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Title: Risk factors determining the outcomes in femoral neck fractures treated with internal fixation

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Risk factors determining the outcomes in femoral neck fractures treated with internal fixation

Abstract:

Objectives: to determine *the r*isk factors determining the radiological outcomes in femoral neck fractures treated with internal fixation.

Design: both prospective and retrospective study*.*

Setting: level 1 trauma centre.

Patients/Participants*:* 108 patients treated at a single institution for femoral neck fractures in whom the femoral head has been preserved and with a minimum follow-up of 1 year were included.

Intervention*:* The patients with femoral neck fractures treated with cannulated screws, dynamic hip screws and reconstruction nails were identified and included in the study.

Main Outcome Measurements*:* Preoperative displacement, post-operative displacement, type of reduction (closed vs open),Pauwels angle, Gardens fracture type and time to fixation was gathered from the patient notes and correlated with the outcomes of non-union and avascular necrosis (AVN).

Results: The mean follow-up was 42 months (12-190 months). 5(4.6%) patients developed non-union at the end of follow-up. Higher preoperative displacement and postoperative displacement was significantly associated with higher occurrence of non-union ($p<0.05$). The type of reduction did not affect the outcome of non-union.16 (14.8%) patients developed AVN at the end of follow-up. Higher preoperative

displacement, postoperative displacement ,open reduction and percutaneous screw fixation (as opposed to closed reduction and percutaneous screw fixation) and gardens fracture type was significantly associated with higher occurrence of AVN ($p<0.05$). Open reduction decreased the risk of AVN only in the setting of perfect anatomic reduction. Pauwels angle and age did not significantly affect either AVN or non-union. Of 35 patients with perfect anatomic reduction only 1 (2.8%) patient developed non-union and 2 (5.6%) patients developed AVN. When the post-operative displacement (in mm) was compartmentalized into 0-5,6-10,11-15, >15 the incidence rate of non-union was 1.2%(1/82), 8.3%(1/12), 11%(1/9), 40%(2/5) respectively. Similarly when the post-operative displacement (in mm) was compartmentalized into 0-5, 6-10, 11-15, >15 the incidence rate of AVN was 6 %(5/82), 8.3 %(1/12), 55 %(5/9) and 100% (5/5) respectively.

Conclusion: Perfect post-operative anatomic reduction reduces the incidence of AVN and non-union in femoral neck fractures where the head has been conserved. Higher post-operative displacement increases the incidence of both non-union and AVN. Open reduction may be a risk factor for the development of AVN unless perfect anatomic reduction is achieved.

Keywords: femoral neck fractures, internal fixation, avascular necrosis, non-union, risk factors.

Running title: risk factors in femoral neck fracture

Introduction:

Femoral neck fractures have a bimodal distribution and are extremely common fractures in the elderly due to low energy injuries, but they also occur in the younger age patients mostly due to high energy injuries. The inclination in the management of these fractures in the younger patients is laid on preserving the femoral head using internal fixation techniques such as cannulated screws, dynamic hip screws (DHS) and reconstruction nailings.[1 2 3,4]

The risk factors after internal fixation for neck of femur fractures have not been studied in depth and there is a paucity of literature analyzing these fractures in younger patients. The special need to preserve the head of femur in younger patients, results in complications like osteonecrosis and non-union, which is not seen in older patients who are managed with prosthetic replacement. These complications lead to considerable morbidity and are usually managed by revision surgeries like total hip arthroplasty, which when done in younger patients, will ultimately lead to further revisions.

There have been studies on the effect of preoperative displacement [2 5] and time to fixation [6]on the outcomes of non-union and avascular necrosis, but the results have been mixed.

An in-depth analysis of various factors like preoperative displacement, post-operative displacement, type of reduction, Pauwels angle, Gardens fracture type and time to fixation when studied in the backdrop of the complications like osteonecrosis

and non –union may shed more light into the bio-mechanics, complications and prognosis of these fractures.

The femoral head has a unique distal to proximal blood supply which makes it more prone to develop non-union and AVN once the blood supply has been disrupted by a fracture. So we hypothesized that the postoperative displacement (perfect anatomic reduction) may be more important than the preoperative displacement.

We studied some of the main risk factors, which may determine the radiological outcomes in femoral neck fractures, treated with internal fixation in the setting of a level -1 trauma center.

