bearing and hip mobilization. Patients started walking with crutches approximately 48–72 h after surgery except in case of pre-operatively non-ambulatory patients.

Radiographic examinations, including standard anteroposterior (AP) and lateral (Lat) views of the hip and AP view of the pelvis, were performed before and after surgery and at follow-up, usually carried out at 6 weeks, 3 months, 6 months, and 1 year after surgery.

On the pre-operative X-rays the fracture classification, according to Evans classification system, was evaluated

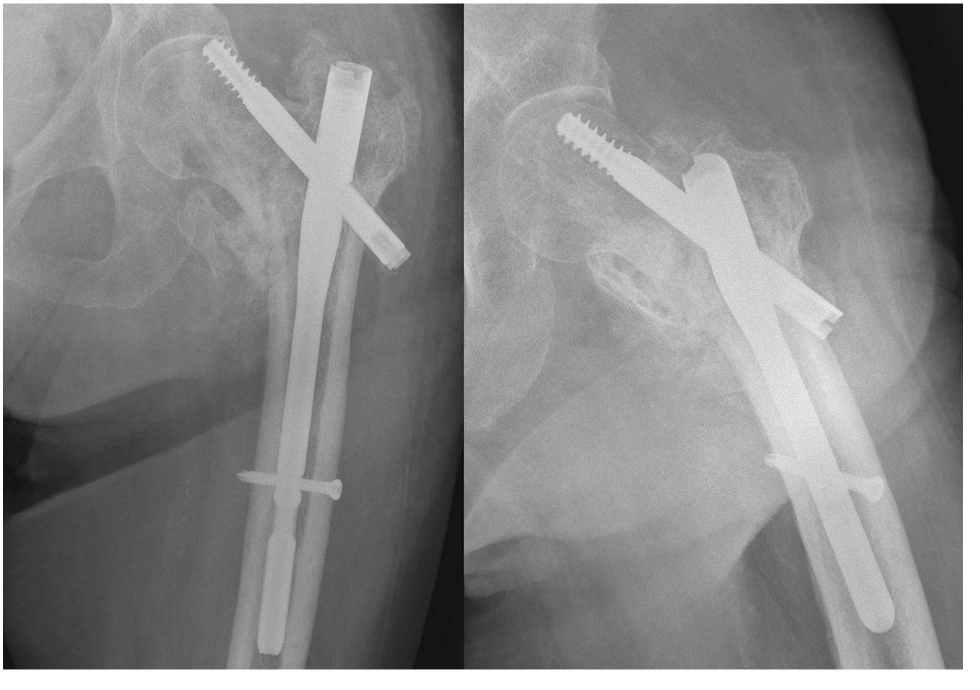

Fig. 1 X-ray of left hip, anteroposterior (AP), and lateral (Lat) views, 4 month follow-up of CM nail fixation of a pertrochanteric fracture. Collapse of the femoral head–neck fragment with the resulting protrusion of cephalic screw (cut-out) is shown

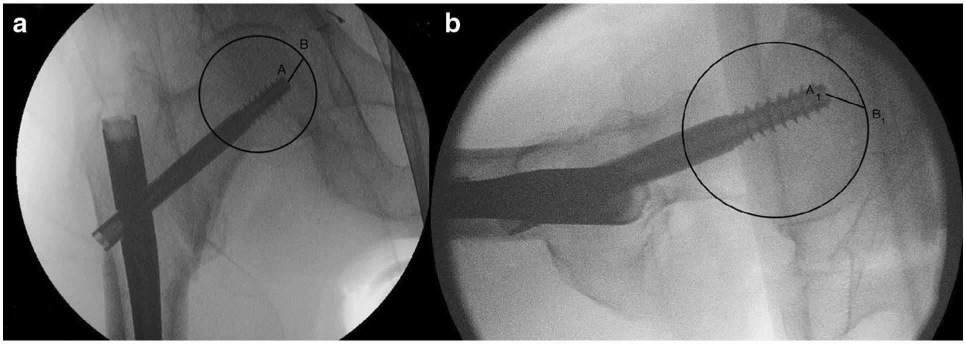

Fig. 2 Fluoroscopy of right hip, anteroposterior (AP), and lateral (Lat) view. The tip apex distance (TAD) is represented by the sum of AB (**a**) and A_1B_1 (**b**) distances ($TAD = AB + A_1B_1$)

