# The relationship between femoral neck fracture in adult and avascular necrosis and nonunion: A retrospective study

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ABSTRACT

*Background:* One of the most serious sequelae of femoral neck fractures (FNFs) is avascular necrosis (AVN), and this complication translates to significant morbidity and mortality. This study was conducted to determine the relationship between the etiologies and management of FNFs at our institution and the development of AVN or nonunion.

*Materials and methods:* This study was a retrospective medical chart review of all adult patients admitted and managed for FNF.

*Results:* There were a total of 69 FNF patients reviewed. FNF was caused by a fall in 37 patients (53.6%), a road traffic accident in 16 (23.2%), motorcycle and motorbike accidents in 8 (11.6%), and heavy exercise in 8 (11.6%). Twenty-four patients (34.8%) had fixation within 24 h of injury, and 45 (65.2%) went more than 24 h before fixation. The mean RUSH score at 6 months was 21.4 ± 5.1. There were 4 patients (5.8%) with a collapsed FNF and 4 patients (5.8%) had a nonunion FNF. AVN was documented in 12 patients (17.4%). Of the 12 patients who had AVN, 8 (66.7%) received fixation within 24 h from the time of the injury, whereas only 4 (33.3%) received fixation more than 24 h after the injury. There was a significant negative correlation between the time of fixation and AVN.

*Conclusion:* We report a 17.4% incidence of AVN over 10 years in patients managed with FNF. AVN was found to be significantly correlated with the mode of injury (fall and RTA among younger male patients).

## 1. Introduction

Femoral neck fractures (FNFs) are fractures of the flattened pyramidal bone connecting the femoral head and the femoral shaft. It is not common in healthy individuals but common among athletes, military recruits, and young adults because of high energy activities such as sports and road traffic accidents, in adults because of falls, in women because of estrogen imbalances, and in patients because of bone mineralization and deficiencies [1–4]. In the USA in 2013, there were a reported 146 cases per 100,000 people [5]. Mortality can be as high as 30% in one year, particularly if treatment is delayed over 24 h [6].

FNFs are classified using the Garden Classification of anteroposterior radiographs into Types I to IV, where Type I is incomplete fracture, Type II is complete but non-displaced fracture, Type III is complete and partially displaced fracture and Type IV is complete and fully displaced femur [7]. Another classification is Pauwel's classification, which is a biomechanical classification based on the vertical orientation of the fracture line and is commonly used to determine the appropriate treatment for FNFs, particularly among younger adults [8].

The radiographic union score for the hip (RUSH) is a score system used to describe healing of femoral neck fractures, particularly among patients who might require additional surgery, and patients with a 6-month RUSH score < 18 have a greater probability of undergoing re-operation [9].

Surgical management of FNFs includes open reduction and internal fixation (ORIF), which has some fixation failures [10], primary total hip arthroplasty (TA), which is cost-effective for displaced FNFs in patients 45–65 years old [10], cannulated screw (CS) fixation for young and middle-aged patients [11], dynamic hip screw fixation (DHS) [12], and hemiarthroplasty [13]. The decision of what type of surgical management to use depends on several factors, including displacement of the femoral neck, presence of hip joint arthritis, age, and other factors [14]. Approximately 24% of patients who had THA underwent revision within 5 years because of aseptic loosening, infection and other causes [15]. Some surgeons, however, prefer ORIF and some prefer THA for displaced FNFs, particularly among active older patients with Garden Type III fracture [16]. A case of peritrochanteric fracture was also reported to be successfully operated with a dynamic interlocking

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trochanteric gamma nail [17].

One of the most serious sequelae of FNFs is avascular necrosis (AVN), which occurs in 10–45% of patients with FNFs, particularly those who have displaced and nonunion FNFs [18]. Nonunion occurs in almost 20% of FNFs and is more common in men than women, and common with increasing age [19]. Approximately 33% of displaced FNFs are associated with complications [20]. One study showed that age and type of fixation are not significantly correlated with the incidence of AVN, but the amount of vascular damage at the time of the fracture determines the development of vascular necrosis [21]. On the other hand, a separate study showed that fracture type and age are the most significant predictors of the development of AVN [22].

