The effect of nail diameter on proximal femoral shortening after internal fixation of pertrochanteric hip fractures with short cephalomedullary nails

Zoe B. Cheung^{*}, Stephen Selverian, Joseph Barbera, David A. Forsh

Department of Orthopaedic Surgery, Icahn School of Medicine at Mount Sinai, New York, NY, 10029, USA

ARTICLE INFO

Keywords:

Proximal femoral shortening
Abductor lever arm
Femoral height shortening
Hip fracture
Cephalomedullary nail

ABSTRACT

Objective: Investigate the effect of distal nail diameter on proximal femoral shortening (PFS) after cephalomedullary nailing of hip fractures.

Methods: A retrospective cohort study of 80 patients aged 50 years and older with pertrochanteric hip fractures treated with a 10 or 11 mm short cephalomedullary nail (CMN) was performed. We measured abductor lever arm shortening, femoral height shortening, and PFS.

Results: There was no difference in abductor lever arm shortening ($p = 0.09$), femoral height shortening ($p = 0.86$), and PFS ($p = 0.34$) between the 10 and 11 mm groups.

Conclusions: Our results suggest that distal nail diameter does not affect PFS.

Level of evidence: III.

1. Introduction

Hip fractures are a significant public health problem worldwide due to the associated morbidity and mortality. The morbidity and complications associated with hip fractures are further aggravated by immobility.¹ Hip fractures also have a significant socioeconomic impact, incurring an estimated annual cost of over \$5.4 billion in the United States.² With rising rates of osteoporosis and a higher frequency of falls in the elderly population, the incidence of hip fractures continues to increase. Projections estimate that up to 6.3 million people per year will sustain hip fractures by 2050.³

Approximately 40%–50% of all hip fractures are extracapsular hip fractures that can be treated with extramedullary or intramedullary fixation.⁴ Cephalomedullary nailing has become a popular method of fixation for pertrochanteric hip fractures. Proximal femoral shortening (PFS) is a common sequela after cephalomedullary nailing for hip fractures. While controlled sliding of the lag screw and resultant fracture compression is desirable, PFS has also been shown to adversely affect fixation stability, physical function and mobility.^{5–7} Excessive lag screw sliding and PFS have been associated with fixation failure and lag screw cut out.⁵ Furthermore, PFS has been correlated with poor functional outcomes, including reduced mobility, decreased gait velocity, and changes in gait symmetry.^{6,7} While PFS is an expected occurrence after cephalomedullary nailing for hip fractures, there remains limited

literature on the risk factors for PFS.

In the geriatric hip fracture population, the femoral diaphysis and metadiaphyseal junction are more capacious, which does not allow for close distal cortical contact with a cephalomedullary nail (CMN). This mismatch allows for movement of the nail in the distal fracture segment – a phenomenon that has been termed the “Bell-clapper effect”.⁸ Given this effect, it remains unclear whether the behavior of the nail distally has an impact on PFS. In short CMNs, the diameter of the proximal nail body is the same and the diameter of the lag screw is the same, while the distal nail diameter differs. The role of nail diameter on PFS has not been previously documented. The objective of this study was to investigate the effect of distal nail diameter on PFS after internal fixation of pertrochanteric femur fractures with short CMNs. Our hypothesis was that distal nail diameter does not impact PFS after cephalomedullary nailing of hip fractures.

2. Materials and methods

2.1. Study cohort

Institutional review board approval was obtained for this study. A retrospective cohort study was performed of patients aged 50 years and older with a pertrochanteric hip fracture (AO/OTA 31A1,2,3) who underwent internal fixation with a short, trochanteric entry CMN

^{*} Corresponding author. Department of Orthopaedic Surgery, Icahn School of Medicine Mount Sinai, 5 East 98th Street, 9th Floor, New York, NY, 10029, USA.
E-mail address: zoe.cheung@mountsinai.org (Z.B. Cheung).

(Gamma3, Stryker, Kalamazoo, MI) at our institution between July 2017 and October 2019. We included patients who had a minimum follow-up of 30 days postoperatively. Exclusion criteria included patients who had prior surgery on the injured hip, malreduction on final intraoperative fluoroscopy, or low quality fluoroscopy/radiographs precluding appropriate radiographic analysis. Age, gender, and fracture pattern according to the AO/OTA classification were recorded for all patients.

