The effect of patient, fracture and surgery on outcomes of high energy neck of femur fractures in patients aged 15-50

Wayne Hoskins PhD[1,2]

Johnny Rayner MBBS[3]

Rohan Sheehy MBBS[3]

Harry Claireaux MBChB[4,5]

Roger Bingham, FRACS[1,3]

Roselyn Santos[6]

Andrew Bucknill FRCS[3]

Richard N de Steiger FRACS[7,8]

Xavier Griffin PhD[4,5]

1. Traumaplasty.Melbourne
   East Melbourne, Victoria Australia
2. Faculty of Medicine, Dentistry and Health Sciences
   The University of Melbourne
   Parkville, Victoria Australia
3. Department of Orthopaedic Surgery
   Royal Melbourne Hospital
   Parkville, Victoria Australia
4. Nuffield Department of Orthopaedics
   University of Oxford
   Oxford, United Kingdom
5. John Radcliffe Hospital

Oxford University Hospitals NHS Trust
Headington, Oxford United Kingdom

6. Trauma Service
Royal Melbourne Hospital
Parkville, Victoria Australia
7. Epworth Healthcare, University of Melbourne
Australian Orthopaedic Association National Joint Replacement Registry
Adelaide, South Australia Australia
8. Australian Orthopaedic Association National Joint Replacement Registry
Adelaide, South Australia Australia

Please address all correspondence to:

Name: Wayne Hoskins

Address: Royal Melbourne Hospital, Grattan St, Parkville VIC 3052 Australia

Phone: +613 9342 8479

Fax: +613 9342 8780

Email: waynehoskins@icloud.com

Acknowledgements

The authors would like to acknowledge the Royal Melbourne Hospital Trauma Registry and the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) for the generous assistance provided in this study. The final version of this paper has been prepared in collaboration with the Royal Melbourne Hospital Trauma Registry and AOANJRR.

The research was supported by the National Institute for Health Research (NIHR) Oxford Biomedical Research Centre (BRC)

The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health.

Conflict of Interest and Source of Funding

None declared.

Abstract

Objectives

To define the effects of patient, fracture and surgical factors on the outcome of high-energy femoral neck fractures in patients aged from 15-50.

Design

A retrospective review of a prospectively recorded database. Minimum follow-up was 18 months.

Setting

Level 1 Trauma Center.

Participants

32 patients meeting the inclusion criteria were identified between January 2008 and July 2015.

Intervention

Surgically managed fractures.

Main Outcome Measurements

The primary outcome measures were the development of osteonecrosis or non-union leading to total hip arthroplasty (THA). Secondary outcome measures were osteotomy or other surgical procedures, surgical complications, quality of reduction, malunion and the IHOT12 and EQ-5D.

Results

The mean follow-up was 58.5 months (range 980-3048 days) Three of the 32 patients (9.4%) required THA. No other surgical procedures were performed. None of the 29 other patients developed radiologically apparent osteonecrosis. Fracture type, displacement, anatomical reduction and fixation type were not statistically significant risk factors effecting these outcomes. For all patients, an average of 8% loss of femoral neck height and 10% femoral neck offset were seen.

Conclusions

At a mean 4.9 year follow-up, the incidence of high-energy femoral neck fractures leading to THA was 9.4%, as a consequence of osteonecrosis or non-union. Mal-union was common. The long term functional consequences of high energy femoral neck fractures remain poorly understood. Longer term analysis of the patients in this study may provide a better understanding of the natural history, and clarify the importance of anatomical reduction, and the role of anatomical reduction of these fractures.

Level of Evidence

Therapeutic Level III

Key words: Femur, Hip Fractures, Trauma, Young

Introduction

Femoral neck fractures in young adults are relatively rare, accounting for 3% of all hip fractures[1], and are typically associated with high-energy mechanisms and poly-trauma[2,3]. Neck fractures in young adults have long been considered an orthopaedic emergency, due to the risk of osteonecrosis and subsequent morbidity[4]. Other complications such as non-union and mal-union are not infrequent, and nearly one in five patients will require re-operation[5]. Functional results can be poor[6], particularly if femoral neck shortening occurs[7,8].