It has been mentioned that time is essential in the management of FNFs, particularly in the development of AVN. One study showed that the rates of AVN increase over time when patients underwent surgery before 12 h had elapsed to after 12 h from 12.5% to 14.0% [23], while another study showed that a delay of more than 48 h before surgery did not influence the rate of union or the development of AVN when compared with operations within 48 h of injury [24]. Some studies reported that bleeding from the holes of cannulated screws predict the development of AVN [25], some due to damage to the blood supply of the femoral head brought about by the initial high energy trauma [26] and some due to the extent of fracture displacement [27]. Other studies have suggested that FNFs treated using cannulated screws, particularly among middle-aged and elderly patients, have reduced AVN incidence [28]. Because of these studies, we undertook this study to determine the relationship between the etiologies and management of FNFs in our institution and its relationship to the development of AVN or nonunion.

## 2. Methods

We conducted a retrospective medical chart review of all adult patients aged 18 years–70 years admitted and managed for FNF in the last 10 years (2007–2017) at Security Forces Hospital, Riyadh, Saudi Arabia. All fresh trauma and referred cases were included in the study. All patients were followed up in the orthopedic trauma clinic 2 weeks, 4 weeks, 8 weeks, 16 weeks, 30 weeks and 52 weeks after surgery. At each follow-up, an anteroposterior radiograph of the hip was taken to assess the fixation, to ensure the efficacy of the surgery and to check for any complication, such as AVN. AVN was detected by hip x-ray. If there was any suspicion of AVN in the patient's clinical picture, MRI was requested for confirmation. Patients who have sickle cell disease (SCD), patients who are on steroids, patients who have developmental dysplasia of the hip (DDH), patients who have ipsilateral femoral shaft fracture, immobilized patients, pediatric cases and comatose patients were excluded from the study to homogenize the study population into patients who have FNF/AVN from non-medical conditions. The previously mentioned exclusions were used because those patients are usually treated differently or may have an extra risk of AVN or nonunion, which will make our sample less applicable. Missing and incomplete data were also excluded from the study. A preformed case report form was used to collect the data, which included a demographic profile of the patients (age, gender), comorbidities, smoking history, mode of injury (high or low energy), presence of multiple traumas,

Garden classification, side of injury, time to fixation (in hours), type of reduction, type of implant used, RUSH score (healing), start of weight-bearing activity, development of AVN, and final outcome (whether varus, valgus, displaced or healed). This study was approved by the local research ethics committee at our institution and registered in ClinicalTrials.gov. The current paper was written according to the recently published STROCSS statement [29].

Statistical analysis of the data was performed using the Statistical Package for Social Sciences (SPSS) version 23.0 (SPSS Incorporated, Armonk, NY, USA). The results are expressed in numbers and percentages (for categorical variables) and mean and standard deviation (for continuous variables). Pearson correlations were used to determine the correlation between two variables. Independent t-tests were used to determine significant differences between two means. A multivariate regression analysis was performed to determine the significant predictors of AVN. A p-value of $< 0.05$ was considered statistically significant.

## 3. Results

There were a total of 69 FNF cases of patients reviewed, 60 (87.0%) males and 9 (13.0%) females with a mean age of 37.1 ± 15.5 years (range: 18–70 years old). There were 37 patients who had comorbid conditions such as diabetes and hypertension. Four patients (5.8%) claimed to be smokers. Table 1 shows the detailed demographic profile of the 69 patients.

