



Epidemiology and Diagnosis of Ipsilateral Femoral Neck and Shaft Fractures: A Systematic Review of 1761 cases in 1758 Patients (I.1990-VI.2015)

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Abstract

Objectives: Ipsilateral femoral neck and shaft fractures [IFNSF] are uncommon. The existing literature is characterized by a diversity of small reports with a lack of consensus. We performed a systematic review to examine the epidemiology and diagnosis of this injury.

Methods: Nineteen databases were used to find articles published between January 1990 and June 2015 with no language restriction. Inclusion criteria were studies describing a minimum of five patients 16 years old or older with acute IFNSF and adequate extractable data. Exclusion criteria were trochanteric fracture and malignancy at the time of retrieval. A series from the senior authors was also included.

Results: The selected 85 studies together with our series produced a total of 1758 patients with 1761 cases. The frequency of IFNSF in all femoral shaft fractures was 3, 37%, mostly resulting from high energy trauma. The typical patient was a young adult male; the mean frequency of multiple injuries was 73.5 and ipsilateral knee injuries it was 27.3. Most neck fractures originated at the base of the neck, and the mean frequency of variable cranial exit point was 6 for sub capital, 35.5 for midcervical and 58.3 for basicervical. The mean proportion of vertical shear fractures was 60. The mean frequency of undisplaced neck fractures was 57.4. Shaft fractures were most often in the middle third -mean 74.4- and they were open in a mean of 18.3. The neck fracture was diagnosed postoperatively in a mean proportion of 8.7 of the cases. Diagnosis of the femoral neck fracture using only X-rays in the period 1990-2000 failed to demonstrate the fracture in 14% of the cases; a more careful scrutiny of the radiographs and other views improved diagnosis

leaving 7.88% of the cases without diagnosis in the period 2001-2015. The use of radiographs and CT scans and a protocol of radiographs, CT scans and intraoperative fluoroscopy reduced misdiagnosis to 4.94% and 6.34%, respectively.

Conclusions: This systematic review describes epidemiology of IFNSF, characterizes the usual pathoanatomy of the injuries and shows the influence of imaging protocols in improving diagnosis.

Keywords: Ipsilateral femoral neck and shaft fractures, Femoral neck fractures, Femoral shaft fractures, Segmental femoral fractures.

Introduction

Ipsilateral femoral neck and shaft fractures (IFNSF) are uncommon injuries, occurring in 0.8-9% of femoral shaft fractures [1-4], primarily found in young adults who are victims of high energy trauma, often with multiple associated injuries. The mechanism of injury is an axial force along the femoral axis with the hip in abduction [5-8]. This axial force, primarily applied on the knee, is mostly absorbed in the shaft, leading to a high frequency of undisplaced – and hence undiagnosed – femoral neck fractures [9,10]. Since the first report of this combined injury by Becher [11] IFNSF has been the subject of numerous publications. Most of these have been retrospective reports of small case series. Some were literature reviews [2,9,12-21], and a few were systematic reviews [3,4].

There are few and diverse estimates of the current incidence

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of ipsilateral neck fractures in the existing series of femoral shaft fractures, and there is a belief that this incidence may be increasing [9,19,22,23]. The anatomic patterns of the femoral neck fractures and the frequency of some epidemiologic factors are reported with considerable variation. Although new diagnostic tools are available, there remains a number of missed neck fractures in the combined injury, historically estimated at between 10 and 50% of the cases [2-4,8,17,20,24].

We have conducted a systematic review in order to provide current concise and consolidated dataset describing the epidemiology, pathoanatomy and diagnosis of IFNSF in patients 16 years-old or older. We sought to answer five key questions:

- 1) What is the frequency of ipsilateral femoral neck fractures relative to all femoral shaft fractures?
- 2) What common factors regarding age, sex, severity and type of trauma, and associated injuries can be identified?
- 3) What fracture patterns are represented and in what frequency?
- 4) What is the typical time to diagnosis of the femoral neck fracture relative to presentation?
- 5) What is the relative accuracy of the diagnostic methods reported?