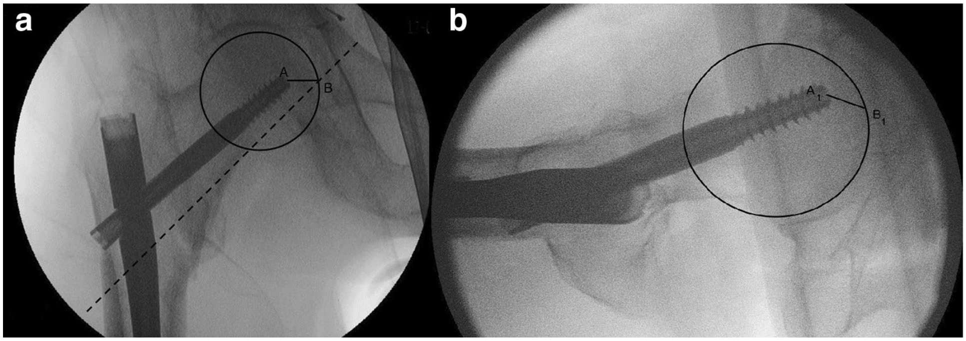

Fig. 3 Fluoroscopy of right hip, AP, and Lat view. The Calcar Tip Apex Distance (CalTAD) is represented by the sum of AB (**a**) and A_1B_1 (**b**) distances ($CalTAD = AB + A_1B_1$). Dashed line represents the line tangential to the medial cortex of the femoral neck on AP view

[9]. Evans type III, IV, and V fractures were considered unstable.

On the post-operative X-rays, the following were evaluated:

1. the Tip Apex Distance (TAD): sum of the distance from the tip of the screw to the apex of the femoral head on AP and Lat views [10, 11] (Fig. 2)
2. the Calcar Tip Apex Distance (CalTAD): sum of the distance from the tip of the screw to the apex of the femoral head on Lat view and the distance from the tip of the screw and the point in which the femoral head crosses a line tangential to the medial cortex of the femoral neck on AP view [7] (Fig. 3)
3. the Parker's ratio, calculated in both the AP and Lat views to give a value within a range of 0–100% for each view. The percentage indicates the distance of the screw from the inferior border of the femoral neck in AP view (the superior border is considered as 100%) (Fig. 4), or from the posterior border of the femoral neck in lateral view (the anterior border is considered as 100%) [12] (Fig. 5)
4. the quality of reduction according to Baumgaertner method. The results were categorized as good, acceptable, or poor. The displacement criteria were defined as a distance $<$ 4 mm between fracture fragments, on either the AP or Lat view. Correct angular reduction criteria were met when the neck-shaft angle on the AP view was normal or slightly valgus (130°–150°), and $<$ 20° degrees of angle were seen on the Lat view. A reduction was categorized as good when both criteria were met, acceptable when one criteria was met, and poor if neither criteria were met [8]. For each radiographic measurement, the known diameter of the nail was used to correct for image magnification.

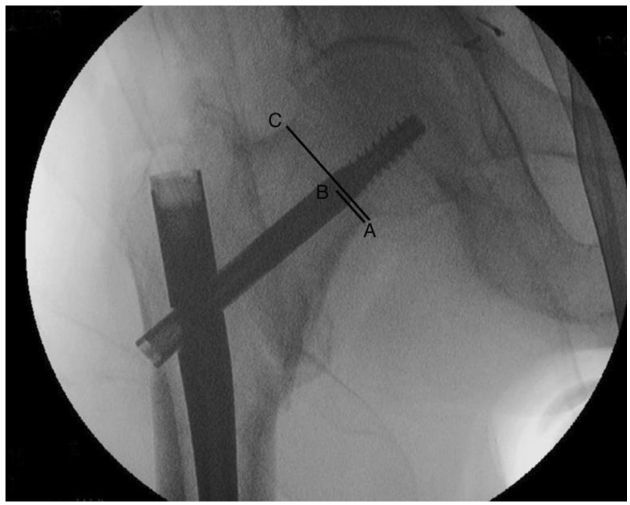

Fig. 4 Fluoroscopy of right hip and AP view. The Parker's ratio on AP view is represented by the percentage AB/AC ×100 indicating the distance of the screw from the inferior border of the femoral neck (the superior border is considered as 100%)