Materials and methods:

This study was approved by Institutional Review Board and was done at a level -1 trauma center. This is both a retrospective and prospective study including patients between January 2000 to December 2006 treated at our institution with cannulated screws, DHS and reconstruction nailing for femoral neck fractures. Only those patients with a minimum follow-up of 2 years and with documented preoperative and post-operative x-ray films were included in the study. Thus 108 patients (out of 138 patients treated) who fit the criteria were identified and included in the study. A retrospective chart review was done and relevant variables like preoperative displacement, postoperative displacement, type of reduction, time to fixation, Pauwels angle and Gardens fracture type were gathered from the patient notes and x-rays. A prospective

limb for the study was also established and the subjects were followed up for a minimum of 1 year.

Preoperative displacement (in mm) was assessed using an electronic ruler on the preoperative antero-posterior (AP) and lateral hip x-ray. Immediate postoperative AP and lateral views of the hip were used to measure the postoperative displacement. The postop displacement was compartmentalized into 0-5, 6-10, 11-15, and >15 mm to correlate the significance with the outcome variables.

Similarly Pauwels angle was measured using the preoperative AP pelvic views and was graded as I (<30 degree),II (30-55 degrees) and III (>55 degrees) as described by Pauwel. Gardens fracture type was assessed by preoperative AP pelvic views and classified as type 1, 2, 3 and 4 as described [7]. Gardens type 1&2 were considered undisplaced and type 3 &4 were considered displaced.

Time to fixation was assessed from the time of injury to the start of operative procedure for the femoral neck fracture. Orthopedic trauma association (OTA) classification system was used to classify the fractures as subcapital, transcervical and basicervical . The decision to use a specific implant, operative approach and the need to open the fracture site was determined by the surgeon and varied widely (Table 1). All the patients who received reconstruction nails had ipsilateral femoral shaft fracture (19 patients).

Closed reduction was defined as reduction achieved by not visualizing the fracture site and open reduction was defined as any reduction which was attained by

visualizing the fracture site. Closed reduction was either followed by percutaneous screw fixation or DHS placement. In all the patients who received DHS, reduction was achieved by closed means. But for statistical analysis between open and closed reduction only percutaneous screw fixation was included to minimize the confounding by the type of implant.

The outcome variables were non-union and AVN. Non-union was defined as the failure of fixation due to loss of reduction, implant failure or visibility of fracture line at a minimum of six months after the primary procedure. AVN was assessed radiologically with the method described by Ficat [8].

Two-sample Wilcoxon rank-sum (Mann-Whitney) test and Pearson chi-square were used to correlate the statistical significance between the risk factors and the outcome variables. The significance level was set at $p<0.05$. Statistical analysis was done using the software STATA (STATA Corp, College Station, TX)

Results:

Patient characteristics:

The mean follow-up was 42 months (12-190 months). There were 72 male and 32 female patients. The mode of injury ranged from fall, motor vehicle accident, sports injury, assault to gunshot injuries (Table 1). Most of the patients were treated with closed reduction and percutaneous screws (60%)and the fracture site was opened only when there was difficulty in reduction (12%)(Table 1).The number of cannulated screws

used ranged from 3(71 patients),4(5),5(2) and were usually placed in a triangular fashion.19 (18%)patients received reconstruction nails and all of them had a ipsilateral femoral shaft fracture.6 patients received DHS and 5 patients received DHS with a derotation screw. The Gardens fracture type, OTA fracture type and Pauwels angle were assessed and this data was eventually used in the analysis (Table 1). The time to fixation was compartmentalized into <12, 12-24,24-48,48-72 and >72 hrs (table 1), and most of the patients were operated within a day (78%).

Patient outcomes:

5(4.6%) patients developed non-union at the end of follow-up. Higher postoperative displacement was associated with significantly higher rate of non-union ($p<0.05$) (Table 2). Out of 35 patients with perfect anatomic reduction (0 mm) only 1 (2.8%) developed non-union. When the post-operative displacement (in mm) were compartmentalized into 0-5,6-10,11-15, >15 the incidence rate of non-union was 1.2%(1/82), 8.3%(1/12), 11%(1/9), 40%(2/5) respectively (Table 2). When the risk of developing non-union was compared between the 0-5 mm group and the rest of the group the hazard ratio was 1.9 (Table 4).

