Cephalomedullary Nail Fixation for Prophylactic Treatment of Incomplete Femoral Neck Stress Fractures in Athletes

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Background: The traditional management of femoral neck stress fractures (FNSFs)—such as cannulated screw fixation—requires a period of protected weightbearing and does not provide fixed angle stability.

Purpose: To report the technique and outcomes of a single surgeon's case series of prophylactic fixation of incomplete FNSFs using cephalomedullary nailing (CMN) followed by immediate weightbearing.

Study Design: Case series; Level of evidence, 4.

Methods: A retrospective review of 17 FNSFs treated using CMN by a single surgeon over 7 years was conducted. descriptive, injury, and treatment-related data were collected. Perioperative complications and recovery courses were included for each case. Descriptive statistics were used to summarize the characteristics, clinical presentation, diagnostic imaging findings, treatment details, and follow-up outcomes of the study population.

Results: There were no perioperative complications across the 17 injuries. The mean intraoperative blood loss was 67 mL (range, 20-150 mL). In all 17 cases, immediate full weightbearing was recommended. All patients were able to initiate a return to running by 6 weeks postoperatively. Time until completion of narcotic use was noted for 15 cases, with narcotic medications no longer required at 2 weeks for 12 injuries (71%), at 6 weeks for 2 injuries (12%), and at 3 months for 1 injury (5.9%). Patients had a mean of 12.4 months of follow-up (range, 6-48 months). At the final follow-up, 5 cases (29%) had persistent pain—1 from gluteus medius tendinosis and 4 from painful distal interlocking screws. Two patients underwent the removal of symptomatic hardware.

Conclusion: This study demonstrated that prophylactic fixation of FNSFs with CMN in endurance athletes is a safe and effective construct that permits early return to baseline impact activity because of the inherent stability of the construct, with a favorable complication profile—although with a 30% rate of persistent pain from the surgical site.

Keywords: cephalomedullary nailing; endurance athletes; femoral neck stress fractures; military; return to sport

Femoral neck stress fractures (FNSFs) represent 3% to 5% of all athletic-related stress fractures, and they commonly occur in military recruits and endurance athletes.[4,24,26] Several risk factors for developing FNSFs in military recruits include repetitive marching and running, as well as female sex, poor entry fitness scores, calcium and vitamin D metabolic abnormalities, and lower bone mineral density.[1,20,22,29] Anatomic risk factors—including coxa vara, acetabular retroversion, and femoroacetabular impingement—may also predispose patients to the development of FNSFs.[5,15,19,21]

The primary goal of treatment of incomplete FNSFs is to prevent progression to complete fracture, as complete femoral neck fractures have devasting complications—including malunion, nonunion, osteonecrosis, need for additional future surgery, and long-term disability.[18] Thus, management of these injuries is dependent on the severity of the stress fracture at presentation and the risk of progression.[27] Nonoperative management has been described as 6 weeks of nonweightbearing and can

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be appropriate for patients with isolated stress edema without a fracture line or compression-sided fracture lines involving <50% of the femoral neck width in the absence of an associated joint effusion.[4]

Operative treatment is indicated for compression-sided stress injuries with a fracture line involving >50% of the femoral neck width, those in the presence of an effusion, and all tension-sided fracture lines.[26] Operative FNSFs are often treated with cannulated screws, requiring multiple weeks of protected bearing with a gradual return to full weightbearing by 12 weeks.[4,11,24,30] While scant literature exists, cephalomedullary nailing (CMN) can be considered a viable option for the fixation of FNSFs in young, active individuals. This technique, which can be performed with minimal muscular dissection, provides a high level of stability and allows for immediate mobilization and weightbearing because of the fixed angle construct, which is particularly beneficial in the young athletic patient population.[28]

We present a case series for prophylactic fixation of incomplete FNSFs using CMN. Compared with other commonly utilized treatment modalities, CMN allows for rapid return to preinjury activities because of the stability of the fixation construct and minimally invasive application. This case series aimed to report the technique and outcomes of CMN fixation for incomplete FNSFs in a cohort of endurance athletes. The hypothesis was that the use of CMN in patients with FNSFs would be safe and effective, allowing immediate weightbearing after fixation.

