Anatomy of the Greater Trochanteric ‘Bald Spot’

A Potential Portal for Abductor Sparing Femoral Nailing?

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Abstract Soft tissue injury occurs when using a piriformis portal for femoral nailing. Standard trochanteric portals also can injure the gluteus medius and external rotator tendons, which may be a source of hip pain after nailing. On the lateral facet of the greater trochanter, a “bald spot” may exist that is devoid of tendon insertion. This may be a potential portal for intramedullary nail insertion. We defined the dimensions and location of this region. Cadaveric specimens were dissected to expose the tendon insertions on the greater trochanter. A computer navigation system was used with a stylus and bone morphing to determine the tendon insertions and bald spot anatomy. The greater trochanteric bald spot is covered by the subgluteus medius bursa and has no tendon insertions. Its center lies 11 mm distal to the tip of the greater trochanter and 5 mm anterior to the midline. The shape is ellipsoid with a diameter of 21 mm. This region is large enough to accommodate the size of most nailing system reamers without tendon footprint infringement. Use of this modified entry site may reduce soft tissue injury with nailing procedures and minimize subsequent hip pain.

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Introduction

Antegrade intramedullary nailing of femoral shaft fractures is a standard technique that leads to predictable fracture stabilization and healing [22, 26, 28]. A piriformis fossa starting portal has been used traditionally, but recent studies indicate with appropriate nails and techniques, insertion through a trochanteric entry site is also effective [23, 25]. Both of these entry portals, however, require perforation and penetration of the hip abductor and external rotator tendons, which may cause substantial injury to these structures and may be a source of postoperative morbidity [1, 4, 6–8, 15, 27].

Clinically, persistent hip pain and limp are not uncommon after such procedures, and some authors suggest a major component of this pain is damage to the abductor tendons [1, 6, 7, 12]. Bain and colleagues reported a 40% incidence of persistent trochanteric pain after femoral nailing [1]. McConnell et al. [15] reported that after insertion of a cephalomedullary nail into 34 cadaveric hips, as much as 53% of the abductor tendon insertion was disrupted, although a detailed evaluation of tendon insertion anatomy was not performed.

Evidence from previous anatomic studies suggests the insertion of the gluteus medius tendon does not insert broadly on the greater trochanter, but rather covers the posterior tip and extends laterally and anteriorly [9, 18, 24]. The gluteus minimus inserts anteriorly on the greater trochanter, and between these two structures lies the subgluteus medius bursa [9, 21]. Robertson et al. recently described a bare region between tendon insertions [24], but did not report its dimensions and position. Although these prior studies were not conducted to examine the potential insertion of intramedullary nails, the implication of a bursa overlying the bone suggests a bald spot exists on the tip of

the greater trochanter, devoid of tendon insertions, which may allow for passage of an intramedullary nail without injuring the tendons.

We examined the anatomic insertions of the tendons on the proximal femur and geometrically defined the “bald spot.” Secondly, we analyzed whether the dimensions of the bald spot varied with specimen size.

Materials and Methods

We obtained 10 fresh-frozen cadaveric hips from five specimens, three of which were male. The average age was 74 years (range, 66–82 years). The specimens were dissected and the muscle bellies of the gluteus medius, gluteus minimus, and external rotators were isolated and reflected from their origins. We then circumferentially incised the hip capsule at its most distal insertion site on the femoral neck, the ligamentum teres was excised, and the hip was dislocated. The femur was retained with the tendon attachments remaining intact and attached to the greater trochanter.

We used two data acquisition methods to determine the tendon insertions. Owing to the difficulty in manually measuring the complex and irregular geometry of the proximal femoral tendon insertions, a highly accurate computer navigation system was used. This allowed for digital integration of the various structures, accurate determination of surface areas, and calculation of virtual distances between various anatomic landmarks. First, a standard fluoroscopic C-arm was mounted with a navigation reference frame, which was used to acquire anteroposterior and lateral images of the proximal femur. We used a computer navigation system (Praxim, La Tronche, France) with a navigated stylus with an accuracy of 1 mm. The system was calibrated and standardized points on the bone were acquired using the stylus, which allowed for subsequent navigation-acquired data points to be superimposed on the fluoroscopic images (Fig. 1). In succession, we traced the individual tendon insertions of the gluteus medius, gluteus minimus, and piriformis tendon, and the origin of the vastus lateralis with the stylus. Additionally, the bald spot, the region on the greater trochanter without tendon insertion, was similarly traced with the stylus. We acquired data points every 3 mm of the periphery during tracing.