Table 2 shows the details of the FNF injury. FNF was caused by a fall in 37 patients (53.6%), a road traffic accident (RTA) in 16 patients (23.2%), motorcycle and motorbike accidents in 8 patients (11.6%) and heavy exercise in 8 patients (11.6%). Multiple traumas were present in 16 patients (23.2%). There were 8 patients (11.6%) with Grade I Garden FNF, 8 patients (11.6%) with Grade II FNF, 20 patients (29.0%) with Grade III FNF, and 33 patients (47.8%) with Grade IV FNF. Forty-one patients (59.4%) had a right-sided FNF. Twenty-four patients (34.8%) had fixation within 24 h of injury and 45 (65.2%) had their fixation after 24 h of injury. Forty-four patients (63.8%) had a close reduction of the fracture. There were 29 patients (42.0%) who had a dynamic hip screw (DHS), whereas 40 patients (58.0%) had a cannulated screw (CS). The mean RUSH score at 6 months was 21.4 ± 5.1 (range: 10–28), and the mean full weight-bearing follow-up was 5.6 ± 3.9 months (range: 1–12 months). There were 4 patients (5.8%) with collapsed FNF, and 4 patients (5.8%) had a nonunion FNF.

AVN of the head of the femur was documented in 12 patients (17.4%), and all of them had their AVN documented by an MRI. Of the

**Table 1**
Demographic profile of the 69 patients treated for FNF at Security Forces Hospital, Riyadh, Saudi Arabia between 2007 and 2017.

| Demographic variables | Mean (SD) | n |
|---|---|---|
| Age, in years | 37.1 (15.5) | |
| Gender | | |
| Male | | 60 (87.0) |
| Female | | 9 (13.0) |
| Presence of co-morbid condition | | 37 (53.6) |
| Comorbidities[a] | | |
| Diabetes mellitus | | 12 (17.4) |
| Hypertension | | 8 (11.6) |
| CVA | | 8 (11.6) |
| ESRD | | 8 (11.6) |
| Osteopenia | | 8 (11.6) |
| Osteoporosis | | 8 (11.6) |
| Hypothyroidism | | 5 (7.3) |
| Epilepsy | | 4 (5.8) |
| Insensible pain syndrome | | 4 (5.8) |
| Psychiatric | | 4 (5.8) |
| Smoking, yes | | 4 (5.8) |

[a] Some patients have multiple comorbidities.

**Table 2**
Details of the FNF injury and its management in 69 patients.

| Variables | Mean (SD) | n (%) |
|---|---|---|
| RUSH score at 6 months | 21.4 (5.1) | |
| Weight-bearing follow-up, in months | 5.6 (3.9) | |
| Garden classification | | |
|   Grade I | | 8 (11.6) |
|   Grade II | | 8 (11.6) |
|   Grade III | | 20 (29.0) |
|   Grade IV | | 33 (47.8) |
| Side of fracture | | |
|   Right | | 41 (59.4) |
|   Left | | 28 (40.6) |
| Time of fixation | | |
|   Within 24 h | | 24 (34.8) |
|   24–48 h | | 12 (17.4) |
|   More than 48 h | | 33 (47.8) |
| Type of reduction | | |
|   Open | | 25 (36.2) |
|   Close | | 44 (63.8) |
| Type of implant | | |
|   DHS | | 29 (42.0) |
|   CS | | 40 (58.0) |
| AVN, yes | | 12 (17.4) |
| Outcome of FNF | | |
|   Collapsed | | 4 (5.8) |
|   Nonunion | | 4 (5.8) |
| MRI, yes | | 4 (5.8) |

12 patients who had AVN, 8 (66.7%) had their fixation within 24 h of the injury, whereas only 4 (33.3%) had their fixation more than 24 h after injury. There was a significant negative correlation between the time of fixation and AVN ($r = -0.307$, $p = 0.010$).