METHODS

Study Design and Setting

This was a single surgeon (R.J.W.) case series at a tertiary level-1 trauma center. Institutional review board approval was obtained for this study. An institutional database was queried using Current Procedural Terminology codes 27495 and 27187 for patients from 2015 to 2022. The inclusion criteria were as follows: (1) diagnosis of FNSF based on radiological findings (Figure 1); (2) treatment with CMN; (3) performed by a single surgeon at a single institution; and (4) a minimum of 6-month follow-up. Patients who sustained pathologic fractures, avascular necrosis, or polytrauma were excluded.

Data Collection

Descriptive characteristics—including age, sex, and body mass index (BMI)—were recorded. Preoperative vitamin D levels were included when available. Injury characteristics—including presenting chief complaint, mechanism of injury, and fracture characteristics—were collected. Intraoperative specifics—including the type of CMN, the number and length of proximal and distal screws, and reported blood loss—were recorded. Intraoperative, postoperative, and radiographic complications were documented. Postoperative recovery course—including time to weightbearing as tolerated, time to weightbearing without an assistive device, and duration of narcotic use—was collected.

Statistical Analysis

Descriptive statistics were used to summarize the descriptive characteristics, clinical presentation, diagnostic imaging findings, treatment details, and follow-up outcomes of the study population. Categorical variables were reported as frequencies and percentages, while continuous variables were reported as means with standard deviations or medians with interquartile ranges, depending on their distribution.

RESULTS

A total of 14 patients (17 FNSFs) met the inclusion criteria. Three patients experienced bilateral FNSFs, and all 3 patients experienced the second fracture within 6 months of the first fracture. The cohort comprised a majority of female patients (n = 11; 79%), with a mean age of 28.2 ± 9.9 years (range, 16-49 years). All 14 patients were avid runners or recreation athletes. The BMI was available for 16 injuries and was distributed as healthy (18.5-24.9 kg/m^2) for 10 injuries, overweight (25-29.9 kg/m^2) for 5 injuries, and class 1 obesity (30-34.9 kg/m^2) for 1 injury. Seven injuries (41%) had diagnoses of femoroacetabular impingement (FAI) based on alpha angle measurement. One patient had bilateral FAI and dysplasia and underwent bilateral operations for FNSF (Table 1). Eleven patients had preoperative vitamin D levels recorded. Five of the eleven patients (45%) were receiving vitamin D supplementation before their operation. Three patients had a vitamin D level of <30 ng/mL.

All injuries were incomplete, compression-sided fractures that had either failed a course of nonoperative treatment or had discrete fracture lines visible on magnetic resonance imaging (MRI). Fifteen (88.2%) were repetitive

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Ethical approval for this study was obtained from the University Hospitals Institutional Review Board (reference No. STUDY20221509).