Methods

This review was conducted in accordance to the PRISMA guidelines [25]. Data were documented according to a standardized protocol, where objectives and inclusion criteria were specified in detail.

Searches were conducted using the Cochrane Library, Dialnet, Embase, Google, J-Stage, KoreaMed, Lilacs, Medline, PubMed, OvidSP, Scielo, ScienceDirect, and Springer engines, and the AAOS, Indian Medical Journals, OTA, Science Links Japan, Turkish Academic Network and Information Center, and Wanfang Med Online web sites, using the keywords “ipsilateral femoral neck and shaft fractures” or “ipsilateral hip and femoral shaft fractures” or “hip and shaft fractures” or “femoral neck and shaft fractures” or “femoral neck-shaft fractures”. The senior authors (AB and JMG) selected potentially relevant abstracts and obtained full copies of the articles. Additionally all references of the retrieved articles were also reviewed for further potential references.

Criteria for eligibility

Studies selected were original clinical articles published between January 1990 and June 2015, that addressed IFNSH in patients 16-year old and older-. Other inclusion criteria were a minimum of five patients in the study, and with acute IFNSF and adequate extractable data. Exclusion criteria were trochanteric fracture or malignancy at the time of retrieval. There was no language restriction.

Data extraction

Retrieved articles were translated if required and further information from authors was eventually requested. The studies were assessed by the senior authors for adequate methodology using a pro-forma, including level of evidence, patient numbers, and inclusion/exclusion criteria. The two reviewers agreed on the methods of assessment prior to reviewing the eligible studies. Duplicate publications were also excluded. Selected references were used to clarify the mechanism and classification of injuries, and diagnostic procedures. For the “present series” data was obtained from the records of the senior authors’ hospitals.

The assessment of the frequency of ipsilateral femoral neck fractures relative to all femoral shaft fractures included series of femoral shaft fractures which included cases of ipsilateral femoral neck fractures, with data extracted as type of study, time period of study, number of patients, and number of cases of IFNSF. The study of the other issues was based on detailed case reports of IFNSF or

cases with useful information –reported with a minimum of 5 cases, and data were extracted as type of study; age, sex, severity and type of trauma, and associated injuries; fracture patterns; time to diagnosis of the femoral neck fracture; and accuracy of diagnostic methods. The eventual effect of the date of publication on the distinct frequency of IFNSF and on the distinct incidence of missed diagnosis, in the periods 1990-2000 and 2001-2015, was also evaluated. The analysis of data was performed and recorded using Microsoft Excel (Microsoft Corp, Redwood, and Washington). Some authors provided relevant data differently or did not provide them in some instances. Therefore it was not always possible to calculate each parameter with data from all the studies. The number of pooled studies for each parameter was recorded.

Statistical analysis

As the majority of the data collected were from case reports and case series statistical analysis was not possible. Descriptive statistics were employed where possible (mean and standard deviation).

Results

The search study resulted in 234 references. After selection based on the title and the abstract 197 full text articles were examined, with 111 of these being excluded. Thus, 85 published studies [26-111] met the inclusion criteria; fifty-seven were written in English, nine in Korean, five in Spanish, four in Chinese, two in French, two in Italian, two in Portuguese, one in Czech, one in German, one in Thai and one in Turkish language. Although the cases published by Ostermann and Henry [43] had already been included in the article by Henry et al. and not used for the total sum of cases, they were separately analyzed for time to diagnosis as they showed an analysis on this item [27].

The sum of the cases retrieved from the literature and those from the senior authors’ hospitals was 1758 patients with 1761 concomitant fractures, including 3 bilateral cases.

Seventy-five studies were retrospective case series, three were comparative retrospective studies of case series, six were prospective case series, and one was a comparative non-randomized prospective study.