Pre-operative displacement was a significant risk factor for the development of non-union ($p<0.05$) (Table 2) and was treated as a continuous variable. Gardens fracture type was not a risk factor for the development of non-union. The incidence of non-union in undisplaced fractures and displaced fractures were 1/32 (3%) and 4/76(4%) respectively. Time to fixation, OTA fracture type, age and Pauwels angle were not

148 significant risk factors (Table 2).The type of reduction(closed vs open) did not make any
149 difference to the development of non-union (table 5).

150 16 (14.8%) patients developed AVN at the end of follow-up. Pre-operative displacement
151 was a significant risk factor for the development of AVN ($p<0.05$) (Table 3) and was
152 treated as a continuous variable. Gardens fracture type was also a risk factor for the
153 development of AVN with higher fracture type developing more AVN (Table 3). The
154 incidence of AVN in undisplaced fractures and displaced fractures were 1/32 (3%) and
155 15/76(19%) respectively. Time to fixation, OTA fracture type, age and Pauwels angle
156 were not significant risk factors (table 3).

157 Higher postoperative displacement was associated with significantly higher rate of AVN
158 ($p<0.05$) (Table 3). Out of 35 patients with perfect anatomic reduction only 2 (5.6%)
159 patients developed AVN. When the post-operative displacement (in mm) was
160 compartmentalized into 0-5, 6-10, 11-15, >15 the incidence rate of AVN was 6 %(5/82),
161 8.3 %(1/12), 55 %(5/9) and 100% (5/5) respectively (Table 3). When the risk of
162 developing AVN was compared between the 0-5 mm group and the rest of the group
163 the hazard ratio was 3.9. (Table 4).The Ficat grading of AVN was 7(44%),7(44%) and 2
164 (12%) for grades 1,2 and 3.None of the patients developed grade 4 AVN.

165 Open reduction and percutaneous screw fixation was a risk factor for the development
166 of AVN as opposed to closed reduction and percutaneous screw fixation($p<0.05$) (table
167 6).When the post-op displacement was compartmentalized into undisplaced (0mm) ,1-
168 5mm,6-10mm,11-15mm and >15 mm and factored with the type of reduction ,open
169 reduction decreased the risk of AVN if perfect anatomic reduction was achieved(table

7).If perfect anatomic reduction was not achieved ,closed reduction fared better in the preventing AVN. We found a trend that showed, if the post-op displacement after open reduction was greater, there was a higher risk of AVN, though this was not statistically significant (table 7).

Associated injuries include 22 femoral shaft fractures, 3 tibial fractures, 2 calcaneal injuries, 2 upper limb fractures, 1 acetabular fracture, 1 thoracic injury, and 1 severe head injury.

All the patients in the grade 1&2 Ficat classification were treated conservatively and were asymptomatic at the last follow-up. Both the patients with grade 3 AVN were treated with total hip arthroplasty.

3 patients with non-union were treated with total hip arthroplasty, 1 with hemiarthroplasty and 1 patient was treated with valgus intertrochanteric osteotomy and the non-union healed well in 12 weeks.

The complications following the surgery included varus collapse and varus malunion (2 patients), abductor weakness (1),trochanteric bursitis(1),leg length discrepancy (6),heterotrophic calcification (1),valgus impaction(1) and chronic hip pain (1).

Discussion:

Femoral neck fractures pose a great orthopedic challenge when trying to preserve the femoral head. The results of treatment have not been reported properly. The blood

supply of the femoral head is quite precarious and early anatomic reduction, stable fixation and compression of the fracture usually promotes fracture union, however complications like non-union and AVN still do occur. Many groups [9 2 6 5 10 11 12]have studied the results of femoral neck fractures treated with internal fixation techniques ,but the risk factors for the outcome have not been consistently studied(table 7).