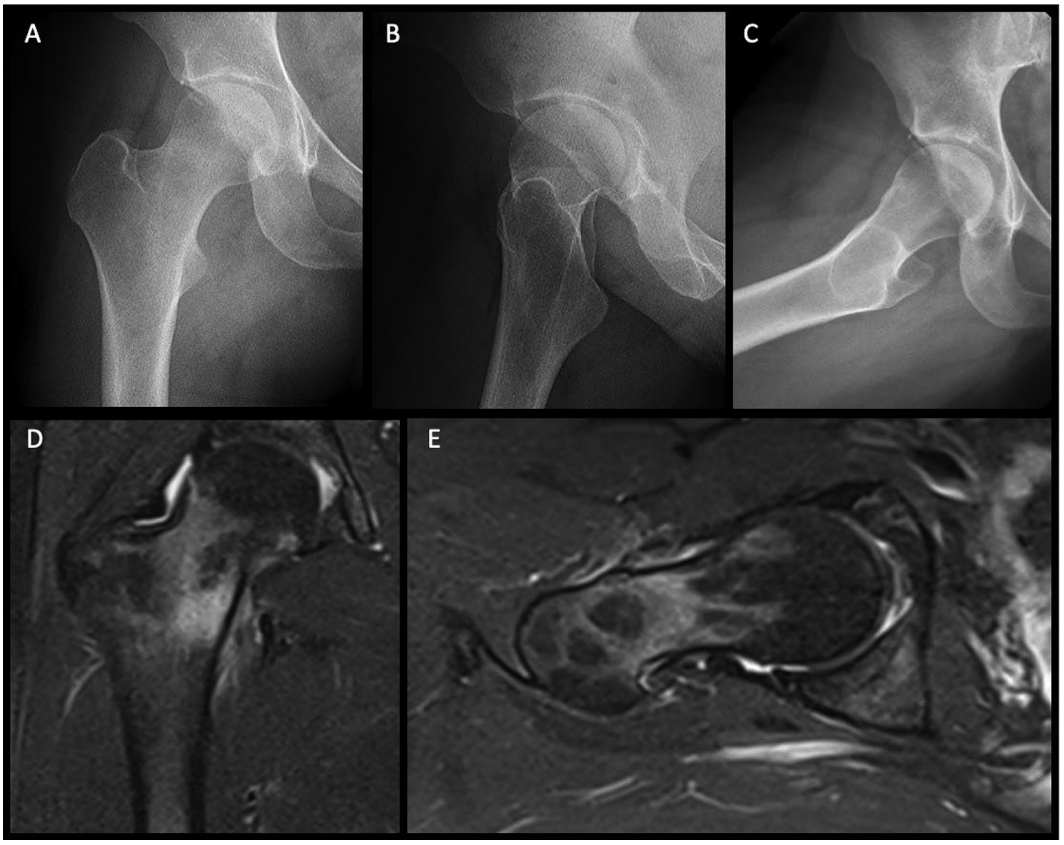

Figure 1. Imaging of a patient with a right-sided FNSF. Radiographs of a right femur: (A) anteroposterior view, (B) external rotation view, and (C) lateral view. T2-weighted fat-saturated MRI of a right femur: (D) coronal view and (E) axial view. An initial trial of nonoperative management failed in this patient, with an MRI demonstrating a femoral neck stress injury, with a nondisplaced fracture line on radiographs. FNSF, femoral neck stress fracture; MRI, magnetic resonance imaging.

stress injuries, with the patient reporting no identifiable likely moment of injury. One patient reported a popping sensation while on a rowing machine, while another felt a *pop* while running. At initial evaluation, 11 cases described a period of hip pain lasting >1 month with progressive worsening. Six of these patients had attempted nonoperative management consisting of activity modification and physical therapy before evaluation. The remaining patients were evaluated within 1 month of initial symptoms.

All injuries were treated with a piriformis fossa entry reconstruction CMN (T2 PF Alpha, Titanium alloy, Stryker), with 2 cephalomedullary lag screws across the femoral neck (Figure 2). All nails were placed using a percutaneous insertion technique under fluoroscopic guidance to minimize incision burden. A 3-cm incision was made proximal to the tip of the greater trochanter through the skin, subcutaneous tissue, and gluteal fascia. The length of the nail was determined by measuring a ball-tipped guide wire advanced to the distal femoral metaphysis. Nail diameter was determined via sequential reaming until an appropriate interference fit was obtained. The most frequently used nail diameter was 9 mm (n = 7 of 17; 41%), followed by 10 mm (n = 5; 29%) and 12 mm (n = 1; 6%), with a length ranging from 320 to 440 mm. These nails were statically locked distally using either 1 (n = 14; 82%) or 2 (n = 3; 16%) screws. The mean intraoperative blood loss was 67 mL (range, 20-150 mL). No intraoperative or early postoperative complications occurred—including no postoperative infections. One patient experienced a fall 2 days after the procedure, resulting in increased acute postoperative pain.

