Timing of proximal femoral shortening in the early postoperative period after cephalomedullary nailing of hip fractures

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ABSTRACT

Objectives: Examine the timing of proximal femoral shortening (PFS) after cephalomedullary nailing of hip fractures.

Methods: A retrospective cohort study of 21 patients ≥ 50 years old with pertrochanteric hip fractures treated with a short cephalomedullary nail (CMN) was performed. Abductor lever arm shortening, femoral height shortening, and PFS were measured.

Results: Mean PFS at 10–21 days postoperatively was 5.54 mm, compared to 11.31 mm at final follow-up. The percentage of total PFS that occurred within 10–21 days postoperatively was 53.9%.

Conclusion: Approximately half of total PFS occurs within 1.5–3 weeks and is notable on radiographs by the first postoperative visit.

1. Introduction

Hip fractures are a major public health concern. The morbidity and mortality of hip fractures, as well as the associated socioeconomic costs, remain high. The incidence of hip fractures continues to upend as the rate of osteoporosis and the incidence of falls continue to rise in the elderly population. The majority of osteoporotic fragility fractures are hip fractures, and as many as 6.3 million people per year are projected to sustain hip fractures by 2050.^{1,2}

Extracapsular hip fractures in the trochanteric region comprise approximately 40%–50% of all hip fractures.³ Pertrochanteric hip fractures can be treated with either extramedullary or intramedullary implants, but cephalomedullary nails (CMN) have gained recent popularity due to the ease of surgical technique, less invasive surgical approach, and theoretical biomechanical advantage compared to extramedullary fixation.^{3,4}

Proximal femoral shortening (PFS) frequently occurs after internal fixation of pertrochanteric hip fractures with CMNs.⁵ Controlled sliding of the lag screw allows for compression at the fracture site, which in turn, promotes fracture healing. However, excessive sliding of the proximal fracture fragment can occur, and is thought to be an important contributor to fixation failure and lag screw cut out.⁶ Additionally, prior studies have demonstrated an adverse association between PFS and functional outcomes, including mobility with regards to gait velocity and symmetry.^{7,8} Furthermore, PFS can negatively impact hip

abductor function, which also impairs mobility.

To the best of our knowledge, the timing and magnitude of PFS in the early postoperative period after cephalomedullary nailing has not been previously documented. Given the demonstrated adverse effects of PFS on function and mobility, the timing and magnitude of PFS in the postoperative period may have implications for early postoperative rehabilitation and progress towards functional recovery. The objective of this study was to investigate the timing and magnitude of PFS in the early postoperative period after internal fixation of pertrochanteric hip fractures with CMNs.

2. Materials and methods

Institutional review board approval was obtained for this study. We performed a retrospective cohort study of patients aged 50 years and older who underwent internal fixation with a short, trochanteric entry CMN (Gamma3, Stryker, Kalamazoo, MI) for a pertrochanteric femur fracture (AO/OTA 31A1,2,3) at our institution between July 2017 and October 2019. Patients who had radiographic follow-up within 10–21 days postoperatively and radiographic follow-up at a minimum of 50 days postoperatively were included. Exclusion criteria included patients who had previous surgery on the injured hip, patients who were mal-reduced on final intraoperative fluoroscopy, and patients with low quality fluoroscopy/radiographs precluding radiographic analysis. We also excluded patients who had < 5 mm overall PFS at most recent

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follow-up. Patient age and gender were recorded. Fracture pattern according to the AO classification was recorded.

With regards to surgical technique, all patients were positioned supine on a standard fracture table. The fractures were reduced by closed or open techniques as needed. Instrumentation of the short CMNs was performed according to the instructions provided by the manufacturer. All nails were statically locked distally. Postoperatively, all patients were allowed to immediately bear full weight as tolerated.

All images were retrieved from the PACS software (Centricity, GE Healthcare System Inc., Chicago, IL). Rotated radiographs were excluded, as they would interfere with accurate radiographic measurements. Tip-apex distance (TAD) was measured using PACS software on final intraoperative fluoroscopy according to the method described by Baumgaertner et al.⁹

We used Adobe Photoshop (version 21.0.1, Adobe Inc., San Jose, CA) to measure PFS at 10–21 days postoperatively and at most recent follow-up. PFS was quantified according to a modified version of the method described by Zlowodski et al.⁸ The anteroposterior view of the injured hip on final intraoperative fluoroscopy was utilized for comparison with anteroposterior views of the injured hip on follow-up radiographs to quantify PFS at 10–21 days postoperatively and most recent follow-up, respectively. We overlaid the injured proximal femur from the radiograph at 10–21 days postoperatively or at most recent follow-up on the injured proximal femur from final intraoperative fluoroscopy. The known diameter of the lag screw was used to aid in adjusting the size of the radiographs to account for differences in magnification between intraoperative fluoroscopy and follow-up radiographs. Follow-up radiographs that had an injured femur with > 2 mm difference in diaphyseal cortex diameter than the injured femur on final intraoperative fluoroscopy after size adjustment were excluded.