The incidence of non-union is reported to be around 3% to 36%, with many around 20% [11 5] (Table 8) depending mainly on the degree of displacement and stability of the reduction achieved. Haidukewych et al in their analysis found an overall non-union incidence of 8% and the incidence in displaced and un-displaced was 10% and 4.5% respectively [2].Tooke et al in their series analyzing 32 patients with femoral neck fractures treated with cannulated screws found an overall incidence of 3% of non-union and a 5.5 % in Garden type 3 and 4 fractures[11].Lu-yao et al did a meta -analysis of 106 reports of femoral neck fractures and reported an incidence rate of non-union as 23% to 37%[13].While most of the groups (Table 8) have analysed the role of OTA fracture type and Gardens fracture type in promoting non-union , we felt post operative reduction is the main risk factor because of the adequacy of perfect anatomic reduction. We found anatomic reduction significantly reduces the incidence of nonunion when the postop displacement was treated both as a continuous variable and when compartmentalized into 5mm increments. This correlates with a previous study from Mayo clinic who studied the postop displacement and angle of reduction [2].

Our analysis shows that time to fixation is not a risk factor for the development of non-union nor were type of reduction, pauwels angle, gardens fracture type, OTA

fracture type or age. The relevance of pauwels angle to the radiological outcome has been questioned by many [14,15] lately and its continued use in determining the radiological outcome should be guarded ,as its validity is yet to be studied in depth.

Incidence of AVN following internal fixation has been reported to be 11-36%[9] [10] (table 8) depending mainly on the degree of displacement and time lag to fixation. In a retrospective study conducted at the Mayo clinic involving 83 femoral neck fractures in the age group 15 to 50 years the overall incidence of osteonecrosis was 23% and the incidence in displaced vesus undisplaced fractures were 27% and 14% respectively [2]. Another retrospective study conducted by Asnis et al analyzing 141 patients with fracture neck of femur treated with cannulated screws the overall incidence of osteonecrosis was 22% and the incidence in displaced and undisplaced fractures were 20% and 16% respectively [9].Jakob et al also found a statistically significant difference in the development of avascular necrosis between displaced and undisplaced fractures in a cohort of 71 patients[5].We established that postoperative displacement significantly reduces the occurrence of AVN, which is indubitable in the hazard ratio of 3.9 when the incidence is compared between 0-5 mm group vs the rest of the group (table 4). This further stresses the importance of perfect anatomic reduction in preventing AVN. Our results show that first signs of AVN occurred at an average of 11.25 months (5-20 months) (fig 1).

Open reduction of the fracture site may disrupt the medial circumflex femoral artery blood supply to the femoral head and predispose to the development of AVN .Our results (table 6) clearly show that open reduction increases the incidence of AVN. The

only instances where open reduction fared much better than closed reduction was when perfect anatomic reduction was achieved(table 7). Also the trend towards increasing the risk of AVN was higher as the post-op displacement was higher after open reduction. This has not been shown before by any group and requires further studies. Thus every attempt should be made by the surgeon to fix the fracture by closed means, and only venturing to open the fracture site if the reduction is not anatomical. Also every attempt should be made to achieve anatomic reduction if the fracture site is opened, to minimize the risk of AVN.

Gardens fracture type significantly influenced the development of AVN which was concurred by most other studies [9 2 5 11] .This can be explained by the disruption of blood supply when the fracture is more displaced and rotated. Time to fixation was shown to be insignificant in the development of AVN .This contradicts the Toronto study which showed that delayed surgical fixation of subcapital fractures was associated with a higher rate of AVN [6] .The difference between the studies such as inclusion of only the subcapital fractures in their study, as compared to all femoral neck fractures in our study may be one of the reason for discord. Also the time line of compartmentalization was different in both the studies. We recently fixed a grossly displaced femoral neck fracture which was 242 days old after the injury but still did not develop AVN (case report waiting to be published).Thus more studies need to be done to come to a more concrete conclusion.

An ipsilateral femoral shaft fracture with concurrent femoral neck fractures was a special sub-group we encountered, which used recon nails for the treatment. Of the 22

patients who had this condition only 19 cases were treated with recon nailing, due to the fact that 3 femoral neck fractures were missed in the initial diagnosis due to the hairline nature of the fracture. Thus the practice to routinely use fluoroscopy to screen the femoral neck during any intramedullary nailing for femoral shaft fractures cannot be overstressed. Tornetta in a recent study came up with a standard protocol which showed that evaluation of femoral neck with fine-cut computed tomography and dedicated internal rotation hip radiographs considerably improved the diagnostic ability of an associated femoral neck fracture in the presence of a femoral shaft fracture [16] . The non-union rate in this sub-group was 1/22(4.5%) which is comparable to the overall non-union rate (5%).The AVN rate (9%) was significantly lower than the overall AVN rate (15%).This may be due to the fact that most of the energy causing the fractures is dissipated to the femoral shaft fractures thus relatively protecting the femoral neck from severe damage. Swiontkowski ,in his literature review of these type of fractures showed an non-union rate of 5% and AVN rate of 15%.[3].