Frequency of IFNSF

The average frequency of ipsilateral femoral neck fractures in the total number of shaft fractures, in 16759 cases from 21 papers [32,37,40,41,45,50,54,59,60,65,68,71,77,82,88,89,90,92,94,95,99], was very low -3.37%-.

Age, sex, type of injury, associated injuries, and ipsilateral knee injuries (Table 1). The mean age of the patients at the time of injury in 60 studies was 36.5 years and the mean proportion of males in 63 studies was 78.9%. The severity of trauma was informed in 58 series: the mean frequency of cases resulting from high energy was 99.2, leaving a mean of 0.8 for low energy traumatic cases. The type of trauma was noted in 47 studies: the mean frequency of traffic accidents was 87.1, of falls from a height 12.3, and from a simple fall from the same height it was 0.5. The mean frequency of associated injuries (skeletal and/or visceral) in 44 studies was 73.5, and for associated knee injuries the mean was 27.3 in 34 studies.

Fracture patterns (Table 2). Most neck fractures with information on their topography originated at or near the base of the femoral neck, and the cranial exit point was variable, either being subcapital, midcervical or basicervical. The mean incidence of subcapital fractures was 6.0, of midcervical fractures 35.5, and of basicervical fractures it was 58.3. The vertical inclination of femoral neck fractures was noted if they were classified as such by the author, in cases of Pauwels’ type 3 inclination [112], or if they belonged to the AO-OTA subgroup B2.3 pattern [113]. The mean incidence of these vertical neck fractures in 16 series was 60.0. Neck fractures were also classified in undisplaced, which included Garden types I and II, and displaced in cases of Garden types III and IV [114]. The mean frequency of displaced neck fractures was 42.6; of the displaced fractures, the mean proportion of displaced fractures in subcapital fractures was 48.3,

Table 1: Demographic and Trauma Related Data (n = 65).

Variable	Number Studies (References)	Results Mean (SD)
Number of cases	65 [26,27,29-40,42,44-48,50-58,61,63-65,67-69,71-73,76-78,80,81,83-87,89-92,94,96-98,100-102,106,109-111] and the present series	17.8 (10.8)
Age	60 [26,27,29-38,40,42,44,45,48,50-55,57,58,61,63-65,67-69,71-73,76-8,80,81,83-92,94,96-98,100-102,109-111] and the present series	36.5 (27.4)
Sex	63 [26,27,29-40,42,44,45,48,49,51-58,61,63-65,67,69,71-73,76-78,80,81,83-87,89-92,94,96-98,100,102,106,109-111] and the present series	78.9 % Males
Severity of trauma	58 [26,27,29-40,42,45,46,48,50-55,57,58,61,63-65,67-69,71-73,76-78,80,81,83-86,89-92,94,96,98,101,102,109-111] and the present series	High energy: 99.2 (3.6) Low energy: 0.8 (3.6)
Type of trauma	47 [26,27,29-32,34,36-38,40,42,45,46,48,50,51,53-55,57,58,61,63,65,67,71-73,76,78,81,83-85,89-92,94,96,98,101,102,109,110] and the present series	Traffic accident: 87.1 (14.5) Fall from height: 12.3 (14.7) Fall: 0.5 (3.2)
Associated injuries	44 [26,29-38,40,42,44,45,48,53-55,63,65,67,68,72,73,76,78,81,84-86,90-92,94,96,98,100-102,106,109,110] and the present series	73.5 (21.7)
Associated knee injuries	34 [26,29,31,35,36-38,40,44,45,47,48,53-56,65,68,72,73,78,81,85,86,90,92,94,98,100-102,109,110] and the present series	27.3 (21.0)

Table 2: Fractures patterns data (n = 73)