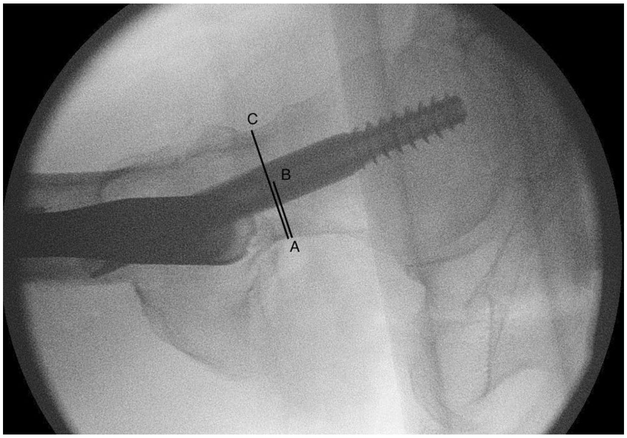

Fig. 5 Fluoroscopy of right hip, Lat view. The Parker's ratio on Lat view is represented by the percentage AB/AC ×100 indicating the distance of the screw from the posterior border of the femoral neck (the anterior border is considered as 100%)

Latest follow-up X-rays were evaluated to record cut-out complications. On the basis of cut-out occurrence, the study population was divided in two groups: patients who did not experience cut-out (Group A) and patients who experienced cut-out (Group B).

The data collected on the study population were analyzed to find an eventual correlation with the occurrence of cut-out. The independent variables were divided in non-modifiable (not-related to surgery) and modifiable (related to surgery) causes of mechanical failure. The "not related to surgery" variables were age, gender, side of the fracture, American Society of Anesthesiologists (ASA) class, and Evans classification of the fracture. The "related to surgery" variables were the nailing system, quality of reduction and the TAD, CalTAD, and Parker ratio measures.

Statistical analysis

Descriptive statistics are presented as mean ± standard deviations or counts and percentages, respectively, for continuous and nominal variables. Differences between groups are reported with the corresponding *t* test or the Chi-square test *p* values, respectively, for continuous and nominal variables. For each of the variables listed above, univariable odds ratios were estimated (significance *p* value set at <0.01) to determine which variables had a strong significant correlation with the onset of the cut-out. For nominal variables, odds ratio was estimated using as a reference category the value more frequent. Some of the nominal variables were re-grouped in two categories to increase the power of the analysis. Variables that reached statistical significance were used for multivariate analysis. A backward conditional stepwise algorithm was used to identify the subset of most powerful and independent predictors. A ROC curve was estimated to evaluate the predictive accuracy of the estimated multivariable model. Since the limited number of events, an internal validation procedure was conducted to evaluate possible overfitting of the multivariable model, using the "rms" library of the R package, version 3.3.2. A nomogram was also estimated to help using the multivariable model as a risk score. Descriptive tables and univariable logistic regression were done with the Medcalc software. Multivariable logistic regression model was estimated using the IBM Statistical Package for Social Science (SPSS) software version 24.

