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ORIGINAL ARTICLE

High incidence of "in–out–in" posterosuperior screws after cannulated screw fixation of femoral neck fractures

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Abstract

Introduction Cadaveric models have demonstrated a high incidence of extraosseous "in–out–in" (IOI) posterosuperior screws after cannulated screw fixation of femoral neck fractures. The purpose of this study was to determine the incidence of IOI screws in vivo and to evaluate their association with osteonecrosis and revision surgery.

Methods A total of 104 patients with 107 hips with a pelvis computed tomography (CT) scan after cannulated screw fixation of a femoral neck fractures were included. Screw position was evaluated on postoperative radiographs and CT scan to determine if screws were IOI or all-in. Osteonecrosis and revision surgeries were documented.

Results IOI posterosuperior screws were identified on CT scan in 58 (54%) hips. On postoperative AP and lateral radiographs, IOI screws were a median (interquartile range) of 10 mm (7–11 mm) and 3 mm (0–4 mm) from the cortex, respectively. The sensitivity and specificity of radiographs to detect IOI screws was 39% and 92%, respectively. The incidence of osteonecrosis and revision surgeries in hips, with and without IOI screws, was 6% versus 6% [Odds ratio (OR) 1.1, 95% confidence interval (CI) 0.2–5.3] and 10% versus 10% (OR 1.0, CI 0.3–3.1), respectively; a true clinical difference cannot be excluded due to the width of the confidence intervals.

Conclusions There was a high incidence of IOI posterosuperior screws on CT scans. Postoperative radiographs had a poor sensitivity for detecting IOI screws. A larger sample size is necessary to evaluate the association of IOI screws with osteonecrosis and revision surgery.

Level of evidence Level III, comparative cohort study.

Keywords Femoral neck fracture · Cannulated screw · Inverted triangle · Posterosuperior screw · Osteonecrosis

Introduction

Femoral neck fractures are commonly treated with cannulated screw fixation [1–3]. This fixation typically consists of three screws placed in a inverted triangle configuration, which has been shown to be biomechanically superior to other screw configurations [4–6]. Ensuring that each screw is abutting the cortex of the femoral neck has been shown to confer additional strength to the construct [4, 5]. However, in a previous cadaveric study, Hoffmann et al. [7] demonstrated that 70% of posterosuperior screws placed into the femoral neck were extraosseous or "in–out–in" (IOI), despite appearing intraosseous on intraoperative and postoperative imaging. An IOI posterosuperior screw could compromise fixation and potentially damage the lateral epiphyseal artery, the blood supply to femoral head, which could increase the risk of femoral head osteonecrosis [7–9].

The purpose of this study was to review patients that received a pelvis computed tomography (CT) scan for unrelated indications after cannulated screw fixation of a femoral neck fractures to determine the incidence of extraosseous IOI posterosuperior screws and to evaluate if these screws were associated with osteonecrosis or revision surgery.

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Methods and materials

After institutional review board approval, we performed a retrospective review of a single level 1 trauma center to identify patients with femoral neck fractures (OTA/AO 31-B) that received fixation with three cannulated screws from the years of 2005 to 2015. Patients were excluded from the analysis if they had less than 6 months of follow-up or did not have a pelvis CT scan that visualized the entire femoral neck and head after the surgery.

The distance from the edge of the posterosuperior screw to the femoral neck cortex at its closest point was measured in millimeters (mm) on the immediate postoperative anteroposterior (AP) and cross-table lateral radiographs (Fig. 1). Images were calibrated using the known diameter of the screw [10]. If the screw appeared to overlap or breach the cortex on radiographs, the distance was recorded as zero. Cases of osteonecrosis and revision surgeries were reviewed. A diagnosis of osteonecrosis was made if the femoral head developed cystic or sclerotic changes and/or collapsed on postoperative radiographs [11, 12].

Pelvis CT scans were obtained for a variety of different reasons, the most common being abdominal pain or distension (26, 24%), repeat trauma (16, 15%), or hip pain (11, 10%). Axial and coronal CT reconstructions were analyzed to determine if the posterosuperior screw were in–out–in (IOI) or intraosseus (all-in). If the screw breached the femoral neck cortex on CT it was considered to be IOI (Fig. 2).