Variable	Number Studies (References)	Results Mean (SD)
Site of Neck Fracture	50 [26,28-32,34,35,39,40,42,44-49,52-55,57,61,63,65-70,72-74,76-81,83-85,90,92,98,102-104,108] and the present series	Subcapital: 6.0 (13.9) Midcervical: 35.5 (22.1) Basicervical: 58.3 (23.1)
Vertical Neck Fractures	16 [31,34,38,48,49,55,57,63,65,74,90,92,97,108,109] and the present series	60.0 (26.1)
Displaced Neck Fractures	55 [26,31-40,45,47,48,51-53,57,58,61-69,72,73,75-77,79-81,84-91,94,96-101,109,110] and the present series	42.6 (24.9)
Displacement by Site Neck Fracture	23 [26,31,32,34,35,38,39,45,51,52,54,57,63,65-67,72,73,77,81,85,98] and the present series	Subcapital: 48.3 (44.9) Midcervical: 66.2 (35.7) Basicervical: 43.2 (36.4)
Site of Shaft Fracture	42 [26,27,29-32,34-36,38,40,42,44,45,47,52-55,57,58,61,63-66,68,72,73,76,77,79,84-86,89,90,92,98,100,109] and the present series	Proximal: 8.5 (9.7) Middle: 74.4 (18.7) Distal: 16.2 (17.9) Segmental: 0.9 (2.4)
Unstable Femoral Shaft Fractures (AO type B or C; Winquist II, III or IV, segmental and spiral)	44 [26,32-35,37,38,40,47,51,54,55,57,58,61,63,65-68,72,73,76,77,79-81,83-85,87,90-92,94,96-98,100-102,109-111] and the present series	69.3 (23.4)
Open Femoral Shaft Fractures	46 [26,27,29,32-36,40,44,45,47-49,53-56,58,61,63,65-69,72,73,76,77,79,80,83-85,87,90-92,94,96,98,100,109,110] and the present series	18.3 (16.2)
Grades of Open Femoral Shaft Fractures (Gustilo)	26 [32,34,40,45,49,54,58,61,63,65-68,73,79,80,83,90-92,96,98,100,109,110] and the present series	Gustilo 1: 36.7 (36.1) Gustilo 2: 57.4 (36.2) Gustilo 3: 5.9 (12.4)

in midcervical fractures it was 66.2, and in the group of basicervical fractures it was 43.2. The femoral shaft fractures were classified according to their location in four types, i.e. proximal third; middle third, distal third, and segmental fractures. The mean incidence of these types was 8.5, 74.4, 16.2 and 0.9, respectively. They were divided into stable and unstable. The mean incidence of unstable fractures i.e. those reported as Winquist II, III and IV [115], segmental and spiral, and those reported as AO groups B and C [113], was 69.3. The mean incidence of open shaft fractures was 18.3. When classified according to the criteria of Gustilo and Anderson [116] the mean frequency of grade I was 36.7, grade II 57.4, and grade III 5.9.

Time of diagnosis of the femoral neck fracture (Table 3). Pre-operative and intra-operative diagnosis was considered a timely diagnosis. Cases with missed diagnosis were those with post-operative diagnosis of the neck fracture. The mean rate of missed diagnosis of the neck fracture was 8.7, and the mean proportion of undisplaced neck fractures among these postoperatively diagnosed cases was 78.8.

Accuracy of diagnostic methods for the femoral neck fracture (Table 4). The accuracy of diagnostic methods for the femoral neck fracture was studied with an analysis of the time of diagnosis of the neck fracture in three different groups according to the imagenologic methods used: a) only X-rays; b) X-rays and CT scans; and c) X-rays,

CT scans and intra-operative fluoroscopy. In addition the first group was also analyzed in two periods, i.e. 1990-2000 and 2001-2015. We found in the group of only X-rays a frequency of missed diagnosis averaging 9.88%, and when this group was divided in the two periods, the frequency was 14.02% in the series published in the period 1990-2000 and 7.88% in between 2001 and 2015. When the diagnostic methods used were X-rays plus CT scans the frequency of missed neck fractures was 4.94%, and in the group of X-rays, CT scans and fluoroscopy it was 6.34%. There was a further series of 28 cases in which X-rays and aspiration of the hip provided diagnosis in every case.