Table 1 Descriptive analysis

	Whole population	Group A	Group B	*p* value
Age	84.7 ± 7.0	84.7 ± 7.0	84.6 ± 7.3	0.962
Gender				0.869
Male	168 (20.7%)	164 (20.6%)	4 (22.2%)	
Female	645 (79.3%)	631 (79.4%)	14 (77.8%)	

There are reported the average +/− standard deviation values of the total population and for each group

Results

The population of patients over 65 years old treated with short CM nail for extracapsular fractures of proximal femur at the Cattinara Hospital-ASUITS of Trieste (Italy) Orthopaedics and Traumatology Unit in the study period counted 1086 cases. On the basis of the inclusion/exclusion criteria, the study population counted 813 cases, with an F:M ratio of 4:1 and a mean age of 84.7 years. The majority (74.7%) were ASA > 2 and 533 fractures (65.5%) were considered unstable at Evans classification. The detailed demographic characteristics of the study population and the results of pre-operative radiographic analysis are shown in Tables 1 and 2. Table 3 shows the distribution of different CM nailing systems and the results of post-operative radiographic evaluation. Mechanical failure with radiographic evidence of cut-out was recorded in 18 cases (2.2%) (Table 4), with F:M ratio of 3:5 and mean age of 84.6. The majority of cases were ASA > 2 (77.7%) and an unstable fracture pattern according to Evans was noted in 15/18 (83.3%) cases.

There was no statistically significant association between cut-out and age, sex, side of fracture, and ASA class (Tables 1, 2). On the other hand, Evans classification demonstrated a significant correlation between severely unstable fracture patterns (Evans V) and cut-out (Table 2).

As far as the "related to surgery" (Table 5) variables were considered, the average values for group A were 20.1 for TAD, 19.4 for CalTAD, and 36.5 for ParkerAP. In group B, mean values were 29 for TAD, 28.7 for CalTAD, and 45.0 for ParkerAP.

Table 2 Descriptive analysis of variables "non-related to surgery"

	Whole population	Group A	Group B	*p* value
Side				0.996
Right	407 (50.0%)	398 (50.0%)	9 (50.0%)	
Left	406 (50.0%)	397 (50.0%)	9 (50.0%)	
ASA				0.031
2	124 (15.3%)	118 (14.8%)	6 (33.3%)	
> 2	689 (84.7%)	677 (85.2%)	12 (66.7%)	
Evans classification				< 0.001
≤4	718 (88.3%)	707 (88.9%)	11 (61.1%)	
5	95 (11.7%)	88 (11.1%)	7 (38.9%)	

For each variable, categories and the corresponding number and % of patients in each group

Quality of reduction was good in the majority of group A patients (64%), while the cut-out group showed a good quality of reduction in 16.6% (Table 3).

The results of univariate analysis (Table 6) show that variables found to be significantly different in the two groups were the Evans classification, the TAD, the Cal-TAD, the Parker AP, and the quality of reduction. There was no statistically significant difference for the nail system and Parker's ratio in the lateral view.

The results of multivariate analysis showed that TAD, Parker AP, and quality of reduction were independently significantly correlated to cut-out (Table 7). The estimated optimism from the internal validation procedure was 0.006 and the estimated shrinkage was 0.96, therefore a negligible amount of overfitting was found.

Table 3 Descriptive analysis of variables "related to surgery"

	Whole population	Group A	Group B	*p* value
Cephalomedullary nail				0.109
Gamma3	474 (58.3%)	466 (58.7%)	8 (44.4%)	
ZNN	182 (22.4%)	179 (22.6%)	3 (16.7%)	
IMHS-CP	142 (17.5%)	135 (17%)	7 (38.9%)	
ELOS	15 (1.8%)	15 (1.9%)	0 (0%)	
Quality of reduction				< 0.001
Good or acceptable	781 (96.1%)	770 (96.9%)	11 (61.1%)	
Poor	32 (3.9%)	25 (3.1%)	7 (38.9%)	

For each variable, categories and the corresponding number and percentage of patients in each group