In all 17 FNSFs, immediate full weightbearing was recommended. All patients were able to initiate a return to running by 6 weeks postoperatively. Time until completion of narcotic use was noted for 15 injuries, with narcotic medications no longer required at 2 weeks for 12 injuries (71%), 6 weeks for 2 injuries (12%), and 3 months for 1 injury (5.9%) (Table 1). No hardware complications were noted on radiographic imaging.

The mean follow time was 12.4 months (range, 6-48 months). A minimum of 1 year of follow-up data were available for 8 injuries. Four patients reported pain at the site of the distal interlocking screw. One of these patients developed heterotopic bone over the distal interlocking screw site. Of those patients, 2 underwent symptomatic hardware removal. One patient reported anterior thigh pain that had progressively worsened over a few months and

TABLE 1
Patient demographics, treatment, and clinical outcome[a]

Patient	Age, y	Sex	Side Affected	Hip Issues	Nail Size, mm	Proximal/ Distal Screws	Blood Loss, mL	Time to No Narcotic Use	Notes at Latest Follow-up
1	16	M	R	FAI	10 × 440	2/1	20	<2 wk	1 y: pain at distal screw
2	17	F	R	None	9 × 340	2/1	25	<2 wk	9 mo: unremarkable
3, L	20	F	L	None	10 × 380	2/1	100	<2 wk	1.5 y: pain at distal screw
3, R	21	F	R	None	10 × 380	2/1	50	<2 wk	9 mo: pain at distal screw
4	20	F	L	FAI	9 × 380	2/2	25	<2 wk	6 mo: unremarkable
5, R	24	F	R	FAI + dysplasia	10 × 400	2/2	—	<2 wk	1 y: unremarkable
5, L	24	F	L	FAI + dysplasia	10 × 400	2/2	—	<3 mo	9 mo: unremarkable
6	24	F	R	None	9 × 380	2/1	100	<2 wk	6 mo: unremarkable
7	25	F	L	None	—	2/1	—	<2 wk	4 y: unremarkable
8	25	F	L	None	9 × 400	2/1	50	<2 wk	1 y: unremarkable
9	26	M	L	FAI	10 × 360	2/1	150	<2 wk	8 mo: pain at distal screw
10	31	F	R	None	9 × 360	2/1	50	<2 wk	8 mo: unremarkable
11, R	36	F	R	None	9 × 320	2/1	50	—	1.5 y: unremarkable
11, L	36	F	L	None	9 × 340	2/1	—	<6 wk	1 y: unremarkable
12	37	F	L	FAI	10 × 400	2/1	150	<3 mo	6 mo: unremarkable
13	48	M	R	None	12 × 380	2/1	75	<6 wk	1 y: gluteus medius tendinitis
14	49	F	L	FAI	—	2/1	25	<2 wk	6 mo: unremarkable
Overall	28.2 ± 9.4	15 F (88)	9 L (53)	NA	(9.5 ± 0.8) × (376 ± 29.5)	NA	66.9 ± 45.3	NA	11.5 ± 3.6 mo

[a]Data are presented as n (%) or mean ± SD. Dashes indicate data not included in operative reports. F, female; FAI, femoroacetabular impingement; L, left; M, male; NA, not applicable; R, right.