Parametric and nonparametric statistical tests were used depending on the presence of non-normally distributed data as determined by the Shapiro–Wilks test. The distribution of parametric and nonparametric continuous data was presented as mean ± standard deviation and median (interquartile range (IQR)), respectively. Student's *t* test and Kruskal–Wallis test were used to compare parametric and nonparametric continuous data across groups. The median difference and 95% confidence interval (CI) between nonparametric continuous data was calculated with the Hodges–Lehmann estimator. Fishers exact test was used to evaluate differences between categorical data. Sensitivity and specificity for postoperative radiographs to diagnose IOI posterosuperior screws was calculated. A *p* value less than 0.05 was considered statistically

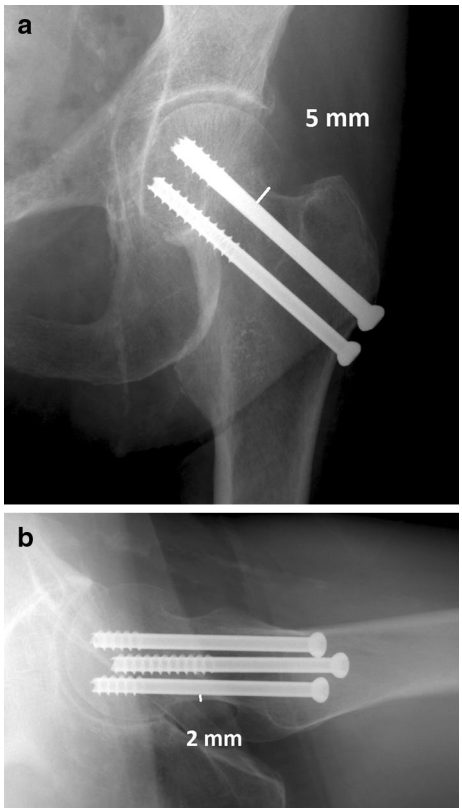

Fig. 1 Postoperative anteroposterior (**a**) and lateral (**b**) hip radiographs after percutaneous cannulated screw fixation of a valgus impacted femoral neck fracture. The posterosuperior screw appears to be intraosseous on these two views; however the combined distance between the screw and cortex on both views is 7 mm

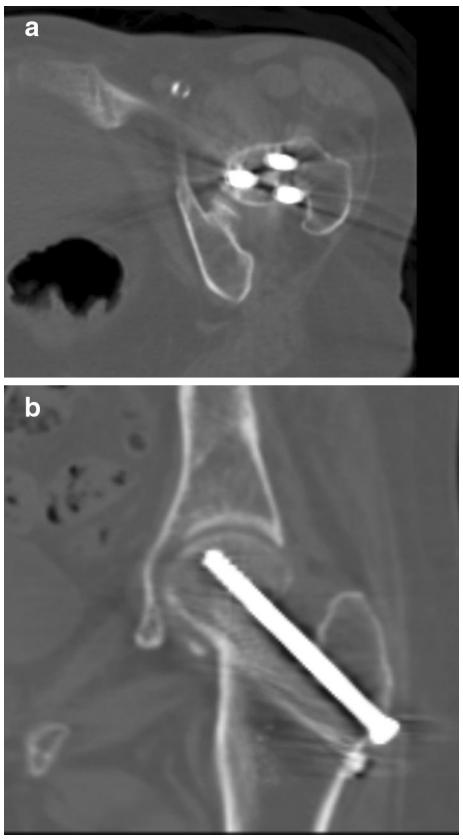

Fig. 2 Axial (**a**) and coronal (**b**) reconstructions of the pelvis obtained 14 months after surgical fixation. The CT scan was obtained as part of an evaluation after another fall. The CT confirms the posterosuperior screw is extraosseous. The patient went on to uneventful union without evidence of osteonecrosis

significant. All analyses were carried out using JMP Pro version 14 statistical software (SAS; Cary, NC).

Results

We identified 362 patients with femoral neck fractures who underwent fixation with three cannulated screws. After excluding patients without a pelvis CT scan that visualized the femoral head and neck or patients with less than 6 months of follow-up, a total of 104 patients with 107 hips were included in analysis. Seventy-seven patients (74%) were female. The average age at the time of surgery was 74 years (range 21–95 years). The average time from operative fixation to the CT scan was 42 months (range 0–124 months). Radiographic follow-up of at least 6 months was available for 77 patients with 80 hips (75%).

There were no cases of cortical perforation of the inferior or anterosuperior screws. The posterosuperior screw was found to be IOI on CT scan in 58 (54%) of the 107 hips. Comparatively, on postoperative AP radiographs all posterosuperior screws appeared all-in and on cross-table lateral radiographs 25 (23%) posterosuperior screws appeared IOI. CT scans confirmed that 22 (88%) of the 25 screws that appeared IOI on cross-table lateral radiographs were actually IOI. The IOI screws had closer proximity to the cortex on postoperative radiographs than the all-in screws (Table 1). The sensitivity and specificity for postoperative cross-table lateral radiographs to detect extraosseous posterosuperior screw was 39% and 92%, respectively.