Table 4 Cut-out's results

Patients	Gender	Age (yy)	Side	Nail	EVANS	ASA	Quality of reduction	TAD	CalTAD	Parker AP	Parker LAT
a	F	85	R	Gamma3	5	3	Poor	36.18	40.54	62	57
b	F	87	L	Gamma3	3	3	Poor	27	27	43	47
c	M	91	L	ZNN	2	3	Acceptable	30.24	27.53	38	66
d	F	85	R	IMHS	5	3	Poor	29.04	31.23	66	42
e	F	87	L	Gamma3	3	3	Good	31.02	26.11	35	68
f	M	77	R	IMHS	5	2	Good	19.32	29.97	55	39
g	F	85	R	IMHS	5	3	Poor	26.4	26.36	39	23
h	F	87	L	IMHS	4	3	Poor	31.46	33.82	58	40
i	F	67	L	ZNN	3	2	Poor	30.85	17.88	23	37
j	F	80	L	Gamma3	5	3	Poor	37.21	40.48	47	28
k	F	92	L	IMHS	3	3	Acceptable	25.8	17.06	50	27
l	F	91	R	Gamma3	5	3	Acceptable	32.63	33.72	41	34
m	F	85	L	Gamma3	3	2	Acceptable	20.66	28.43	59	53
n	F	100	L	ZNN	5	3	Acceptable	31.85	28.42	51	58
o	F	86	R	Gamma3	4	2	Acceptable	36.84	31.91	32	38
p	M	77	R	IMHS	2	2	Good	26.15	25.37	33	56
q	F	76	R	IMHS	2	2	Acceptable	23.52	27.33	47	38
r	M	85	R	Gamma3	3	3	Acceptable	25.85	23.38	32	59

Table 5 Descriptive analysis of "related to surgery" variables that describe the position of the cephalic screw

	Whole population	Group A	Group B	*p* value
TAD	20.3 ± 5.3	20.1 ± 5.2	29.0 ± 5.1	< 0.001
CalTAD	19.6 ± 5.0	19.4 ± 4.7	28.7 ± 6.2	< 0.001
ParkerAP	36.7 ± 9.3	36.5 ± 9.1	45.0 ± 12.0	< 0.001
ParkerLat	47.3 ± 8.9	47.33 ± 8.8	45 ± 13.4	0.273

There are reported the values of the average and standard deviation for the total population and for each of the groups

Table 6 Univariate analysis

	OR	95% C.I. of OR		*p* value
		Inferior	Superior	
Age	0.998	0.9340	1.0672	0.962
Gender	0.909	0.2955	2.8004	0.868
Side	1.002	0.3938	2.5519	0.995
ASA	2.868	1.0560	7.7924	0.038
Evans classification	5.113	1.932	13.530	0.001
CM nail				0.155
(vs Gamma3), ZNN	0.976	0.256	3.721	0.971
(vs Gamma3), IMHS	3.020	1.075	8.48	0.0358
(vs Gamma3), ELOS*	–	–	–	–
Quality of reduction	19.6	7.012	54.788	< 0.001
TAD	1.267	1.172	1.370	< 0.001
CalTAD	1.286	1.186	1.393	< 0.001
ParkerAP	1.093	1.043	1.145	< 0.001
ParkerLat	0.972	0.925	1.022	0.271

*Odds ratio for the ELOS category was not evaluable since the low number of cases

Table 7 Multivariate analysis

	OR	95% C.I. of OR		*p* value
		Inferior	Inferior	
First phase				
Evans classification	1.374	0.354	5.341	0.646
Quality of reduction	10.516	2.511	44.046	0.001
TAD	1.289	1.097	1.514	0.002
CalTAD	1.037	0.892	1.205	0.640
Parker AP	1.074	1.007	1.146	0.030
Second phase				
Quality of reduction	11.564	2.914	45.893	0.000
TAD	1.287	1.096	1.512	0.002
CalTAD	1.039	0.893	1.208	0.622
Parker AP	1.075	1.007	1.147	0.029
Third phase				
Quality of reduction	11.028	2.813	43.231	0.001
TAD	1.328	1.193	1.477	< 0.001
Parker AP	1.087	1.038	1.138	< 0.001