One of the major finding of the study is the importance of perfect anatomic reduction to prevent the occurrence of non-union and AVN .This is more so when open reduction is performed**.** It is also noteworthy that perfect anatomic reduction can lead to AVN as occurred in nearly 6% of our cases .This may be due to other causes such as vessel injury at the time of the accident or during the surgery. More studies in this realm will give us a specific threshold post operative displacement, which may predict the occurrence of AVN and guide the surgeon as to what to expect from the operative results. Also further studies can put forth a new classification system based on the postoperative displacement that may predict the outcome of AVN in a reproducible

manner. This might lead to a treatment algorithm combining different factors that influence failure following the surgery so that the clinician can discern the proper treatment protocol when faced with these clinical scenarios. Another interesting study will be measuring the post-op shortening of the femoral neck and its significance in causing non-union and AVN. In addition measuring the post-op displacement at 1 year, may give an idea about the role of weight bearing in changing the reduction and leading to non-union /AVN.

The major limitations of our study include: the largely retrospective nature of the study, the involvement of multiple surgeons which in itself is a confounding factor and the use of a patient database not specifically designed for research but mainly for patient care. Strengths of our study include the relatively large number of patients treated at our institution with long follow-up, which led to good power for the study and accurate rates of non-union and AVN.

Summary: The future management of femoral neck fractures may be revolutionized by the development of newer implants but the basic concepts of fracture fixation like quality of reduction and stability will still hold good in treating these extremely challenging fractures.

Gender	
Male	76(70)
Female	32 (30)
Mode of injury	
Fall	32 (30)
Motor vehicle accident	72 (66)
Sports injury	2 (2)
Assault	1 (1)
Gunshot	1 (1)
Laterality	
Left	63 (58)
Right	45 (42)
Type of fracture	
Basicervical	47 (44)
transcervical	42 (38)
Subcapital	19 (18)
Gardens fracture type	
1	16 (15)
2	16 (15)
3	57 (53)
4	19 (17)
Treatment	
Closed reduction with percutaneous screws	65 (60)
Open reduction with percutaneous screws	13 (12)
DHS	6 (5.5)
Recon nail	19 (17.5)
DHS+cannulated screws	5 (5)
Pauwels angle	
1	44 (40)
2	37 (34)
3	27 (26)
Time to fixation(hrs)	
<12	16 (15)
12-24	68 (63)
24-48	16 (15)
48-72	6 (5)
>72	2 (2)

TABLE 1: Patient characteristics of the patients involved in the study.(% in parentheses)

Risk factors	NON-UNION	p-value
Post-operative displacement (mm) 0-5 6-10 11-15 >15	 1/82(1.2) 1/12(8.3) 1/9(11) 2/5(40)	 **0.0226**
Time to fixation <12 hrs 12-24 hrs >24-48 hrs >48 hrs	 2/16(12.5) 1/68 (1.4) 1/16 (6.25) 1/8 (12.5)	0.0691
Gardens fracture type 1 2 3 4	 1/16 (6.25) 0/16 (0) 1/57(1.7) 3/19 (15.7)	0.0757
OTA fracture type Subcapital Transcervical Basicervical	 1/18 (5.5) 1/42 (2.3) 3/48 (6.25)	 0.844
Pauwels angle I II III	 2/44 (4.5) 2/37 (5.4) 1/27 (3.7)	0.950
Preoperative displacement(mm)	Continuous variable	**0.0438**
Age	Continuous variable	0.0716

Table 2

Different Risk factors correlated with non-union.(% in parentheses)