Patient, fracture and surgical factors may all contribute to outcome[9]. High energy femoral neck fractures tend to be comminuted[10] and displaced in up to 80% of cases[1]. Vertical fracture patterns are unstable, and may lead to failure of fixation or mal-union[11-13]. The younger patient age mandates that surgical treatment preserves the native femoral head wherever possible[14]. A range of fixation devices has been described[12,15], yet various studies have not identified the ideal treatment strategy[9,16], and a failure of fixation has been seen with all implants and techniques[12,15].

The surgical management of high energy femoral neck fractures is challenging[10], and traditional teaching suggests that early surgical fixation is required. The relationship between surgical timing and the risk of osteonecrosis has not been confirmed[1,6]. It is thought that anatomical reduction is essential to preventing osteonecrosis, non-union and mal-union[12], although previous studies have not clearly made this correlation[1]. Achieving an anatomical reduction is often difficult, and fractures may collapse, and produce shortening of the femoral neck or varus neck posture[10]. It is unclear whether closed reduction of the fracture is adequate, or whether open reduction is necessary[5,12]. Likewise, if the fracture is anatomically reduced, it is unclear what type of fixation device can best maintain this reduction[14].

Orthopaedic literature has differed in its definition of the young patient, with study methodologies considering either 50[1], or 60[5] as the upper limit of young. A physiological rather than a biological definition has been proposed[16], but seems difficult to objectively quantify. Studies typically do not have a uniform distribution of patients age, with up to two thirds of patients aged in the latter decade of the age group being considered[9]. Most studies have shown a heterogeneity in injury mechanism and do not exclude low energy trauma[6,7,9,11,12,17]. These factors may impact the validity of extrapolating the prognosis and outcomes of femoral neck fractures, when only considering at the age group up to 50 years, and those suffering high energy fractures.

The low incidence of neck of femur fractures in young adults makes it difficult to achieve an appropriately powered randomised controlled trial, even across multi-centre studies[6]. Population based studies that correlate the results of trauma registries and joint replacement registries, may be the best way to identify any correlation between the management of traumatic injury, and its long-term outcomes. The aim of this study is to assess the effect of patient, fracture and surgical factors on the outcome of high energy femoral neck fractures in young patients aged between 15-50. Specifically, this study aims to identify the rate of re-operation, in particular, the incidence that the treatment of high energy femoral neck fractures leads to subsequent total hip arthroplasty (THA).

Materials and Methods

A retrospective review was performed of all patients aged between 15 to 50 years that received surgical management for a femoral neck fracture at a Level 1 Trauma Center during the period of January 2008 to July 2015. Data was sourced from a prospectively recorded trauma database, the Royal Melbourne Hospital (RMH) Trauma Registry. Patients were identified using Abbreviated Injury Scale (AIS) codes for neck of femur fractures and cross checked with the Orthopaedic Department's electronic database. Patients with extra-capsular neck of femur fractures, low energy fractures (defined as a fall <1m in height), pathological fractures, patients with conditions adversely affecting bone density, or alcoholism were excluded from the study, based upon the findings of Robinson et al.[18]. Clinical and radiological reviews were performed. Minimum follow up was 18 months. The RMH Trauma Registry, RMH Orthopaedic database and patient records were sourced to record information on patient demographics, co-morbidities, injury details, mechanism, ambulance and transfer details and injury severity score (ISS). Pre-operative plain radiographs were used to classify fractures using the AO / OTA (Arbeitsgemeinschaft Osteosynthese / Orthopaedic Trauma Association) fracture classification system. Fractures were classified as displaced or undisplaced[11], and the fracture verticality was measured using Pauwels Classification[10]. The time to theatre after presentation to the emergency department was recorded, as were the details of surgical treatment, including reduction method (open or closed), fixation device(s) used, and the quality of fracture reduction (displaced or undisplaced/anatomical) seen on the first available post-operative radiograph. Patients were classified as major trauma with an ISS above 12, ICU admission requiring mechanical ventilation of more than 24 hours, or urgent surgery under 48 hours for intracranial / intrathoracic / intra-abdominal injury, or fixation of pelvic or spinal fractures. Final radiological imaging was reviewed to determine the presence of osteonecrosis and classified using the Steinberg classification (modified Ficat and Arlet)[19]. All classifications and radiographic measurements were performed by two authors to ensure accuracy (RS and JR).

