Is non-operative treatment still relevant for Garden Type I fractures in elderly patients? The femoral neck impaction angle as a new CT parameter for determining the indications of non-operative treatment

Jérémy Hardy, Camille Collin, Pierre-Alain Mathieu, Guillaume Vergnenègre, Jean-Louis Charissoux, Pierre-Sylvain Marcheix

Original article

Is Non-Operative Treatment Still Relevant for Garden Type I Fractures in Elderly Patients? The Femoral Neck Impaction Angle as a New CT Parameter for Determining the Indications of Non-Operative Treatment

Jérémy **Hardy** [1], Camille **Collin** [1], Pierre-Alain **Mathieu** [1], Guillaume **Vergnenègre** [1], Jean-Louis **Charissoux** [1], Pierre-Sylvain **Marcheix** [1]

1: Service de chirurgie orthopédique, CHU de Limoges, 2 Avenue Martin Luther King, 87000 Limoges, France

Corresponding author: J Hardy, Service de chirurgie orthopédique, CHU de Limoges, 2 Avenue Martin Luther King, 87000 Limoges, FRANCE

E-mail: geremyhardy@wanadoo.fr

ABSTRACT

Background: The indications of non-operative treatment of undisplaced femoral neck fractures are controversial. The objective of this study was to assess whether two computed tomography (CT) parameters, the femoral neck impaction angle (IA) and the femoral neck posterior tilt angle (PTA), were effective in predicting the risk of secondary displacement after non-operative treatment of Garden I femoral neck fractures in patients aged 65 years or over.

Hypothesis: The working hypotheses were that the IA in the coronal plane and PTA in the axial plane predicted secondary displacement after non-operative treatment of Garden I femoral neck fractures, could be reproducibly and reliably measured on CT scans, and could serve to identify Garden I fractures at risk for secondary displacement after non-operative treatment.

Methods: 49 patients aged 65 years or over with Garden I fractures treated non-operatively were included in a prospective single-centre study. CT images were used to measure the IA as the position of the fracture line relative to the femoral head in the coronal plane and the PTA as the position of the femoral head centre relative to the femoral neck axis in the axial plane.

Results: After non-operative treatment, secondary displacement occurred in 22 (45%) patients. The PTA was not significantly different between the groups with vs. without secondary displacement (p=0.62). IA values ≤135° were significantly associated with secondary displacement (odds ratio, 11.73; 95% confidence interval [95%CI], 3.04-45.28; p=0.004). An IA ≤135° was 72.73% sensitive and 81.48% specific for predicting secondary displacement. IA measurement was reproducible, with intra-class and inter-class Cohen's kappa values of 0.94 (95%CI, 0.90-0.97) and 0.9011 (95%CI, 0.83-0.94), respectively.

Discussion: The IA measured on CT images may hold promise for identifying Garden I hip fractures at high risk for secondary displacement after non-operative treatment. IA measurement is reproducible and reliable and may help to determine the indications of non-operative treatment.

Level of evidence: II, prospective cohort study

Key words: Femoral neck fracture. Elderly. Non-operative treatment. Predictive test. Secondary displacement.

Introduction

Intracapsular femoral neck fractures in individuals older than 65 years constitute a major public health burden and are projected to increase 2-fold by 2050 (1). In patients with Garden type I femoral neck fractures, non-operative treatment carries a high risk of secondary displacement, of 30% according to a 2017 meta-analysis (2). Consequently, many surgeons routinely perform internal fixation (3). In frail elderly patients, however, surgery is associated with complications including an 18% risk of death compared to 14.7% after non-operative treatment (4) and a 10% risk of infection after internal fixation (3). In addition, internal fixation has been followed in up to 28.7% of patients by secondary displacement (5), a complication requiring salvage arthroplasty, which carries far higher rates of mortality and morbidity (dislocation and infection) compared to primary arthroplasty (6).

To our knowledge, no clinical predictors of secondary displacement of Garden I fractures have been reported (7). Pauwels' angle measured on radiographs has been found ineffective in assessing the risk of secondary displacement (8). In contrast, after internal fixation of Garden I fractures, the posterior tilt angle predicted the risk of secondary displacement (9).

The objective of this study was to assess whether two computed tomography (CT) parameters, the femoral neck impaction angle (IA) and the femoral neck posterior tilt angle (PTA), were effective in predicting the risk of secondary displacement after non-operative treatment of Garden I femoral neck fractures in patients aged 65 years or over. Should these parameters prove effective, they could be used to identify patients at high risk for secondary displacement. Internal fixation could then be reserved for high-risk patients, thereby protecting other patients from the risks inherent in internal fixation surgery. The working hypotheses were that the IA in the coronal plane and PTA in the axial plane predicted secondary displacement after non-operative treatment of Garden I femoral neck fractures, could be reproducibly and reliably measured on CT scans, and could serve to identify Garden I fractures at risk for secondary displacement after non-operative treatment.