Table 3 shows a comparison between patients who did not have AVN ($n = 57$) and patients who had AVN ($n = 12$) of the femoral head. There were no significant differences in the percentage of AVN between gender ($p = 0.140$), presence of co-morbid conditions ($p = 0.121$), smoking ($p = 0.344$), multiple trauma ($p = 0.360$), Garden classification ($p = 0.209$), type of implant ($p = 0.057$), mean age ($p = 0.288$) or full-weight bearing at follow-up ($p = 0.685$). Of the 12 patients who had AVN, 8 (66.7%) had RTA compared to 4 patients (33.3%) of those who did not have RTA ($p = 0.001$). All patients who had AVN had right femur fracture ($p = 0.002$), and 8 (66.7%) of the 12 patients who had AVN had their fixation within 24 h of the injury ($p = 0.011$). Additionally, 8 (66.7%) of the 12 patients who had AVN had an open reduction compared to 17 (29.8%) who did not have AVN ($p = 0.016$) (see Table 4).

Pearson correlations showed that the development of AVN was significantly correlated with mode of injury ($r = 402$, $p = 0.001$), type of injury ($r = 0.241$, $p = 0.046$), side of injury ($r = 0.379$, $p = 0.001$), time of fixation ($r = 0.307$, $p = 0.010$), type of reduction ($r = 0.291$, $p = 0.015$), and RUSH score at 6 months ($r = -0.649$, $p < 0.001$). Logistic regression analysis was performed using AVN as the dependent variable, and all significantly correlated variables were entered into the regression model. The significant predictors for AVN by regression analysis included the side of the fracture ($p = 0.001$, beta $= -0.275$, 95% CI $= -0.341$ to $-0.086$), RUSH score at 6 months ($p < 0.001$, beta $= -0.880$, 95% CI $= -0.087$ to $-0.047$), presence of co-morbid conditions ($p = 0.000$, beta $= -0.452$, 95%CI $= -0.600$ to $-0.090$), presence of multiple trauma ($p = 0.010$, beta $= 0.310$, 95%CI $= 0.070$ to 0.486), and full weight-bearing follow-up ($p < 0.001$, beta $= -0.624$, 95% CI $= -0.080$ to $-0.043$). (Table 5).

## 4. Discussion

AVN has been known to occur in a variety of conditions and most commonly in FNF and any other conditions that disrupt the blood supply to the femoral head. When AVN occurs as sequelae of FNFs,

management becomes more problematic. Several studies had differing views of the relationship between FNF fracture type and type of management, including some demographic characteristics of patients such as age and the time of fixation to the occurrence of AVN [21–23].

Similar to most studies, the most common cause of FNFs in our studied population was secondary to a fall injury, which was documented in 37 patients (53.6%), followed by RTA in 16 patients (23.2%, Table 2). This finding is likely because most of our patients who had a fall injury were middle-aged males (mean age of $42.8 \pm 19.1$ years) with some co-morbid conditions such as DM and HTN, and RTA was found among younger adult males (mean age of $31.8 \pm 5.2$ years) without any co-morbid conditions [1–4]. Understandably, older men who have co-morbid conditions have a higher risk of fall injuries compared to females in this study since most of the comorbid conditions, such as DM and HTN, were seen among our male patients. Furthermore, our population in this study was mostly young soldiers, which increases the chance of femoral neck fracture as they may be doing heavy exercises, which explains the sustained fracture due to intense trauma and not falls.

Additionally, similar to other studies, AVN was documented in 12 (17.4%) of our patients [18]. However, in contrast to previous studies, only 4 patients (5.8%) had displaced and nonunion FNFs, which is significantly lower than the 20%–33% in previous reports [19,20]. Despite the fact that all of our patients who had AVN were men, they were of significantly younger age (mean of $30.7 \pm 8.3$ years) compared to reports from previous studies [19–21]. A low RUSH score at 6 months was also validated and shown to identify nonunion and healing of femoral neck fractures radiographically, with 100% specificity and 100% positive predictive value. Patients with a RUSH score < 18 have