The primary outcome measure was the development of osteonecrosis or non-union requiring THA. Patient data was cross referenced with the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR). The AOANJRR includes information on all arthroplasty procedures performed within Australia. The RMH Orthopaedic database, RMH radiology database, a separate radiological database incorporating a number of other public and private hospitals and patient files were cross checked to maximise data quality. All available relevant radiological imaging were reviewed for each case.

Secondary outcome measures were osteotomy or other secondary surgical procedure, surgical complications, fracture mal-union measured as loss of femoral horizontal offset and vertical neck length recorded on the most recent post-operative imaging as a percentage of loss compared with the opposite side. Horizontal offset was measured as the perpendicular distance from the centre of the femoral head to a line forming the centre of the femoral canal. Vertical neck length was measured as the perpendicular distance from the centre of the femoral head to a line forming the inferior aspect of the lesser trochanter. The duration of radiological follow up was recorded as the time to the final available radiograph, computer tomography, nuclear medicine or magnetic resonance scan. The International Hip Outcome Tool (IHOT12) and EuroQol EQ-5D were used as patient reported outcome measures and performed via telephone follow up. A sub group analysis was made between patients with anatomical reduction and non-anatomical reduction with regards to the development of mal-union. Approval was received from the RMH Human Research and Ethics Committee: QA2015116.

Statistical analyses were performed using R 3.2.1 (R Foundation for Statistical Computing, Vienna, Austria). Data was summarised using mean and standard deviations or frequencies for continuous and categorical data, respectively. Fisher's exact test was used to compare differences among categorical variables and analysis of variance (ANOVA) was used to compare mean differences across continuous variables. For comparison of anatomical and non-anatomical reduction on mal-union Wilcoxon rank-sum test was used comparing categorical predictor variable with continuous outcome variable (following categorisation of data as non-parametric by Shapiro-Wilk test). Statistical significance was ascribed when the p value was <0.05.

Results

Fifty-three patients were identified over the 7.5 year duration of the study, 21 of which were excluded for extracapsular fractures or low energy trauma, leaving 32 patients for analysis. Descriptive statistics outlining patient characteristics and outcomes for continuous variables is shown in table 1. The mean follow up period was 58.5 months (range 980-3048 days).

Three of 32 patients (9.4%) developed osteonecrosis or non-union leading to THA. No osteotomies nor other surgical procedures were performed. There were no radiological cases of osteonecrosis in patients who did not have THA. 29 of 32 patients (90.6%) were male. 10 of 32 patients (31.3%) were involved in a major trauma. 16 of 32 patients (50%) had an isolated neck of femur fracture. In terms of the AO-OTA fracture classification, 14 of 32 (43.8%) were 31-B1, 11 of 32 (34.4%) were 31-B2, and 7 of 32 (21.9%) were 31-B3 fractures respectively. 21 of 32 fractures (65.6%) were displaced. Closed reduction was performed in 29 of 32 patents (90.6%). Cannulated screws were used in 13 of 32 patients (40.6%), a sliding hip screw (with or without anti-rotation screw) was used in 14 of 32 patients (43.8%), and 5 of 32 patients (15.6%) were treated with a cephalomedullary device. Reduction was graded as anatomical in 21 of 32 patients (65.5%), and displaced in 10 of 32 (31.3%) patients; data on this variable was missing in 1 patient. Only 3 patients were contactable for follow up of the IHOT and 5Q-ED.

There was no association between development of osteonecrosis or non-union requiring THA and: age (P=0.14), injury severity score (P=0.37), time to theatre (P=0.56), gender (P=0.81), suffering major trauma (P=0.19), fracture class (P=0.87), fracture displacement (P=0.49), operative type (open vs closed) (=1), fixation method (P=0.56), or quality of reduction (P=0.30).

There was no association between the quality of reduction attained and: fixation method (P=0.30), operative type (open vs closed) (P=1), fracture displacement (P=0.055), or fracture class (P=0.36).

Quality of reduction was not associated with malunion as defined by either offset loss (P=0.74) or length loss (P=0.79).

Three patients completed the patient reported outcome measures, this was not included in the analysis.