Next, we performed navigated surface bone morphing to generate a virtual bone model of each specimen. The periphery of the insertions of each tendon and the bald spot were again traced with the navigated stylus and subsequently were integrated into the generated bone surface model. We determined the precise morphologic features of the bald spot relative to several anatomic landmarks and to

Fig. 1 Each specimen was mounted with a navigation reference marker, and several screws were placed as additional references. The tendon insertions then were traced with a navigated stylus.

the three cardinal planes. All distances and angles were averaged between the 10 specimens.

We determined the radius of the femoral head on the morphed bone model using the navigation software, and the cadaveric specimen also was measured manually using a digital caliper to determine the accuracy of the computer-generated model. To determine if the size of the bald spot varies with size of the specimen we computed a Pearson's correlation coefficient to determine any relationship between the size of the femoral head and the diameter or surface area of the bald spot.

Results

We uniformly found a bald spot on the lateral facet of the greater trochanter, devoid of tendon insertion, and bordered anteriorly and distally by the gluteus minimus, posteriorly by the gluteus medius, and proximally by the piriformis tendon. The shape of this area is slightly ellipsoid with the major axis running in the posterosuperior to anteroinferior planes at an angle of 34° (range, 17° – 48°) relative to the femoral shaft axis. The average surface area is 354 mm^2 (range, 237 – 490 mm^2), and a least-squares circle constructed has a diameter of 21 mm (range, 17–25 mm) (Fig. 2).

On the anteroposterior view, the geometric center of the bald spot lies on the lateral facet, 11 mm distal to the tip of the trochanter (range, 7–14 mm). On the lateral view, the center lies 5 mm (range, 0–9 mm) anterior to the center of

Fig. 2A–B The bald spot is bordered posteriorly by the gluteus medius, anteriorly by the two heads of the gluteus minimus, and superiorly and medially by the piriformis. Examples of (A) a gross specimen and (B) the bone morphing model after navigated determination of tendon footprints are shown.

the greater trochanter and 15 mm (range, 5–26 mm) anterior to the posterosuperior prominence of the trochanter (Figs. 3, 4).

We found no correlation between the size of the femoral head and either the diameter or surface area of the bald spot ($r^2 = 0.05$ for both). The radius of the femoral head as measured by the navigation system from the computer-generated model and the actual measurement differed by 1 mm (standard deviation, 0.5 mm). This indicated the model we used was precise and within the resolution limits of the camera system and acceptable clinical thresholds.

Discussion

The soft tissue injury associated with antegrade intramedullary nailing is well recognized [8, 15, 17, 19]. With the high success rates of fracture healing with this procedure,

Fig. 3A–B (A) The center of the bald spot lies 11 mm distal to the tip of the greater trochanter on the lateral facet and (B) 5 mm anterior to the middle of the tip of the greater trochanter on a lateral view. The average surface area is 354 mm², and the average diameter is 21 mm.

however, the soft tissue injury associated with nail insertion is generally an accepted comorbidity. Although several etiologies have been implicated as causes of post-nailing hip pain, inserting large diameter reamers through tendon insertions is a likely source of pain. In this study, we sought to precisely define the soft tissue anatomy of the proximal femur to determine if a region devoid of tendon insertions consistently exists.

The main limitation of this study is the number of cadavers used. With the small numbers anatomic variability cannot be established. However, the center of the bald spot was in a consistent location in all specimens. The age of the specimens also may have skewed the anatomic results based on age-related changes, but it is unlikely tendon footprints change substantially with age. Finally, the clinical feasibility of using this starting point has not been rigorously tested. Specifically, concern exists for increased hoop stresses and malreductions, particularly in proximal fractures. However, using an implant that was designed to be inserted 10° off axis of the femoral shaft (Lateral Entry Femoral Nail (LEFN), Synthes USA, West Chester, PA), the bald spot starting point has been used successfully in 10 cases to date (Fig. 5). Although detailed perioperative data have not been collected, no intraoperative or late complications occurred. Regardless, clinical use should be approached with caution until additional data regarding the biomechanical consequences of using this portal are delineated.