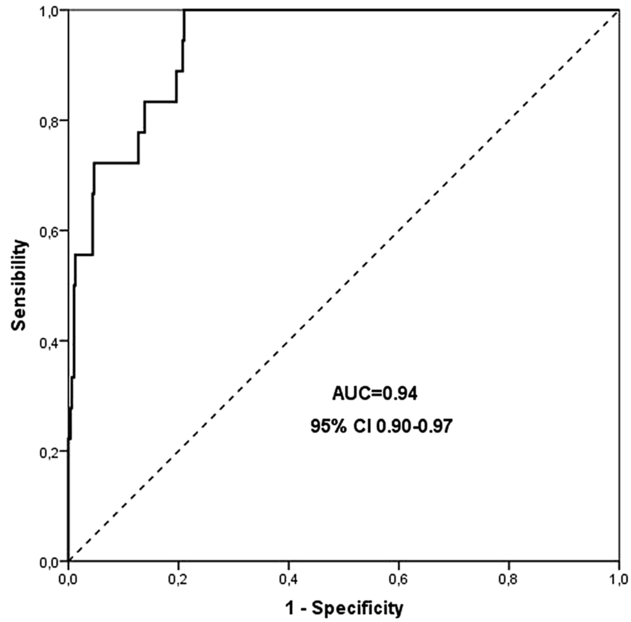

Fig. 6 Continuous line represents the ROC curve of the predicted values from the multivariable model. Specificity is reported on the *x*-axis and sensibility on the *y* axis. An area under the curve of 0.94 is obtained, with 95% confidence interval of 0.90–0.97, $p < 0.001$

Predicted values from the multivariable model were tested at a Receiver-Operating Characteristic (ROC) curve, obtaining an Area Under the Curve (AUC) of 0.94 with 95% confidence interval of 0.90–0.97, $p < 0.001$ (Fig. 6). Based on mechanical failure predictors identified in the present study, a nomogram for determination of individual probability of cut-out is proposed (Fig. 7).

Discussion

Mechanical failure of osteosynthesis leading to cut-out is a relevant cause of morbidity in hip fracture population. Several authors attempted to define the cut-out predictors, to prevent this complication. Nonetheless, conclusive evidence is still lacking. Many variables have been evaluated and purposed as risk factors, whereas limits between a fracture likely to heal and a fracture likely to fail still need to be tracked.

In the present study, age, gender, side of the fracture, and ASA class were not found to be predictors of cut-out, confirming the previous literature reports [13].

Unlikely, fracture pattern did result to be a statistically significant cut-out predictor at the univariate analysis, but multivariate analysis could not confirm this data (at the third phase). In the present study population unstable fracture pattern seems, therefore, to be an important variable to consider but non independently causing cut-out. The literature