Patients who met the selection criteria were divided into 2 groups based on nail diameter – that is, 10 mm nail diameter versus 11 mm nail diameter. Nail diameter was determined based on the distal nail diameter, as the proximal nail diameter of all the short CMNs was the same (i.e., 15.5 mm). The 10 mm diameter nails were 170 mm in length. The 11 mm diameter nails were 180 mm in length. The diameter of the lag screws was also the same across all CMNs (i.e., 10.5 mm). All patients were positioned supine on a standard fracture table for surgical fixation. The fractures were reduced by closed, percutaneous, or open techniques as indicated. Instrumentation with the short CMNs was performed according to the steps provided by the manufacturer. All of the CMNs were statically locked distally with a 5 mm diameter screw. Postoperatively, all patients were allowed to immediately weight bear as tolerated.

2.2. Radiographic measurements

Intraoperative fluoroscopy and follow-up radiographs were retrieved from the PACS software (Centricity, GE Healthcare System Inc., Chicago, IL). Radiographs that were rotated were excluded, as they would preclude accurate radiographic measurements. Canal diameter of the injured hip was measured at the narrowest part of the proximal femur on injury radiographs using the PACS software. On final anteroposterior (AP) views of the injured hip on intraoperative fluoroscopy, tip-apex distance (TAD) was measured using the PACS software according to the method described by Baumgaertner et al.⁹

Adobe Photoshop (version 21.0.1, Adobe Inc., San Jose, CA) was utilized to measure PFS on AP radiographs of the injured hip at most recent follow-up. PFS was measured according to a modified version of the method described by Zlowodski et al.⁷ The AP radiograph of the injured hip at most recent follow-up was overlaid on the AP view of the injured hip on final intraoperative fluoroscopy. The known diameter of the lag screw was used to make the appropriate adjustments to the size of the radiographs to account for magnification differences. After appropriate size adjustment, radiographs that had >2 mm difference in the diaphyseal cortex of the proximal femur compared to intraoperative fluoroscopy were excluded.

We then measured shortening between final intraoperative fluoroscopy and the most recent follow-up radiograph in the x and y planes (Fig. 1). Shortening in the x plane represented abductor lever arm shortening. Shortening in the y plane represented femoral height shortening. Total PFS was represented by the z vector, in which $z^2 = x^2 + y^2$. A single investigator (Z.C.) performed all measurements to reduce inter-observer bias.

2.3. Statistical analysis

The overall incidence of total PFS >10 mm was reported. Means and standard deviations for TAD, abductor lever arm shortening, femoral height shortening, and overall PFS were also reported in each comparison group. Student's t-tests were performed to compare TAD, abductor lever arm shortening, femoral height shortening, and overall PFS between the 10 mm and 11 mm nail diameter groups. Statistical significance was set at the level of $p = 0.05$.

3. Results

3.1. Study cohort

A total of 80 patients met the selection criteria and were included in

Fig. 1. The outline of the proximal femur on final intraoperative fluoroscopy was overlapped on the outline of the proximal femur on the follow-up radiograph to measure abductor lever arm shortening in the x plane and femoral height shortening in the y plane.

the study. The baseline characteristics and radiographic outcomes of this cohort are outlined in Table 1. There were 62 (77.5%) females and 18 (22.5%) males. The average age was 82.9 years (range, 57–100 years) with a mean follow-up of 153 days (range, 30–709 days). There were 39 (48.8%) left hip fractures and 41 (51.2%) right hip fractures. There were 23 patients in the 10 mm nail diameter group and 57 patients in the 11 mm nail diameter group. There was no significant difference in proximal femoral canal diameter between the 2 groups ($p = 0.14$).

3.2. Tip apex distance

The mean TAD was 17.04 ± 4.77 mm and 17.32 ± 4.70 mm in the 10 mm and 11 mm nail diameter groups, respectively. There was no significant difference in TAD between the 2 groups ($p = 0.81$).

3.3. Proximal femoral shortening

The incidence of abductor lever arm shortening, femoral height shortening, and PFS >10 mm in the 10 mm group was 4.4%, 26.1%, and 30.4%, respectively. The incidence of abductor lever arm shortening, femoral height shortening, and PFS >10 mm in the 11 mm group was 10.5%, 19.3%, 29.8%, respectively.

There was no significant difference in abductor lever arm shortening

Table 1
Baseline characteristics and radiographic outcomes.