There was no detectable difference in osteonecrosis or revision surgeries between patients with and without IOI screws (Table 2); however, the observed confidence intervals of the odds ratios were wide and cannot exclude a clinical difference. Revision surgeries included conversion to total hip arthroplasty (THA) for osteonecrosis ($n=6$), THA for femoral neck non-union ($n=3$), valgus osteotomy and blade plate fixation for femoral neck non-union ($n=1$), and screw exchange for prominent screws after fracture subsidence ($n=1$).

Discussion

This study found that a majority of patients undergoing cannulated screw fixation of the femoral neck had IOI posterosuperior screws and that postoperative radiographs had a poor sensitivity for identifying these screws. These results are similar to a previous cadaveric study that demonstrated a high incidence of IOI screws that were not detected using standard AP and lateral fluoroscopic views of the femoral neck [7]. Although standard fluoroscopic views have a poor sensitivity at detecting IOI screws, the use of sequential fluoroscopic roll-over images have been shown to have a high sensitivity for detecting IOI guidewires and may be able to prevent the placement of IOI screws [13].

The clinical consequences of cortical perforation of posterosuperior screws are not definitively known. The vascular anatomy of the proximal femur has been well described with most of the vascular foramina and terminal branches of the lateral epiphyseal artery residing in the posterosuperior

Table 1 Postoperative hip radiograph measurements

	In–out–in screws ($n=58$)	All-in screws ($n=49$)	Difference, 95% CI	*P* value
In–out–in on AP [*n* (%)]	0 (0%)	0 (0%)		
In–out–in on lateral [*n* (%)]	22 (37%)	3 (6%)	−30%, −42 to −13%	0.0004*
Distance of screw to cortex on AP (mm)	10 (7–11)	14 (11–19)	4, 2–6	< 0.0001*
Distance of screw to cortex on lateral (mm)	3 (0–4)	4 (4–6)	2, 0.8–3.6	0.0001*

Distance measurements are presented as median (interquartile range) due to data being nonparametric

CI confidence interval, *AP* anteroposterior

*A *p* value less than 0.05 was considered statistically significant

Table 2 Osteonecrosis and revision surgery

	In–out–in screws ($n=58$)	All-in screws ($n=49$)	Odds ratio, 95% CI	*p* value
Osteonecrosis [*n* (%)]	4 (6%)	3 (6%)	1.1, 0.2–5.3	1.0
Revision surgery [*n* (%)])	6 (10%)	5 (10%)	1.0, 0.3–3.1	1.0

CI confidence interval

*A *p* value less than 0.05 was considered statistically significant

neck. An extraosseous screw in this area could therefore damage the blood supply to the femoral head while also decreasing the stability of the fixation construct due to the cortical breach [7, 8, 14].

We were unable to detect an association between IOI screws and osteonecrosis or revision surgery, however our sample size was small. Based on the observed incidence of osteonecrosis between patients with and without IOI screws (6% and 6%, respectively) a total sample size of 1484 patients would be necessary to determine a 50% relative difference in osteonecrosis with 80% power on a 0.05-level two-sided test. A future study with a larger number of patients undergoing postoperative CT scans would be necessary to adequately evaluate the association with IOI screws and osteonecrosis.

This study is limited by its small retrospective nature. Other limitations include the short-term follow-up of this study, which likely underestimates the actual incidence of osteonecrosis. Also, the use of follow-up radiographs and CT scans to diagnose osteonecrosis likely leads to further underreporting. Magnetic resonance imaging (MRI) would have had a higher sensitivity for detecting osteonecrosis but this was not available. Another limitation is the lack of assessment of femoral neck reduction in this study, which is a known risk factor for non-union and revision surgery [1, 3]. Future studies assessing IOI screws would benefit from collecting initial displacement and reduction quality as well.

In conclusion, this analysis of patients undergoing cannulated fixation of a femoral neck fractures revealed a high incidence of IOI posterosuperior screws on CT scans that were not detected on postoperative radiographs. With the numbers examined, we are unable to conclude if these screws were associated with the development of osteonecrosis and the need for revision surgery. Additional methods to prevent IOI screws, like sequential fluoroscopic roll-over images prior to screw insertion, warrant further investigation.

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Compliance with ethical standards

Conflict of interest No external source of funding. A. Sems receives royalties from Biomet. No other authors have a COI.

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