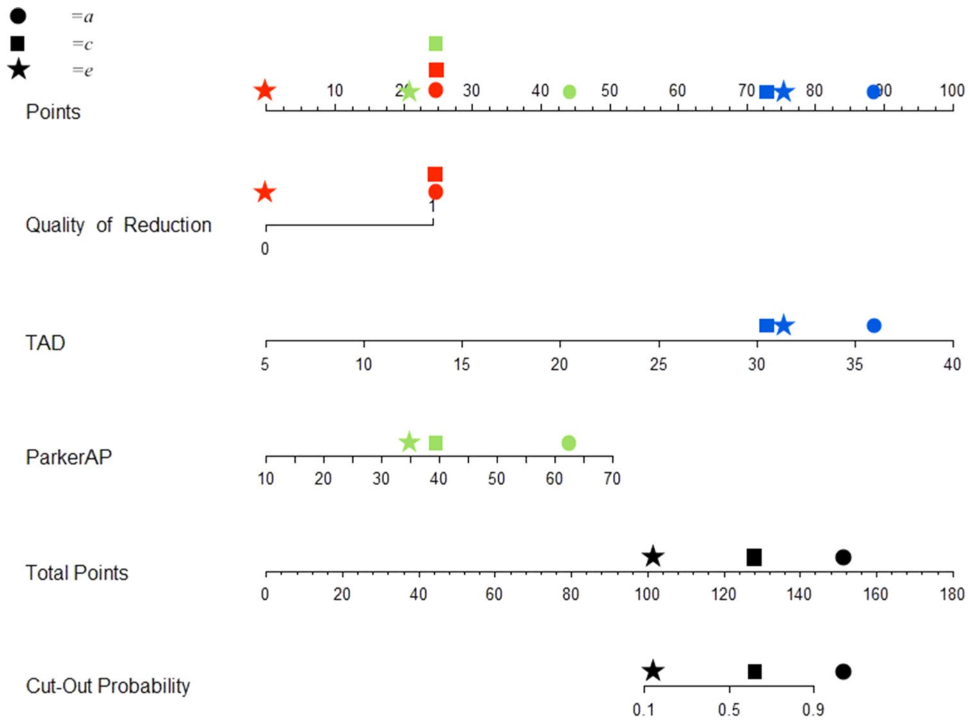

Fig. 7 Nomogram for determination of individual probability of cut-out based on patient characteristics. Points within each line representing the measured parameter are identified in an individual patient. Drawing a straight line between measured Parker AP, reduction quality or TAD, and score "Points" scale (top) allows determination of a total score represented by the sum of single scores obtained with each parameter (total points). Drawing a line between the total score and the probability segment allows determination of the individual probability of cut-out. As an example, Parker AP, TAD, and quality of reduction values of three cut-out cases (patients a, c, and e, see Table 4) are inserted in the nomogram and total score for each case reported, determining the individual probability of cut-out

reports also differ on this topic [2, 8, 13]. In Kashigar et al. study, no statistical significance could be found for fracture pattern [7]. Nevertheless, Bojan et al. report a statistically significant over-representation of complex unstable 31-A3.3 fractures and basicervical 31-B2.1 fractures in the cut-out group ($p < 0.001$) [13]. Moreover, Mavrogenis et al. noted the unstable fracture pattern to be a risk factors for cut-out, besides the suboptimal fracture reduction, the intramedullary implant design, and the non-ideal femoral head lag screw position [2].

Bone quality has been reported by some authors to be an important predictor of mechanical failure [2, 14]. However, radiographic methods to estimate the amount of osteoporosis as the Singh index do not correlate with the actual bone mineral density [15]. Therefore, the authors chose not to evaluate this topic in the present study.

As far as "related to surgery" variables are concerned, the position of the cephalic screw in the femoral head is one of the mostly studied parameters in the literature. Many authors report it to be a relevant factor in causing the cut-out. The optimal position of the lag screw in the femoral neck has been widely discussed: a central-posterior placement of the lag screw in the Lat view and a central-inferior position in the AP view projection are recommended by most authors, because they maximize the biomechanical stiffness and load to failure of the fixation [1]. Mavrogenis et al. reported as optimal position the central–central zone and central-inferior zone respectively on the Lat and AP views [2]. The TAD, CalTAD, and Parker's Ratio have all been purposed as landmarks to define the ideal screw position, and their correlation to cut-out is commonly recognized.

The results of the present study demonstrate a statistically significant correlation of TAD values with cut-out, both in univariate and multivariate analyses. This result appears to be in line with the previous studies reporting the optimization of TAD (< 25 mm) to be critical for preventing pertrochanteric fixation mechanical failure [2, 11, 12]. On the contrary, the study of Mingo-Robinet et al. found no statistically significant association between TAD and the risk of cut-out [16]. Goffin et al. have suggested that TAD should be adjusted depending on the size of the femoral head [17, 18]. The same authors stated that a TAD > 25 mm could not be considered an accurate predictor of lag screw cut-out. The results of the present study reveal, indeed, that the TAD should be as low as possible, but fail to deline a precise cut-off value.

The CalTAD has been introduced and studied more recently in the literature. Kashigar et al. described the

CalTAD as a predictor of lag screw cut-out [7]. The authors describe it as a measurement method that favours the inferior–central region for placing the lag screw. In the present study, the CalTAD appeared to be significantly correlated with cut-out at the univariate analysis, in line with other reports in the literature [7]. On the other hand, the CalTAD was not significantly correlated with cut-out at the multivariate analysis. This result may be explained on the basis of the characteristics of this statistical study, which filters any repeating of information, being the CalTAD a summary of data already provided by the TAD and ParkerAP (the offset of the screw from the profile of the head and the caudo-cranial distance from the calcar). Moreover, the present study demonstrated the Parker AP to be correlated to cut-out with statistical significance both at the univariate and multivariate analysis. The importance of this parameter was previously underlined by Kashigar et al. that considered a higher Parker's AP ratio (more superior lag screw placement) to be significantly associated with an increased rate of cut-out [7].