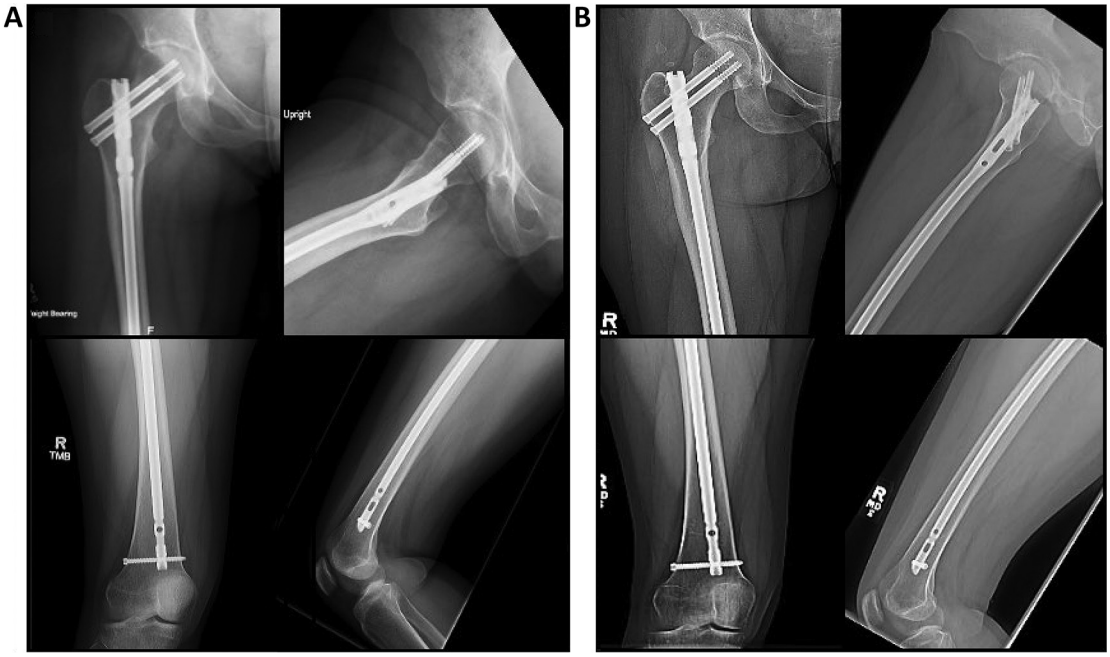

Figure 2. Radiographs from a patient taken (A) immediately after surgery utilizing piriformis entry CMN and (B) at the final follow-up (582 days). CMN, cephalomedullary nailing.

was radiographically diagnosed with gluteus medius tendinosis via MRI. The remaining patients had no issues reported at the final follow-up.

DISCUSSION

We presented the outcomes of a single surgeon's case series of prophylactically managed FNSFs using CMN. All 17 injury cases were allowed to immediately bear weight after the operation. In all cases, the patients had returned to their preinjury level of activity by 6 weeks. However, 5 hips had ongoing pain as a result of the surgery, requiring hardware removal in 2 hips. The series presented utilized long piriformis fossa entry CMNs. This was largely related to the diameters of available shorter CMNs on the market. As short CMNs are designed for use in geriatric intertrochanteric fractures, the nails have larger diameters, which remove a large portion of the bone in the metadiaphyseal region. Thus, the use of smaller diameter long nails maintains the healing potential near the site of pathology while creating control with an isthmic fit.

The available options for FNSF management originate from femoral neck fracture fixation options, which include cannulated screws, sliding hip screws (SHS), and proximal femoral plates.[4,7,8,13] Advances in technology and surgical technique have led to the novel use of CMNs for fixation of the femoral neck, as these fixed angle devices can transfer the loads encountered at the femoral neck to the shaft of the femur, providing enhanced mechanical stability.[2] In a comparative biomechanical analysis of unstable basicervical femoral neck fractures, Rupprecht et al[25] demonstrated that physiological weightbearing activities can be withstood after CMN fixation. Subsequently, a recent meta-analysis compared CMN with SHS constructs for the management of basicervical femoral neck fractures and demonstrated noninferiority of CMN, with no significant clinical or radiographic differences in the included 353 cases.[31] While historically limited to extracapsular femoral neck fractures, CMN fixation of intracapsular femoral neck fractures has been evaluated. Mir et al[23] assessed the outcomes of displaced intracapsular femoral neck fractures treated with a cephalomedullary device and found that this fixation performed well in patients <60 years with a midcervical fracture, demonstrating 100% of patients (6/6) healing without complications after a minimum 12-month follow-up.