Discussion

The frequency of IFNSF continues to be low -3.37%-. Several authors have considered a rise of this combination of injuries, because of an increase in high-velocity trauma, a shift toward smaller motor vehicles with dashboards located at the knee level resulting in a directional force necessary to produce this combined fracture, improved resuscitation capabilities leading to improved survival in these patients, and better recognition of the combined injury [9,19,68,70,75]. However, we could not ascertain this rise, when comparing our findings with those of Alho of the 20th century [3,4].

Table 3: Time of diagnosis of IFNSF.

(n = 76) [26,28,30-45,47,48,51-54,57-59,61,62,64-94,96-102,104,106,107,109,110] and the present series	
Variable	Results Mean (SD)
Preoperative diagnosis of femoral neck fracture	87.0 (14.4)
Intraoperative diagnosis of femoral neck fracture	4.4 (7.0)
Postoperative diagnosis of femoral neck fracture	8.7 (12.2)

Table 4: Method of diagnosis versus time of diagnosis of femoral neck fracture in IFNSF.

Method of diagnosis	N° of series (References)	N° of cases	Preoperative	Intraoperative	Postoperative
X-rays only	78 [26,28,30-45,47,48,51-54,57-59,61,62,64,66-68,70,72-86,89-91,93,94, 96,98,100-102,104,106,107,109] and the present series	1163	86.41%	4.55%	9.88%
X-rays - CT	4 [65,69,92,97]	81	90.12%	4.94%	4.94%
X-rays – CT - fluoroscopy	4 [71,82,93,99]	79	88.60%	5.06%	6.34%

The typical patient is a young adult male. The age range, however, goes between 16 and 90 years, confirming that any patient involved in high-energy trauma may suffer the combined injury [19]. Although mild or moderate injuries may also produce it, this only occurred in less than 1% of the cases in this review and referred exclusively to older patients, with fragile bones. Most commonly, the combined injury occurs in polytraumatized patients, with elevated Injury Severity Score [3,13,98], usually produced by traffic accidents and, much less frequently, by falls from a height. Knee injuries are the most commonly associated musculoskeletal injuries, dependent on the axial force mechanism of IFNSF.

The incidence of subcapital, midcervical and basal fractures was similar to that found by Alho in his systematic reviews published in 1996 and 1997 [3,4], the fracture being more frequently basal. Most neck fractures were clustered at or near the base of the neck, a fracture type that has been reported by few authors [48,49,51,117], differing from the spiral type commonly seen in isolated femoral neck fractures [10,23,49,118]. This shear fracture of the femoral neck is a unique pattern related to the mechanism of production of this combined injury [3,16,20,119], and its mean frequency in the review series was 60.

Although the shaft fracture may occur in any of its portions, middle third shaft fractures were the most frequent; The mean incidence of unstable shaft fractures was 69.3, and they were open in a mean of 18.3. These findings reflect the high energy absorbed by the shaft in the combined injury [2,3,7,8,14,32,35,48,54,58,120].

Previous authors have found a substantial number of femoral neck fractures ipsilateral to femoral shaft fractures that remain occult after plain radiographic examination. The femoral neck fracture in this condition is missed for several reasons [2,3,4,9,14,17,19,20,35,3,9,41,89,97,109,121]: 1) there is diversion by treatment of associated life-threatening injuries; 2) focus is on the more obvious femoral shaft fracture and frequent knee injuries; 3) patients who are head injured or obtunded cannot report hip pain, and those who are awake may have their pain masked by the pain of the shaft fracture; 4) 57.4% of the neck fractures are undisplaced or minimally displaced; 5) no routine in taking primary and high quality radiographs of the entire femur with the hip and knee in both frontal and lateral views; and 6) because of superimposition, the greater trochanter obscures the femoral neck in the anteroposterior (ap) radiograph of the hip. The complete diagnosis of the neck-shaft fractures before fixation is important for several reasons: 1) hip fractures in young people are known medical urgencies [122]; 2) better preoperative planning and fixation is thus possible [122], as the previous treatment of the femoral shaft fracture may lead to difficulties in the subsequent management of the overlooked fracture of the femoral neck [36,54,123]; 3) a femoral neck fracture or displacement of a previously nondisplaced neck fracture may occur as a result of intramedullary nail fixation of a femoral shaft fracture [124-126], leading to patient complications [8] and medico-

legal problems; and 4) because it prevents the discomfort, risks, and costs of a second surgery [7,121]. Furthermore, the diagnostic steps are not complete until a careful clinical and imagenologic exam of the ipsilateral knee is complete.