The present study failed to find a significant correlation of the ParkerLat with cut-out. Likely, Kashigar et al. [7] reported the non-significance of ParkerLat in a previous study. Conversely, other studies consider central postion of the screw in the sagittal plane to be correct [11, 12, 19, 20]. In a recent study, Caruso et al. [21] demonstrate a significant correlation with cut-out for peripheral screw positioning according to Cleveland classification. Therefore, despite central position in the lateral view should be considered as a goal, the ParkerLat might not be the most reliable parameter to evaluate this topic.

The quality of fracture reduction has been purposed as a possible predictor of cut-out, with controversial reports in the literature. Kashigar et al. show a significant association at univariate analysis between varus reduction (compared with the contralateral unaffected hip) and cut-out [7]. However, the same authors failed to find a significant correlation between reduction according to the Baumgaertner method and cut-out [7]. In 2015, Chang et al. describe the concept of positive medial cortical support (PMCS) to judge reduction of unstable pertrochanteric fractures treated with CM nail [22]. The PMCS is defined as the medial cortex of the head–neck fragment displaced and located superomedially to the medial cortex of the femur shaft in AP view. They describe PMCS reduction as the key element for stability reconstruction for unstable fractures.

The results of the present study clearly demonstrate that quality of reduction has a central role in determining cut-out occurrence. Both at the univariate analysis ($p < 0.001$) and at the multivariate ($p = 0.003$) analysis, a significant correlation has been noted. At our knowledge, this is the first time that poor quality of reduction results to be significantly correlated to cut-out in the multivariate analysis, with a powerful ROC curve determined by a strict confidence interval. Indeed, Buyukdogan et al. [23] reported a significant difference in cut-out occurrence at multivariate analysis between good quality and moderate quality of fracture reduction according to Baumgartner. However, the reported correlation presented with a large confidence interval and the same authors failed to correlate cut-out with poor quality reduction, leading to a difficult interpretation of the results as stated by the authors themselves. The present study results are, therefore, able to reinforce the literature suggestion for the surgeon to be meticulous in obtaining fracture reduction both during positioning and nailing of pertrochanteric fractures.

Finally, the nailing system was considered as a possible variable related to cut-out. Raw data show a relevant cut-out rate in the IMHS group (38.9% of cut-out cases) despite its use in a limited number of cases (17.5%). However, statistical analysis failed to correlate nailing system with cut-out occurrence. Small sample size together with the high percentage of IMHS cases showing bad TAD, CalTAD, Parker AP, and quality of reduction values (Table 4) might be responsible for this finding, confirming the relevance of these parameters in cut-out occurrence.

The power of the present study statistical analysis enabled the authors to create a nomogram to estimate the probability of cut-out occurrence. This tool could be very useful both during surgery and in post-operative management of pertrochanteric fractures to minimize mechanical failures. However, validation of the model still needs to be performed with an adequately large prospective cohort study.

The limits of the present study are the retrospective design and the few cut-out cases. The strengths of the study are the number of patients involved, the detailed radiographic evaluation, and the thorough statistical analysis.

Conclusions

The occurrence of cut-out after CM nailing of pertrochanteric fractures is mainly correlated to factors depending on the surgical technique. The present study confirms the significant association of inadequate TAD and ParkerAP with cut-out. Moreover, a significant association with quality of reduction is demonstrated both at univariate and multivariate analyses. The pattern of the fracture is not directly a predictor of cut-out; on the other hand, it probably influences the success of surgery determining a more difficult reduction. Cut-out occurrence can be prevented through careful pre-operative planning, correct fracture assessment, and precise operative technique. Nonetheless, in consideration of the low number of cut-out complications in the present work, further studies with more events (cut-out) may be necessary to confirm the predictors found in the present study. A nomogram to estimate cut-out probability is proposed for clinical validation.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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