In this study, we used a precise navigation technique to determine the relationship of the tendon insertions on the greater trochanter and subsequently showed an elliptical region approximately 2 cm in diameter exists on the lateral facet of the trochanter without tendinous insertions. This region potentially may be used as an entry portal for intramedullary nail insertion and may effectively minimize soft tissue injury

Fig. 4A–B Fluoroscopic examples of the position of the bald spot on the (A) anteroposterior and (B) lateral views are shown.

Fig. 5A–B Using direct palpation and fluoroscopic confirmation, the bald spot was identified clinically, and intramedullary nails, seen here in the (A) anteroposterior and (B) lateral views, were inserted successfully using this entry point.

Several authors have reported long-term functional consequences to the hip after antegrade nailing. In a series of patients treated with an antegrade femoral nail with a followup of 21 months, 28% had trochanteric pain that was not associated with hardware prominence [7]. Another series of 32 patients with femoral fractures had 41% of patients with trochanteric pain and high incidences of abductor weakness and functional deficits. Hip abductor weakness may persist for as much as 2 years [6]. A cadaveric nailing study showed substantial soft tissue damage occurred when using traditional entry sites [8]. In a similar study, piriformis nailing resulted in damage to all of the external rotators in the majority of specimens, but even

an entry point on the tip of the trochanter resulted in injury to the piriformis tendon in the majority of cases [17]. The anatomic reasons for this are evident in our data, because the piriformis tendon actually inserts relatively superiorly on the trochanter. This may be an additional reason to consider a more lateral entry point. A more recent anatomic study used a modified medial trochanteric portal and reported no damage to the gluteus medius tendon insertion [20]. Because the gluteus medius tendon inserts obliquely on the wall of the lateral facet, moving the insertion site farther medially will likely avoid damage to this tendon. However, our anatomic data suggest this portal is medial to the bald spot and likely causes injury to the piriformis and gluteus minimus tendons. Clearly, multiple factors may lead to trochanteric pain and abductor weakness after femoral nailing, including superior gluteal nerve injury, heterotopic bone formation, and inadequate rehabilitation [1, 2, 4, 11, 19], but the effects of reaming through a tendon insertion site must be considered [16].

Injury to the gluteus medius tendon insertion has been recognized as a major cause of recalcitrant hip pain, known as greater trochanteric pain syndrome [3, 14]. Patients with greater trochanteric pain syndrome present with dull, aching, lateral-sided hip pain, which is aggravated by weightbearing and resistant hip abduction [13]. De novo tears occur most commonly in middle-aged women, affecting nearly 25% of women in their sixth and seventh decades of life [5, 10]. Although their cause is unclear, poor vascularity of the gluteus medius footprint has been proposed as a possible etiology [10]. Therefore, iatrogenic injury to the gluteus medius footprint is likely to result in persistent tears and tendinopathy. In turn, these tears may be the underlying cause of recalcitrant lateral-sided hip pain after femoral nailing. Avoiding injury to the gluteus medius and other tendons may reduce the

incidence of lateral-sided hip pain after trochanteric nail insertion.

We identified an elliptical area, approximately 21 mm in diameter, on the lateral facet of the greater trochanter, which is covered by bursal tissue and on which no tendons insert. The center of this bald spot is approximately 11 mm inferior on the lateral facet of the greater trochanter and is 5 mm anterior to the center of the trochanter when viewed laterally. Femoral antegrade trochanteric intramedullary nailing through this portal may minimize soft tissue injury and decrease the incidence of hip pain and abductor dysfunction postoperatively. However, before advocating clinical use of this portal, additional studies are necessary to determine the feasibility of reproducibly inserting a nail through this portal using a percutaneous fluoroscopically assisted technique and the effect on hoop stresses and fracture reduction using currently available nails.

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