Risk factors	AVN	p-value
Post-operative displacement(mm) 0-5 6-10 11-15 >15	 5/82 (6) 1/12 (8.3) 5/9 (55) 5/5 (100)	 **0.0000**
Time to fixation <12 hrs 12-24 hrs >24-48 hrs >48 hrs	 4/16 (25) 8/68 (11.7) 4/16 (25) 0/8 (0)	0.6972
Gardens fracture type 1 2 3 4	 1/16 (6.25) 0/16 (0) 6/57 (10.5) 9/19 (47.3)	**0.0002**
OTA fracture type Subcapital Transcervical Basicervical	 2/18 (11.1) 8/42 (19) 6/48 (12.5)	0.745
Pauwels angle I II III	 6/44 (13.6) 8/37 (21.6) 2/27 (7.4)	0.275
Preoperative displacement(mm)	Continuous variable	**0.0000**
Age	Continuous variable	0.0639

TABLE 3

Different risk factors compared with AVN. (% in parentheses)

Post-operative displacement (mm)	OUTCOME	Odds ratio	p-value
	Non-union		
0-5	1.2%(1/82)		
6-10	8.3%(1/12)	1.971014	0.5457
11-15	11%(1/9)		
>15	40%(2/5)		
	AVN		
0-5	6 %(5/82),		
6-10	8.3 %(1/12),	3.915254	0.0665
11-15	55 %(5/9)		
>15	100% (5/5)		

Table 4

Post-operative displacement increases the odds of development of non-union and AVN.

Type of fixation	Non-union		p-value
	NO	YES	
Closed reduction with percutaneous screws	63 (58.3)	2 (1.8)	
Open reduction with percutaneous screws	11(10.1)	2 (1.8)	
DHS	6 (5.5)	0	0.365
Recon nail	18 (16.6)	1 (0.9)	
DHS+cannulated screws	5 (4.6)	0	
Closed reduction with percutaneous screws	63 (96.9)	2 (3.1)	
Open reduction with percutaneous screws	11 (84.6)	2 (15.4)	0.066
Closed reduction with percutaneous screws	63 (96.9)	2(3.1)	0.651
Recon nail	18(94.7)	1(5.3)	

Table 5.Type of fixation correlated with non-union. (% in parentheses)

Type of fixation	AVN		p-value
	NO	YES	
Closed reduction with percutaneous screws	58 (53.7)	7 (6.4)	0.136
Open reduction with percutaneous screws	8 (7.4)	5(4.6)	
DHS	5(4.6)	1 (0.9)	
Recon nail	17(15.7)	2(1.8)	
DHS+cannulated screws	4(3.7)	1(0.9)	
Closed reduction with percutaneous screws	58(89.2)	7(10.8)	**0.012**
Open reduction with percutaneous screws	8(61.5)	5(38.5)	
Closed reduction with percutaneous screws	58(89.2)	7(10.8)	0.976
Recon nail	17(89.4)	2(10.6)	

Table 6. Type of fixation correlated with AVN. (% in parentheses)

Post –operative displacement	AVN after closed reduction		AVN after Open reduction		p-value
	No	Yes	No	Yes	
0 mm	25(96.1)	1(3.9)	1(100)	0	**0.000**
1-5mm	24(96)	1(4)	6(85.7)	1(14.3)	0.177
6-10mm	6(85.7)	1(14.3)	1(100)	0	0.661
11-15mm	3(75)	1(25)	0	2(100)	0.583
>15mm	0	3(100)	0	2(100)	0.169

Table 7.The occurrence of AVN after closed and open reduction factored with post-op displacement (% in parentheses).

Study	n	Nonunion	AVN	Risk factors assessed
Our study	108	5(4.6%)	16 (14.8%)	Postop displacement, type of reduction, preop displacement, pauwels angle, gardens fracture type ,OTA fracture type, time to fixation
Haidukewych,G.J. 2004[2]	83	6(8%)	17(23%)	Fracture displacement and postop displacement
Upadhayay A 2004[17]	92	16(17%)	15 (16.3%)	Posterior comminution, reduction, screw placement, time to fixation
Jain,R. 2002[6]	38	N/A	6 (16%)	Time to fixation
Jakob,M. 1999[5]	50	18(36%)	N/A	Displaced/non-displaced
Asnis,S.E. 1994[9]	141	5(4%)	13(11%)	Garden fracture type
Dedrick,D.K. 1986[10]	32	5(20%)	9(36%)	none
Tooke,S.M. 1985[11]	32	1(3%)	6(18.8%)	Garden fracture type
Protzman,R.R. 1976[12]	22	13(59%)	19(86%)	none

Table 8.Important studies conducted on femoral neck fractures. (% in parentheses)

Figure legends

Fig 1.Kaplan-meier curves showing the time to occurrence of AVN.