The optimal fixation strategy for incomplete FNSFs has yet to be determined; however, most of these injuries that meet operative criteria are currently treated with multiple cannulated screw constructs. In a survey of 70 military orthopaedic surgeons, 92.86% (65/70) elected for a multiple cannulated screw construct for the management of nondisplaced and incomplete FNSFs.[6] Fullerton and Snowdy[14] described that compression-sided FNSFs display an oblique fracture pattern, which is biomechanically more stable than vertically oriented fractures and can be safely fixed with multiple cannulated screws. In support of this, Griffis et al[16] retrospectively reviewed a series of 53 active-duty military members with incomplete FNSFs treated with multiple cannulated screw constructs and demonstrated that this prophylactic fixation prevented progression to fracture completion in all cases after a mean follow-up of 25 months. Of note, the authors did not comment on the incidence of symptomatic hardware in this patient population. Despite the success rate in preventing fracture completion, the main disadvantage of cannulated screw fixation is the delayed return to full activity, which should be a primary goal in this cohort of patients. Typically, the postoperative protocol requires patients to remain nonweightbearing for 2 weeks, progressive weightbearing from weeks 2 through 12, and a return to run program starting at 12 weeks.[4]

The SHS is a fixed-angle construct with controlled collapse of the fracture allowing for compression at the fracture site with weightbearing often utilized in complete femoral neck fractures in young patients. Thus, the SHS is a biomechanically stable construct allowing immediate weightbearing; however, it also requires a significantly more extensive soft tissue dissection compared with cannulated screws or CMN. This exposure risks the development of iatrogenic postoperative pain, increased intraoperative blood loss, and weakness from muscle injury, in addition to the negative cosmetic impact of a larger incision relative to percutaneous incisions. Therefore, this technique is largely limited to complete femoral neck fracture requiring direct visualization and anatomic reduction.

CMNs are advantageous over cannulated screws for the treatment of FNSFs in athletes because of their increased biomechanical stability as a load-sharing implant and the resultant ability to fully bear weight immediately after surgery.[2] In our cohort, all patients were able to bear weight as tolerated immediately postoperatively, which led to a rapid return to activity with initiation of running 6 weeks after surgery. The ability for an immediate return to full weightbearing may translate to a faster return to play, less muscular atrophy from inactivity, and a higher rate of return to previous activity relative to other fixation constructs; however, further examination with larger patient cohorts is required. Although somewhat more invasive than percutaneous cannulated screw fixation, CMNs have been associated with minimal intraoperative blood loss, short operative times, and a low infection rate.[12] Cannulated screws have also been associated with the creation of a stress riser in the subtrochanteric region of the femur, which can progress to fracture, and this risk is avoided with the use of CMN.[17] A known complication of CMN includes disruption of the hip abductors and external rotators, which has been described to cause postoperative morbidity.[3,9,10] In our series, 1 patient was diagnosed with a gluteus medius tendinosis that was managed with progressive physical therapy. The most common complication in our cohort was pain at the site of the distal interlocking screw. Although not available to discuss within this cohort of patients, this complication potentially could be avoided by placing the CMN without the distal locking screw, as it does not impact fracture stability with adequate isthmic fit. Overall, a shared decision should be made between the patient and the surgeon regarding the benefits of early weightbearing weighed against the potential disadvantages of symptomatic hardware and abductor muscle pain when using this technique.

Limitations

The limitations of this study are secondary to the observational nature of this study. This was a case series from a single surgeon reporting favorable outcomes for treatment FNSFs using CMN. Therefore, we were limited by the available patients presenting with the condition fitting the study inclusion criteria. In addition, as CMN fixation was our preferred method because of the immediate weightbearing, we did not have a comparison cohort available.

CONCLUSION

This study demonstrated that prophylactic fixation of FNSFs with CMN in endurance athletes is a safe and effective construct that permits early return to baseline impact activity because of the inherent stability of the construct with a favorable complication profile—although with a 30% rate of persistent pain from the surgical site. While the results from this series are from a fellowship-trained orthopaedic traumatologist, the CMN technique is a commonly performed orthopaedic technique that can be utilized by providers of many levels. Overall, this proof of concept series demonstrated the ability to use this technique within the study cohort.

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