Discussion

This study showed the rate of THA following high energy femoral neck fracture in patients aged 15-50 was 9.4% at a mean follow up period of 58.5 months. This rate is lower than reported in similar studies, and comes despite fact that two thirds of fractures were displaced, and one third of patients had sustained major trauma. Only half had sustained the femoral neck fracture as an isolated injury. In patients who did not undergo THA, no other surgical procedures occurred, nor was there radiological evidence of osteonecrosis. No statistical difference was found for sex, age, major trauma involvement, ISS, fracture classification, fracture displacement, method of reduction, fixation type, quality of reduction or time to theatre as being risk factors for THA. The quality of reduction did not statistically affect the rate of mal-union.

Liporace et al.'s[12] series of low and high energy Pauwels 3 fracture types in patients aged up to 64 had a 12.9% conversion rate to arthroplasty, which is similar to the 9.4% in our study. The conversion to THA has been neglected in the majority of orthopaedic literature on young neck of femur fractures. A meta-analysis of 564 patients aged 50 or under found a 23.0% incidence of osteonecrosis and 8.9% non-union[1]. It is unknown what percent of these patients went on to require arthroplasty. Our study excluded patients with co-morbidities that affect bone biology[20-22], which may have contributed to the low rate of osteonecrosis and non-union. Femoral neck fractures in young patients from low energy trauma can occur[23-25] secondary to medical comorbidities[3,16]. High energy fractures tend to be more comminuted[10], yet this study suggests the outcome and prognosis for fractures sustained from high energy mechanisms in a healthy cohort may be different, as has been suggested[12]. Cadaver studies have shown a correlation between bone density and fixation stability[26]. Parker et al.[27] also found the incidence of non-union to be age dependent, with a non-union rate of 5.2% in patients younger than 50 years compared to 24.9% for patients in their 70s.

The time to surgery has long been considered important for the development of osteonecrosis. 90% of cases in this study were operated on in under 24 hours from presentation, 40% within 12 hours, and 20% within 6 hours. None of the patients with greater than 24 hours wait until theatre ultimately went on to undergo THA. Liporace et al.'s[12] series from a Level 1 Trauma Center had every patient treated within 24 hours, however their rate of major trauma was lower and 70% of patients had an isolated injury. This study supports previous literature in that femoral neck fractures in young patients can by treated urgently and not emergently[28]. The most consistent variable in the surgeon's control is the quality of the fracture reduction[29-30]**.** Time spent on surgical planning, fracture reduction and fixation technique, with a suitable orthopaedic operative team, should occur at the expense of rushing a patient to theatre for a perceived time to avoid osteonecrosis.

Although not as devastating as osteonecrosis or non-union, the occurrence of mal-fixation and mal-union may be a factor which produces substantial morbidity. This outcome has been sparingly considered by other studies. Slobogean et al.[31] followed

107 patients aged 18 to 55 for 1 year, and found a poor quality of fracture reduction was associated with a lower physical component score of the SF-36, with mal-union trending towards a lower score (p=0.08). The retrospective design of this study did not allow the analysis of patient reported functional and quality of life scores. The mal-union of femoral neck fractures can take various forms[14], most notably femoral neck shortening. Upadhya et al.[7], found the average femoral neck shortening to be 18mm. This study showed one in three patients to have 10% of greater loss of vertical neck length producing varus femoral neck posture, which increases the shear forces through the femoral neck, which can affect implant fixation[32] and decrease the likelihood of bone formation[15]. Femoral neck shortening of more than 5 mm is associated with decreased functional outcomes and an increased incidence of requiring a gait aid[8]. This study showed 40% of patients to have 10% or greater loss of horizontal femoral offset which decreases the moment arm of the abductor muscles, and has a pronounced effect on gait[33]. Despite femoral head preservation, it results in lower physical functioning scores[8]. These biomechanical deformities cannot be overcome with osteotomy procedures. Techniques have been described to stabilise an unstable femoral neck fracture with a length stable construct[34]. Such rigid constructs have been associated with their own spectrum of complications including loss of implant fixation, femoral head penetration and implant fracture[35]. Our study found the outcome measures were independent of implant design.