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Figure

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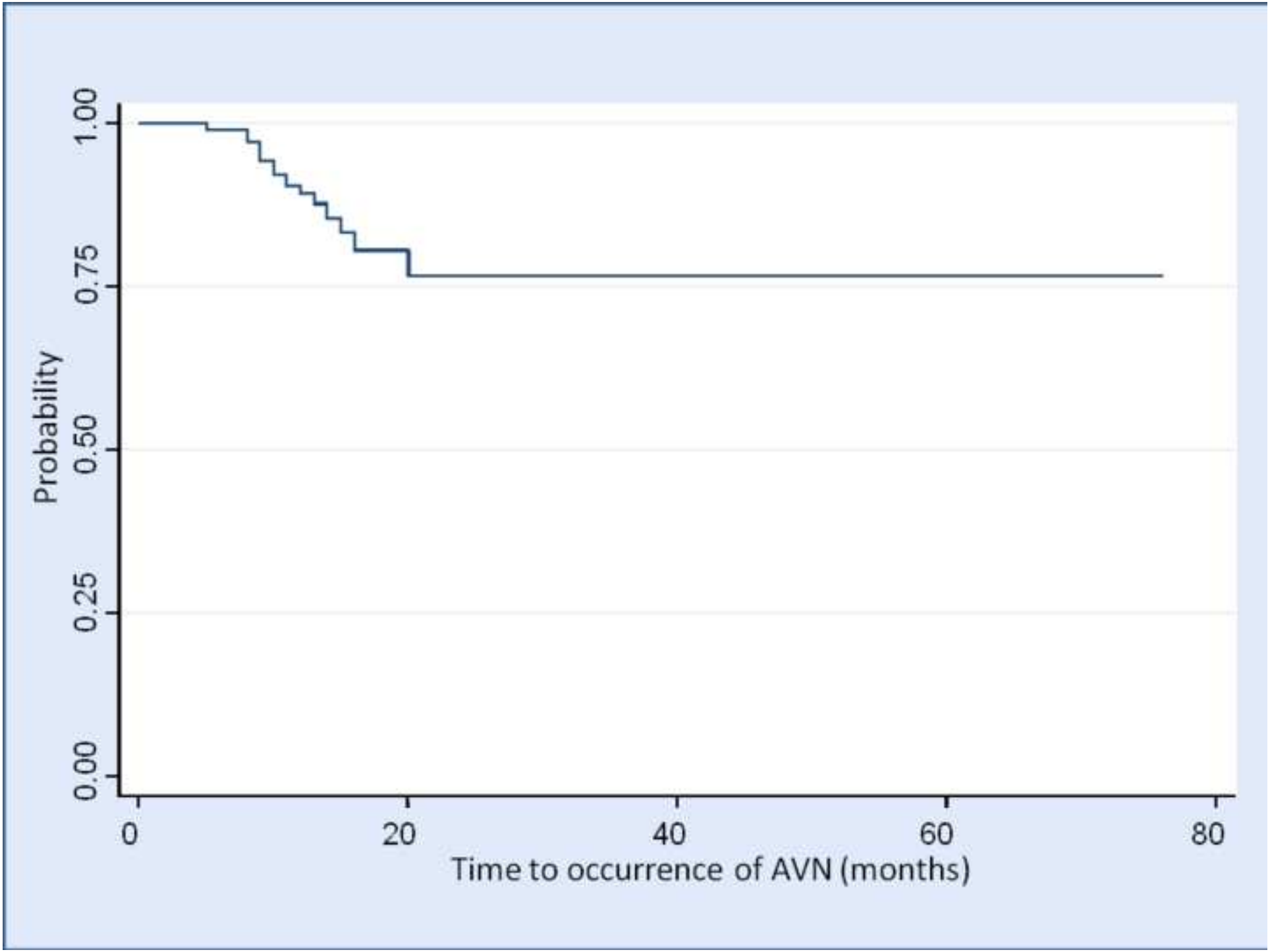

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Risk factors determining the outcomes in femoral neck fractures treated with internal fixation

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