Reducing the frequency of missed diagnosis is dependent upon maintaining a high index of suspicion: all femoral shaft fractures resulting from a high-energy mechanism should be suspected for ipsilateral neck fracture [17,18,75,127]. This attitude and the use of supplementary radiographic views of the hip have led to a reduction of the incidence of diagnostic failure only using radiographs from 14.% in the period 1990-2000 to 7.88 in the period 2001-2015. A cross-table or an obturator oblique view of the hip [128] or an anteroposterior radiograph of the pelvis with placement of a triangular radiolucent block under the buttock of the injured side to produce internal rotation of the hip [92] might facilitate more frequent diagnosis of the femoral neck fracture in the combined injury.

The use of thin cut computed tomography (CT) scans has been advocated as a tool to improve diagnosis of these occult fractures [7,24,35,54,60,69,78,96,97,111,121,127,129-132]. However, femoral neck fractures in IFNSF may be missed even with the use of thin-cut CT scans in these polytraumatized patients [8,20,88,71,24,105]. The group of Dietz and O'Toole in 2008 and 2013 found that CT scans were sensitive but still missed some femoral neck fractures, and suggested that both diagnostic methods should be combined to improve diagnosis [24,105]. The present study also showed that the use of high quality scans with appropriate reconstruction, supplementing high quality radiographs, diminished the incidence of missed femoral neck fractures to a mean 4.94%.

The use of perioperative fluoroscopy, with multiple views using the image intensifier, under anaesthesia, before, during and after fixation of the femoral shaft fracture, as reported by Tornetta et al. [82], and Xue et al. [93], contributes to improved detection of a timely diagnosis of the femoral neck fracture associated with an ipsilateral shaft fracture, when compared with historical reviews, though misdiagnosis is still found with this procedure [7,8,20,88,99]. The analysis of series using radiographs, CT scans and intraoperative fluoroscopy in the present review led to an average of 6.34% of missed neck fractures, a similar finding that those reported separately by Tornetta et al. [82] and Xue et al. [93].

These "clandestine" femoral neck fractures [41] should be suspected whenever there is persistent hip pain or disability after treatment of a femoral shaft fracture, and further clinical and imagenologic evaluation of the hip should be performed [17,41,71].

It is interesting to note that Gavaskar and Tummala have recently described a further method of diagnosis, using frontal radiographs of the ipsilateral hip in femoral shaft fractures and aspiration of the hip to rule out an associated neck fracture, providing diagnosis of the femoral neck fracture in every case [95].

There are certain limitations to the current meta-analysis inherent to the nature of the available data. Most of the analyzed series are retrospective in nature. Small sample sizes, which are typical for studies of this topic, are subject to systematic and random biases. Although we set the minimum number of included patients for eligible studies to be 5, this is a subjectively determined threshold that does not necessarily diminish the deleterious effects of small sample sizes. However, the large number of studies and patients reviewed and the selection of studies with no limitation of language, provide support to the overall results.

In summary, the current study describes the epidemiology and patho-anatomic findings of IFNSF. It supports the use of careful preoperative screening for femoral neck fracture with high quality and appropriately oriented radiographs and CT scans, supplemented by a dedicated intraoperative fluoroscopic imaging of the femoral neck in every patient with a femoral shaft fracture after severe trauma. Randomized studies are not feasible based on the volume and prevalence of this particular combination of injuries. Consequently, meta-analyses such as the present one provide the best evidence available.

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