**Table 3**
Comparison between patients who had AVN versus patients who did not have AVN.

| Variables | Without AVN n = 57 n (%) | With AVN n = 12 n (%) | p-values |
|---|---|---|---|
| Gender | | | 0.140 |
|   Male | 48 (84.2) | 12 (100) | |
|   Female | 9 (15.8) | – | |
| Presence of comorbid conditions, yes | 33 (57.9) | 4 (33.3) | 0.121 |
| Smoking, yes | 4 (7.0) | – | 0.344 |
| Mode of injury | | | 0.001 |
|   RTA | 8 (14.0) | 8 (66.7) | |
|   Fall | 33 (57.9) | 4 (33.3) | |
|   Motorcycle/bike | 8 (14.0) | – | |
|   Heavy exercise | 8 (14.0) | – | |
| Multiple trauma, yes | 12 (21.1) | 4 (33.3) | 0.360 |
| Garden classification | | | 0.209 |
|   Grade I | 8 (14.0) | – | |
|   Grade II | 8 (14.0) | – | |
|   Grade III | 16 (28.1) | 4 (33.3) | |
|   Grade IV | 25 (43.9) | 8 (66.7) | |
| Side of fracture | | | 0.002 |
|   Right femur | 29 (50.9) | 12 (100) | |
|   Left femur | 28 (49.1) | – | |
| Time of fixation | | | 0.011 |
|   Within 24 h | 16 (28.1) | 8 (66.7) | |
|   After 24 h | 41 (71.9) | 4 (33.3) | |
| Type of reduction | | | 0.016 |
|   Open | 17 (29.8) | 8 (66.7) | |
|   Close | 40 (70.2) | 4 (33.3) | |
| Type of implant | | | 0.057 |
|   DHS | 21 (36.8) | 8 (66.7) | |
|   CS | 36 (63.2) | 4 (33.3) | |
| Age, in years (mean ± SD) | 36.3 (17.8) | 30.7 (8.3) | 0.288 |
| RUSH score at 6 months (mean ± SD) | 22.9 (4.0) | 14.3 (3.2) | < 0.001 |
| Full weight-bearing follow-up (mean ± SD) | 5.5 (3.8) | 6.0 (4.4) | 0.685 |

**Table 4**
Pearson correlation coefficients for the development of AVN.

| Variables | Correlation coefficient | p-value |
|---|---|---|
| Mode of injury | 0.402 | 0.001 |
| Type of injury | 0.241 | 0.046 |
| Side of injury | 0.379 | 0.001 |
| Time of fixation | 0.307 | 0.010 |
| Type of reduction | 0.291 | 0.015 |
| RUSH score at 6 months | −0.649 | < 0.001 |
| Age of the patient | −0.130 | 0.288 |
| Gender | 0.178 | 0.140 |
| Presence of comorbidities | −0.187 | 0.125 |
| Smoking | −0.114 | 0.352 |
| Presence of multiple trauma | 0.110 | 0.367 |
| Full weight-bearing follow-up | 0.050 | 0.685 |
| Type of implant used | −0.229 | 0.058 |

**Table 5**
Regression coefficients for the development of AVN.

| Variables | Beta | p-value | 95% CI |
|---|---|---|---|
| Mode of injury | −0.116 | 0.436 | −0.175 to 0.076 |
| Ref: Fall | | | |
| Type of injury | −0.132 | 0.154 | −0.117 to 0.019 |
| Ref: Garden III/IV | | | |
| Side of injury | −0.275 | 0.001 | −0.341 to −0.086 |
| Ref: Left side | | | |
| Time of fixation | −0.185 | 0.153 | −0.352 to 0.057 |
| Ref: ≥ 24 h | | | |
| Type of reduction | −0.107 | 0.530 | −0.357 to 0.186 |
| Ref: Open | | | |
| RUSH score at 6 months | −0.880 | < 0.001 | −0.087 to −0.047 |
| Ref: > 21.4 | | | |
| Presence of comorbidities | −0.452 | 0.009 | −0.600 to −0.090 |
| Ref: Yes | | | |
| Smoking | 0.029 | 0.703 | −0.198 to 0.292 |
| Ref: Yes | | | |
| Presence of multiple trauma | 0.310 | 0.010 | 0.070 to 0.486 |
| Ref: Yes | | | |
| Full weight-bearing follow-up | −0.624 | < 0.001 | −0.080 to −0.043 |
| Ref: > 5.6 | | | |
| Type of implant used | 0.363 | 0.076 | −0.030 to 0.593 |
| Ref: CS | | | |