We then measured shortening in the x and y planes at 10–21 days postoperatively and at most recent follow-up, respectively (Fig. 1). The x vector represented abductor lever arm shortening. The y vector represented femoral height shortening. Overall PFS was represented by the z vector, which was calculated based on the following equation: $z^2 = x^2 + y^2$. All measurements were performed by a single investigator (Z.C.). After quantifying PFS at 10–21 days postoperatively and total

Fig. 1. The outline of the hip on final intraoperative fluoroscopy was overlapped on the outline of the hip on the follow-up radiograph to measure abductor lever arm shortening in the x plane and femoral height shortening in the y plane. Overall proximal femoral shortening (z) was calculated as the sum vector between abductor lever arm shortening and femoral height shortening.

PFS at the most recent follow-up, the percentage of total PFS that had occurred at 10–21 days postoperatively was calculated. Means and standard deviations were reported.

3. Results

A total of 21 patients met the selection criteria and were included in the study. There were 16 (76.2%) women and 5 (23.8%) men. The average age was 79.7 years (range, 57–100) with a mean follow-up of 164 days (range, 55–515). There were 13 (61.9%) left hip fractures and 8 (38.1%) right hip fractures. There were 12 AO type 31A1, 8 AO type 31A2, and 1 AO Type 21A3 fracture patterns. The mean TAD was $17.3 \text{ mm} \pm 6.3 \text{ mm}$. At 10–21 days postoperatively, mean abductor lever arm shortening, femoral height shortening, and overall PFS were $3.13 \text{ mm} \pm 2.87 \text{ mm}$, $3.39 \text{ mm} \pm 2.47 \text{ mm}$, and $5.54 \text{ mm} \pm 2.12 \text{ mm}$, respectively. At most recent follow-up, mean abductor lever arm shortening, femoral height shortening, and overall PFS were $4.41 \text{ mm} \pm 4.41 \text{ mm}$, $9.04 \text{ mm} \pm 6.04 \text{ mm}$, and $11.31 \text{ mm} \pm 5.29 \text{ mm}$, respectively. At 10–21 days postoperatively, the mean percentage of total PFS that had occurred was $53.9\% \pm 20.7\%$ (range, 27.9%–99.7%).

4. Discussion

PFS frequently occurs after cephalomedullary nailing of pertrochanteric hip fractures. Controlled sliding of the lag screw and compression at the fracture site are fundamental concepts in cephalomedullary nail fixation. Although fracture compression is an important contributor to fracture healing, excessive sliding and subsequent PFS can lead to fixation failure, lag screw cut out, and poor functional outcomes. While PFS is a known and expected phenomenon after cephalomedullary nailing of pertrochanteric hip fractures, there remains limited literature on the incidence of PFS. Furthermore, the timing of when PFS occurs in the postoperative period has not been previously documented. Our results in this study showed that approximately half of overall PFS occurs in the early postoperative period within 1.5–3 weeks after cephalomedullary nailing of pertrochanteric hip fractures.

Prior studies have reported that the majority of mechanical fixation failures following cephalomedullary nailing of hip fractures occur within 6 and 18 weeks postoperatively.^{5,10,11} However, this is a wide timeframe and does not provide specific details as to when the majority of PFS actually occurs within this timeframe. Gilat et al. subdivided their cohort into those with radiographs taken at 6–12 weeks and those with radiographs taken at 12–18 weeks postoperatively.⁵ They found no significant difference in PFS between these two groups.⁵ This seems to suggest that a significant proportion of PFS has occurred by 6 weeks postoperatively and minimal increases in shortening occur after that. Our study took a closer look at PFS in the early postoperative period and is the first study to report on the natural history and timing of PFS within this timeframe. Notably, we found that approximately half of overall PFS occurs within the first 1.5–3 weeks postoperatively and can be appreciated on routine radiographs at the first follow-up visit. While the timing of PFS postoperatively likely does not have implications for preventing subsequent fixation failure, it may have clinically relevant effects on functional recovery.