This study showed an anatomical reduction in 65.5% of patients, which compares to 75% of patients in the study by Slobogean et al.[31] which also included low energy fractures. Complication rates are higher with anatomically imperfect reductions of femoral neck fractures[12,36]. Haidekewych et al.[11] found a complication rate of 80% in patients with >10mm of displacement and/or >20 degrees of angulation or any varus fracture reduction, and Liporace et al.[12] found that 2/3 of fractures with >5-10mm of displacement and/or >10-20 degrees of angulation developed non-union. Stability may be affected more by the reduction than by the design of the implants used and the technique of application[32,37]

Controversy exists as to how best to achieve an anatomical reduction. A number of open techniques can be successful at achieving good reduction[14,38,39]. The incidence of open reduction in the literature ranges from 17.7%-47.8%[7,11,12]. Unfortunately these studies did not report on the difference in outcome between open and closed reduction. In this study only 9.4% of cases had open reduction, and none of these patients went on to have THA. It remains unproven whether open techniques produce a more anatomical reduction or decrease mal-union. Even with anatomical reduction, when comminution is present, modern implant devices may not be able to maintain fracture reduction[14]. In patients aged 60 or younger, the incidence of non-union has been found to be higher with open rather than closed reduction (11.2% vs. 4.7%)[5]. This is likely confounded by fracture displacement, inability to reduce the fracture closed and the decision to open the fracture[12]. However, osteonecrosis has been found to be more common in fractures that underwent closed rather than open reduction (28.0% vs. 10.1%)[5]. The requirement for open reduction may warrant further consideration since fellowship trained traumatologists can only identify a mal-reduction 67% of the time on intra-operative fluoroscopy (M. Graves, MD, unpublished data, October 2013). Open reduction allows direct visualisation of the reduction, reduces intracapsular haematoma[3], minimises the risk of multiple closed reduction attempts and allows augmented fixation if required. This study suggests that open reduction of displaced femoral neck fractures in young patients with a high-energy injury mechanism is not associated with additional complications.

Along with comminution, vertical fracture patterns are associated with an increased risk of fixation failure, mal-union, nonunion, and osteonecrosis[28]. This study did not find a relationship between fracture verticality and outcome, other studies have shown this may lead to failure of fixation and mal-union[10-13]. Alternative implants and constructs have been proposed for vertical fracture patterns[40]. Further research is required to identify stable implant constructs that can maintain reduction in the face of comminution and fracture verticality.

This study cross references data with the AOANJRR to identify patients who may have subsequently undergone hip arthroplasty. The challenge of long term follow up of this patient population has been discussed[11]. The mean follow up for this study was almost five years. Most complications of femoral neck fracture are apparent within 2 years[41]. Our follow up time period was longer than most other studies, however, ongoing follow up with the AOANJRR will allow longer term data to be analysed to determine the true natural history of these injuries. A homogeneous patient population was seen in this study, given the exclusion of low energy trauma, medical co-morbidities and those aged over 50 years. A relationship between high-energy trauma and development of osteonecrosis exists[2]. To our knowledge, this is the first study to exclusively look at high energy fractures in young patients. Future studies should include similar inclusion and exclusion criteria so that pooling of data can occur.

Limitations of this study include the low patient numbers and limited statistical analysis, although the sample size was similar to other studies of the same demographic[1]. The majority of injured patients included in studies of femoral neck fractures are from low energy mechanisms[9]. The rarity of high energy femoral neck fractures in young patients means that achieving an appropriately powered study is extremely challenging. A study over 25 years at a Level 1 Trauma centre in patients up to 50 years recruited only 83 participants[11]. A prospective study design with multi-centre recruitment, that included cross referencing with a national joint replacement registry would provide better information to guide surgical decision making and management decisions. Subsequent surgical procedures may have been performed at other hospitals, and we attempted to avoid this by searching radiological databases that included other public and private hospitals. Osteonecrosis may have developed outside the follow up period of this study, yet not all patients with this condition will require THA[42].

Conclusion

Young patients with high energy femoral neck fractures uncommonly require subsequent THA, with the incidence after 5 years being 9.4%. Mal-union is common with 40% of patients having 10% or greater loss of horizontal femoral offset and one in 3 having 10% or greater loss of vertical neck length. The functional and long term consequences of this are poorly understood. Ongoing follow up of this study will allow a better understanding of the natural history of this condition. The main factor under the control of a surgeon is quality of reduction. Further consideration should be given to open reduction techniques to improve the quality of reduction.