a 46% higher risk of repeat surgery [9]. Our results showed a mean RUSH score of 14.3 ± 3.2 in the 12 patients who had AVN and 22.9 ± 4.0 in patients who did not have AVN (Table 3). We did not find any significant correlation with the type of implant used in fixation in contrast to previous studies [25,28].

The highlights of this study were the significant predictors of the development of AVN, which included the mode of injury, right-sided femoral fracture, and time of fixation and are in contrast to the assumption of a direct relationship between the incidence of AVN and the amount of damage to the blood supply to the femoral head, fracture type and even patient age [21,22]. Damage to the blood supply of the femoral head from a fall or RTA causes blood interruption to the femoral head resulting in ischemia and AVN. When diagnosis of this vascular supply interruption becomes obscure even 6 months after surgery, the probability of AVN and a revision surgery becomes high [30]. The significance of the right-sided fracture to the development of AVN in this study cannot be explained.

Another highlight of this study is the significant correlation between the incidence of AVN and the time of reduction. The significant correlation between the incidence of AVN and surgical timing remains controversial. In most studies, the success rate of the surgery, a decrease in repeat surgery, and a decrease in complications including AVN were achieved with immediate reduction within 8 h or at most within 24 h of the injury [23,24]. The development of AVN in particular was found to occur in 16%–23% of cases when reduction was performed within

24–48 h [24,31]. Other studies showed that AVN did not develop in neglected FNF (fixation over 48 h), particularly among younger patients [32,33]. This study showed that 8/12 patients (66.7%) who had AVN had their fixation performed within 24 h of injury. The explanation for the contrasting result between our study and other previous studies remains obscure since other factors, regardless of the time of fixation, may have contributed or played a role in the development of AVN, such as technical factors, the surgeon and many other elements.

## 5. Limitations

We are aware of several limitations in our study. One limitation is that it is a retrospective study, a feature that can introduce some bias. Furthermore, the number of cases was not large (69 patients); Even with large period of data analysis (ten years). We, therefore, recommend a multicenter study where data can be shared and lead to better, more definitive answers.

## 6. Conclusion

We report a 17.4% incidence of AVN over 10 years in patients managed for FNF. AVN was found to be significantly correlated with mode of injury (fall and RTA among younger male patients), right-sided fracture and a time of fixation less than 24 h after injury. Our findings of the significant association between early fixation (within 24 h of injury) and the development of AVN contradicts most of the previous studies. Thus, there is a need to further verify this association in future studies.

## Ethical approval

Ethical approval has been taken from our institution with valid reference number and without any conditions. Reference number: 18 - 266–31 IRB approval number: H-01-R-069.

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## Author contribution

-Saeed Koaban, surgeon: reviewed the final version of the manuscript.
-Raheef Alatassi, surgeon: performed the literature review and data collection, designed the manuscript, and wrote the manuscript.
-Salman Alharbi, surgeon: contributed to the manuscript writing.
-Mansour Alshehri, surgeon: contributed to the manuscript writing.
-Khalid Alghamdi, surgeon: contributed to the data collecting.

## Conflicts of interest

None.

## Research registration number

This study is registered and had a UIN in ClinicalTrials.gov, Protocol Registration and Results System (PRS) Receipt Release Date: September 11, 2018 ClinicalTrials.gov ID: NCT03666637.

## Guarantor

Raheef Alatassi.

## Provenance and peer review

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2019.01.002.

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