Excessive PFS has clinical implications, as previous literature has demonstrated an adverse correlation between PFS and functional outcomes after hip surgery.⁷ The hip abductor muscles play an important role in stabilizing the pelvis during the one-legged stance phase of gait. The gluteus medius and gluteus minimus muscles insert on the greater trochanter. Therefore, shortening of the proximal femur leads to shortening of the abductor lever arm. Maintenance of the abductor lever arm is important, as shortening of the lever arm increases the force of the abductors required for mobility and ambulation. Shortening of the abductor lever arm also increases the joint reactive force at the hip.

In addition to affecting abductor function, PFS has also been shown to reduce gait velocity and cause subtle changes in gait pattern.⁷ PFS has been associated with a reduced gait velocity of 1.1 m/s, compared to normal gait velocity of 1.3–1.5 m/s.⁷ PFS also appears to be associated with an abnormal gait pattern that is characterized by decreased cadence, greater double support phase, decreased step length, and decreased stance phase.^{7,12} Subtle differences in gait parameters between the injured and uninjured limb have also been noted in association with PFS, which may have clinical consequences for physical function and mobility.^{7,13}

Restoration of abductor lever arm length and proximal femoral height in pertrochanteric hip fractures treated with CMNs appears to be challenging. In patients who have radiographic PFS > 5 mm, approximately half of the shortening occurs in the early postoperative period within 1.5–3 weeks postoperatively. This early shortening should be notable on routine radiographs by the first postoperative visit and may have implications for early postoperative rehabilitation and progress towards functional recovery.

There are several limitations to this study. First, this was a retrospective study with a small cohort of patients who met the selection criteria. Unfortunately, we had to exclude patients due to a lack of appropriate follow-up radiographs at the designated postoperative time points. Therefore, our sample size was small. Based on the standard deviation from previous studies,⁵ our sample size was powered to assess shortening to a precision of 2.0 mm. The small sample size did not allow for further subgroup analysis to assess the potential confounding effect of patient demographics or fracture pattern on the timing of PFS. Another potential confounding variable that we were not able to assess in this retrospective study was bone mineral density, as this may also contribute to the timing of PFS. Next, another potential limitation was the reliability of the method of measuring PFS. Using their original methodology, Zlowodzki et al. demonstrated substantial intraobserver reliability in the measurement of PFS.⁸ However, the interobserver reliability of this measurement method remains unclear. In order to minimize measurement bias in this study, a single investigator performed all measurements. Lastly, we elected to limit our inclusion criteria to patients who underwent fixation with short CMNs only in order to minimize the potentially confounding effect of differing nail length.

In summary, our findings demonstrated that approximately half of overall PFS occurs during the first 1.5–3 weeks after internal fixation of pertrochanteric hip fractures with short CMNs. This suggests that a significant amount of shortening occurs in the early postoperative period. This shortening can be identified on routine radiographs by the first postoperative visit and may have implications for early postoperative rehabilitation and functional recovery.

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.

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References

- Johnell O, Kanis JA. An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. *Osteoporos Int*. 2006;17(12):1726–1733.
- Kannus P, Parkkari J, Sievanen H, et al. Epidemiology of hip fractures. *Bone*. 1996;18(1 Suppl):57S–63S.
- Queally JM, Harris E, Handoll HHG, et al. Intramedullary nails for extracapsular hip fractures in adults. *Cochrane Database Syst Rev*. 2014;9:CD004961.
- 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.
- Gilat R, Lubovsky O, Atoun E, et al. Proximal femoral shortening after cephalomedullary nail insertion for intertrochanteric fractures. *J Orthop Trauma*. 2017;31(6):311–315.
- 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.
- 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.
- 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.
- Baumgaertner MR, Curtin SL, Lindskog DM, et al. 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.
- Pascarella R, Fantasia R, Maresca A, et al. How evolution of the nailing system improves results and reduces orthopedic complications: more than 2000 cases of trochanteric fractures treated with the Gamma nail system. *Musculoskelet Surg*. 2016;100(1):1–8.
- Turgut A, Kalenderer O, Karapinar L, et al. Which factor is most important for occurrence of cutout complications in patients treated with proximal femoral nail antirotation? Retrospective analysis of 298 patients. *Arch Orthop Trauma Surg*. 2016;136(5):623–630.
- 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.
- Benedetti MG, Catani F, Benedetti E, et al. To what extent does leg length discrepancy impair motor activity in patients after total hip arthroplasty? *Int Orthop*. 2010;34(8):1115–1121.