References

1. Damany DS, Parker MJ, Chojnowski A. Complications after intracapsular hip fractures in young adults A meta-analysis of 18 published studies involving 564 fractures. Injury. 2005;36:131-141 .
2. Protzman R, Burkhalter W. Femoral-neck fractures in young adults. J Bone Joint Surg Am. 1976;58:689–695.
3. Swiontkowski MF, Winquist RA, Hansen ST. Fractures of the femoral neck in patients between the ages of twelve and forty-nine years. J Bone Joint Surg (Am). 1984;66-A(6):837-846.
4. Swiontkowski MF. Intracapsular fractures of the hip. J Bone Joint Surg Am. 1994;76:129–38.
5. Slobogean GP, Sprague SA, Scott T, et al. Complications following young femoral neck fractures. Injury. 2015;46:484-491
6. Jain R, Koo M, Kreder HJ, et al. Comparison of early and delayed fixation of subcapital fractures in patients sixty years of age or less. J Bone Joint Surg Am 2002;84-A:1605—12.
7. Upadhyay A, Jain P, Mishra P, et al. Delayed internal fixation of fractures of the neck of the femur in young adults: a prospective, randomised study comparing closed and open reduction. J Bone Joint Surg (Br). 200;86-B:1035-40.
8. Zlowodzki M, Brink O, Switzer J, et al. The effect of shortening and varus collapse of the femoral neck on function after fixation of intra- capsular fracture of the hip: a multi-centre cohort study. J Bone Joint Surg Br. 2008;90:1487–1494.

9. Duckworth AD, Bennet SJ, Aderinto J, et al. Fixation of intracapsular fractures of the femoral neck in young patients: risk factors for failure. J Bone Joint Surg (Br). 2011;93-B:811-16.

10. Collinge CA, Mir H, Reddix R. Fracture morphology of high shear angle "vertical" femoral neck fractures in young adult patients. J Orthop Trauma. 2014;28(5):270-5.

11. Haidukewych G, Rothwell W, Jacofsky D, et al. Operative treatment of femoral neck fractures in patients between the ages of fifteen and fifty years. J Bone Joint Surg Am. 2004;86-A:1711–1716.

12. Liporace F, Gaines R, Collinge C, et al. Results of internal fixation of Pauwels type-3 vertical femoral neck fractures. J Bone Joint Surg Am. 2008;90:1654–1659.

13. Weil Y, Khoury A, Zuaiter I, et al. Femoral neck shortening and varus collapse after navigated fixation of intracapsular femoral neck fractures. J Orthop Trauma. 2012;26:19–23.

14. Della Rocca GJ. Gaps and opportunities in the management of the young femoral neck fracture. Injury. 2015;46:515-518.

15. Forsh DA, Ferguson TA. Contemporary management of femoral neck fractures: the young and the old. Curr Rev Musculoskelet Med. 2012;5(3):214-221

16. Pauyo T, Drager J, Albers A, et al. Management of femoral neck fractures in the young patient: A critical analysis review. World J Orthop. 2014;5(3):204-217.

17. Razik F, Alexopoulos AS, El-Osta B, et al. Time to internal fixation of femoral neck fractures in patients under sixty years—does this matter in the development of osteonecrosis of femoral head? Int Orthop. 2012;36(10):2127-2132

18. Robinson CM, Court-Brown CM, McQueen MM, et al. Hip fractures in adults younger than 50 years of age. Epidemiology and results. Clin Orthop Relat Res. 1995;(312):238–246.

19. Mont MA, Marulanda GA, Jones LC, et al. Systematic analysis of classification systems for osteonecrosis of the femoral head. J Bone Joint Surg Am. 2006;88(Suppl 3):16–26.

20. Brinker MR, O'Connor DP, Monla YT, et al. Metabolic and endocrine abnormalities in patients with nonunions. J Orthop Trauma 2007;21:557–70.

21. Loizou CL, Parker MJ. Avascular necrosis after internal fixation of intracapsular hip fractures; a study of the outcome for 1023 patients. Injury. 2009;40(11):1143-6.