	10 mm	11 mm	p-value
Number of patients (n)	23	57	–
Fracture pattern			
31-A1	17	41	0.85
31-A2	5	16	
31-A3	1	0	
Mean canal diameter (mm)	17.2	18.3	0.14
Mean TAD (mm)	17.0	17.3	0.81
Abductor lever arm shortening (mm)	3.01	4.42	0.09
Femoral height shortening (mm)	5.89	6.09	0.86
PFS (mm)	7.48	8.53	0.34

(10 mm group, 3.01 ± 2.98 mm; 11 mm group, 4.42 ± 3.99 mm; $p = 0.09$) or femoral height shortening (10 mm group, 5.89 ± 4.62 mm; 11 mm group, 6.09 ± 5.06 mm; $p = 0.86$) between groups. There was also no significant difference in overall PFS between the 2 groups (10 mm group, 7.48 ± 4.18 mm; 11 mm group, 8.53 ± 5.01 mm; $p = 0.34$).

4. Discussion

PFS is an expected and relatively common phenomenon after cephalomedullary nailing of pertrochanteric hip fractures. Cephalomedullary nailing has become more popular in recent years due to the less invasive approach, relatively easy surgical technique, and theoretical biomechanical advantage of intramedullary fixation compared to extramedullary fixation.¹⁰ Cephalomedullary nail fixation for pertrochanteric hip fractures relies on the concept of controlled sliding of the lag screw leading to compression at the fracture site. Uncontrolled or excessive sliding of the lag screw, however, can result in significant PFS that contributes to fixation failure, fracture displacement, lag screw cut out, and worse functional outcomes. There remains limited literature on the incidence of PFS and risk factors that predispose to PFS following cephalomedullary nailing. In the setting of the “Bell-clapper effect” in geriatric hip fracture patients, the relationship between the behavior of CMNs distally and PFS has not been extensively described. In this retrospective study, we demonstrated that distal nail diameter does not affect PFS after short cephalomedullary nailing of pertrochanteric hip fractures.

In short CMNs, the proximal nail diameter and lag screw diameter are the same, but the distal nail diameter varies. In the Stryker Gamma3 system, the distal diameter of the short nails is either 10 mm or 11 mm. The theoretical advantage of a larger distal nail diameter is to provide a tighter mechanical fit between the nail and the intramedullary canal and minimize toggling motion. However, it has not been previously documented whether the properties of the nail distally have an impact on the behavior of the nail proximally. In this study, there was no difference in PFS between 10 mm diameter short CMNs and 11 mm diameter short CMNs. This indicates that utilizing a larger diameter short CMN does not have an effect on mitigating PFS.

The incidence of PFS >10 mm in our cohort of 80 patients was 30%. This is consistent with prior studies on surgical treatment of pertrochanteric hip fractures, which have demonstrated a 5%–42% incidence of PFS >10 mm.^{11–13} Excessive PFS has clinical implications, as it can lead to fixation failure and lag screw cut out.¹¹ Furthermore, PFS has been correlated with hip abductor dysfunction, gait impairment, and poorer physical outcomes.⁶ Gilat et al. found that PFS was associated with an inability to retain ambulatory capacity after cephalomedullary nailing for hip fractures.¹¹

Shortening of the hip abductor lever arm from sliding of the lag screw affects hip biomechanics and gait. The hip abductor muscles are critical for stabilizing the pelvis during the one-legged stance phase of gait. With a shortened abductor lever arm, the abductor force required for ambulation is increased. The joint reactive force at the hip is also increased when the abductor lever arm is shortened. Additionally, PFS has been associated with gait dysfunction, including decreased cadence, increased double support time, decreased step length, and increased single support asymmetry.¹⁴ Maintenance of abductor lever arm length and femoral height without excessive shortening is therefore important for physical recovery and mobility after hip fracture fixation.

Prior studies examining risk factors for PFS have found a correlation with fracture type, fracture reduction, and intramedullary canal diameter.^{12,15} Unstable fracture patterns have been associated with a greater degree of PFS than stable fracture patterns.^{12,15} Accurate reduction on not only the AP view, but also the lateral view, has been shown to be an important factor in mitigating PFS.¹² Lastly, increasing intramedullary canal diameter, which is closely related to age, has also been shown to be an important contributor to PFS.¹⁵ While fracture type and intramedullary canal diameter are not modifiable factors, fracture reduction

is a modifiable factor. Therefore, obtaining an excellent fracture reduction is essential in order to mitigate PFS and its associated complications.

This study has several limitations. First, this was a retrospective study in which nail diameter was determined at the discretion of the surgeon, thereby introducing selection bias. Another limitation was the reliability of the radiographic methodology of measuring PFS. In their initial study, Zlowodzki et al. demonstrated significant intra-observer reliability for their methodology, but did not examine inter-observer reliability.⁷ While we attempted to minimize measurement bias in this study by having a single investigator perform all measurements, we were unable to account for potential bias from inter-observer reliability. Lastly, bone mineral density testing results were not available for review in our cohort, and this may have been a potential confounding factor affecting PFS.

5. Conclusions

In summary, our results showed no difference in abductor lever arm shortening, femoral height shortening, or PFS in pertrochanteric hip fractures treated with a 10 mm or 11 mm short CMN. This finding suggests that distal nail diameter does not affect PFS in pertrochanteric hip fractures treated with short CMNs.

Institutional review board approval

IRB approval was obtained for the submitted work at our institution.

Declaration of competing interest

Dr. Forsh has financial relationships with Stryker (paid consultant). None of the other authors have any financial interests or affiliations with institutions, organizations, or companies relevant to the manuscript. None of the authors received payment or funding support in kind for any aspect of the submitted work.

References

- 1 Wolinsky FD, Fitzgerald JF, Stump TE. The effect of hip fracture on mortality, hospitalization, and functional status: a prospective study. *Am J Publ Health*. 1997;87(3):398–403.
- 2 Cumming RG, Nevitt MC, Cummings SR. Epidemiology of hip fractures. *Epidemiol Rev*. 1997;19(2):244–257.
- 3 Kannus P, Parkkari J, Sievanen H, Heinonen A, Vuori I, Jarvinen M. Epidemiology of hip fractures. *Bone*. 1996;18(1 Suppl):57S–63S.
- 4 Queally JM, Harris E, Handoll HHG, Parker MJ. Intramedullary nails for extracapsular hip fractures in adults. CD004961 *Cochrane Database Syst Rev*. 2014;9.
- 5 Davis TR, Sher JL, Horsman A, et al. Intertrochanteric femoral fractures: mechanical failure after internal fixation. *J Bone Joint Surg Br*. 1990;72(1):26–31.
- 6 Zielinski SM, Keijsers NL, Praet SFE, et al. Femoral neck shortening after internal fixation of a femoral neck fracture. *Orthopedics*. 2013;36(7):e849–e858.
- 7 Zlowodzki M, Brink O, Switzer J, et al. The effect of shortening and varus collapse of the femoral neck on function after fixation of intracapsular fracture of the hip: a multi-centre cohort study. *J Bone Joint Surg Br*. 2008;90(11):1487–1494.
- 8 Auston D, Donohue D, Stoops K, et al. Long segment blocking screws increase the stability of retrograde nail fixation in geriatric supracondylar femur fractures: eliminating the “Bell-clapper effect”. *J Orthop Trauma*. 2018;32(11):559–564.
- 9 Baumgaertner MR, Curtin SL, Lindskog DM, Keggi JM. The value of the tip-apex distance in predicting failure of fixation of pertrochanteric fractures of the hip. *J Bone Joint Surg Am*. 1995;77(7):1058–1064.
- 10 Anglen JO, Weinstein JN, American Board of Orthopaedic Surgery Research Committee. Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of Orthopaedic Surgery Database. *J Bone Joint Surg Am*. 2008;90(4):700–707.
- 11 Gilat R, Lubovsky O, Atoun E, Debi R, Cohen O, Weil YA. Proximal femoral shortening after cephalomedullary nail insertion for intertrochanteric fractures. *J Orthop Trauma*. 2017;31(6):311–315.
- 12 Ito J, Takakubo Y, Sasaki K, Sasaki J, Owashi K, Takagi M. Prevention of excessive postoperative sliding of the short femoral nail in femoral trochanteric fractures. *Arch Orthop Trauma Surg*. 2015;135(5):651–657.

- 13 Platzter P, Thalhammer G, Wozasek GE, Vecsei V, et al. Femoral shortening after surgical treatment of trochanteric fractures in nongeriatric patients. *J Trauma*. 2008; 64(4):982–989.
- 14 Gausden EB, Sin D, Levack AE, et al. Gait analysis after intertrochanteric hip fracture: does shortening result in gait impairment? *J Orthop Trauma*. 2018;32(11):554–558.
- 15 Song HK, Yoon HK, Yang KH. Presence of a nail in the medullary canal: is it enough to prevent femoral neck shortening in trochanteric fracture? *Yonsei Med J*. 2014;55 (5):1400–1405.