22. Schweitzer D, Melero P, Zylberberg A, et al. Factors associated with avascular necrosis of the femoral head and nonunion in patients younger than 65 years with displaced femoral neck fractures treated with reduction and internal fixation. Eur J Orthop Surg Traumatol. 2013;23(1):61-5

23. Zetterberg CH, Irstam L, Andersson GB. Femoral neck fractures in young adults. Acta Orthop Scand. 1982;53:427–435.

24. Al-Ani AN, Neander G, Samuelsson B, et al. Risk factors for osteoporosis are common in young and middle-aged patients with femoral neck fractures

regardless of trauma mechanism. Acta Orthop. 2013;84:54–59.

25. Boden SD, Labropoulos P, Saunders R. Hip fractures in young patients: is this early osteoporosis? Calcif Tissue Int. 1990;46:65–72.

26. Hedstrom M. Are patients with a nonunion after a femoral neck fracture more osteoporotic than others? BMD measurement before the choice of treatment? A pilot study of hip BMD and biochemical bone markers in patients with femoral neck fractures. Acta Orthop Scand. 2004;75:50–52.

27. Parker MJ, Raghavan R, Gurusamy K. Incidence of fracture-healing complications after femoral neck fractures. Clin Orthop Relat Res. 2007;458:175-9.

28. Ly TV, Swiontkowski MF. Management of femoral neck fractures in young adults. Indian J Orthop. 2008;42(1):3-12.

29. Bosch U, Schreiber T, Krettek C. Reduction and fixation of displaced intracapsular fractures of the proximal femur. Clin Orthop Relat Res. 2002;399:59–71.

30. Conn KS, Parker MJ. Undisplaced intracapsular hip fractures: results of internal fixation in 375 patients. Clin Orthop Relat Res. 2004;421:249–254.

31. Slobogean GP, Stockton DJ, Zeng B, et al. Femoral neck fractures in adults treated with internal fixation: a prospective multicenter Chinese cohort. J Am Acad Orthop Surg. 2017;25:297-303.

32. Chua D, Jaglal SB, Schatzker J. Predictors of early failure of fixation in the treatment of displacedd subcapital hip fractures. J Orthop Trauma 1998;12:230-4. 19.

33. Zielinski SM, Keijers NL, Praet SF, et al. Femoral neck shortening after internal fixation of a femoral neck fracture. Orthopedics 2013;36:e849–58.

34. Boraiah S, Paul O, Hammoud S, et al. Predictable healing of femoral neck fractures treated with intraoperative compression and length-stable implants. J Trauma 2010;69:142–7.

35. Hoshino CM, O'Toole RV. Fixed angle devices versus multiple cancellous screws: what does the evidence tell us? Injury. 2015;46(3):474-7.

36. Huang HK, Su YP, Chen CM, et al. Displaced femoral neck fractures in young adults treated with closed reduction and internal fixation. Orthopedics 2010;33:873.

37. Krischak G, Beck A, Wachter N, et al. Relevance of primary reduction for the clinical outcome of femoral neck fractures treated with cancellous screws. Arch Orthop Trauma Surg. 2003;123(8):404-9.

38. Molnar RB, Routt Jr ML. Open reduction of intracapsular hip fractures using a modified Smith-Petersen surgical exposure. J Orthop Trauma 2007;21:490–4.

39. Davidovitch RI, Jordan CJ, Egol LA, et al. Challenges in the treatment of femoral neck fractures in the nonelderly adult. J Trauma. 2010;68:236-242.

40. Mir H, Collinge C. Application of a medial buttress plate may prevent many treatment failures seen after fixation of vertical femoral neck fractures in young adults. Med Hypotheses. 2015;84(5):429-33.

41. Bachiller FG, Caballer AP, Portal LF. Avascular necrosis of the femoral head after femoral neck fracture. Clin Orthop Relat Res. 2002;399:87-109 .

42. Nikolopoulos KE, Papadakis SA, Kateros KT, et al. Long-term outcome of patients with avascular necrosis, after internal fixation of femoral neck fractures. Injury. 2003;34(7):525-8.

Tables

Table 1. Descriptive statistics outlining patient characteristics and outcomes for continuous variables.

	Age	Injury Severity Score (ISS)	Time to theatre (h)	Pauwels Angle (deg)	Offset loss (%)	Neck length loss (%)	FU duration (mo)	Radiological FU duration (mo)
Mean	38.4	13.1	18.5	55.4	0.21	0.19	59.3	7.8
SD	8.5	8.2	20.3	17.1	0.31	0.31	20	9.8