Material and Methods

Study design and patients

Patients were enrolled in a prospective single-centre study between March 2015 and March 2017. Inclusion criteria were age older than 65 years and Garden I femoral neck fractures documented by radiography and CT. Patients with a history of ipsilateral femoral fracture, a suspicion of pathological fracture, and/or a follow-up duration of less than 6 weeks were not eligible for the study. Of the 55 patients initially considered for inclusion, 3 were lost to follow-up, 1 died 5 days after the injury, and 2 were treated with primary hip arthroplasty. The remaining 49 patients were included in the study and treated non-operatively.

Data collection

Secondary displacement was sought on antero-posterior radiographs obtained 1 week, 3 weeks, 6 weeks, 3 months, and 12 months after discharge. Secondary displacement was defined as varus displacement of the Garden I fracture, resulting in a Garden III and IV fracture, on the antero-posterior radiograph.

For each patient, the following information was collected: age; follow-up duration; and whether secondary displacement occurred, with the time from the injury to secondary displacement.

Non-operative treatment

All 49 patients were managed according to a protocol detailed elsewhere (10). In brief, strict bedrest with analgesics on day 1 was followed on day 2 by chair positioning then on day 3 by full weight-bearing ambulation with help from a physiotherapist. On day 4, an antero-posterior radiograph was obtained to look for secondary displacement. The only role of the physiotherapist was to assist with ambulation.

Imaging study protocol

The diagnosis of Garden I fracture was established by examining the antero-posterior hip radiograph obtained at emergency room arrival. Within 24 hours after admission, CT of the fractured hip was performed. The radiographs and CT images were reviewed by a surgeon (observer 1) and a radiologist (observer 2), who determined whether the patient was eligible for study inclusion. Any disagreement between the two observers was resolved by consensus.

Both observers, who were blinded to the occurrence of secondary displacement, measured the IA and PTA on the CT views. Any differences in angle values between the two observers were resolved by consensus. To allow an assessment of inter-observer reproducibility, a senior surgeon (observer 3) also measured the IA and PTA. Intra-observer reproducibility was assessed by having observer 1 measure both angles again 1 month after the first measurement. For both the inter-observer and the intra-observer reproducibility studies, all observers were blinded to the occurrence of secondary displacement and to the values obtained by the other observers. CT images were evaluated using PACS software version 4.70 (Télémis, Clichy, France).

PTA measurement on lateral hip radiographs has been described by Palm et al. (9). We measured the same angle on axial CT images. The PTA is formed by the axis of the femoral neck and the antero-posterior axis (Figure 1): a line (A) is drawn along the femoral neck, the centre of the femoral head (B) is identified, and the line (C) from point B to the intersection of line A with the circumference of the femoral head is drawn. Lines A and C subtend the PTA.

The impaction angle (IA) was defined for this study as the angle formed in the coronal plane by the axis of the femoral neck and the cranio-caudal axis (Figure 2). A circle (A) tangent to the edges of the femoral head and a line (B) from the proximal to the distal edges of the fracture are drawn. Two lines are then drawn from the centre of the femoral neck to the two points where line B intersects circle A. These two lines subtend the IA.

Statistics

Quantitative variables were described as mean (range) and qualitative variables as number (%).

To determine whether the IA and/or PTA values were associated with secondary displacement, the groups with and without secondary displacement were compared by applying the Mann-Whitney test. If a statistically significant difference was found, logistic regression was performed to compute the odds ratio (OR) as an indicator of the strength of the association between the IA or PTA value and the risk of secondary displacement. ORs were computed with their 95% confidence intervals (95%CIs) and p values.

To identify the cut-off that best discriminated between fractures with and without a risk of secondary displacement, sensitivity and specificity of each angle value for secondary displacement were computed. A receiver operating characteristic (ROC) curve was plotted and the optimal cut-off was identified as the value producing the best compromise between sensitivity and specificity.

To determine whether the IA may hold promise for predicting the risk of secondary displacement, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were computed. True positives (TPs) were defined as IA≤135° and secondary displacement, false positives (FPs) as IA≤135° without secondary displacement, true negatives (TN) as IA>135° without secondary displacement, and false negatives (FNs) as IA>135° with secondary displacement.

Intra- and inter-observer reproducibility of IA measurements was evaluated using Bland-Altman plots (11). The mean of the differences and the limits of agreement (±1.96 standard deviation) were computed. Differences smaller than 10° were considered acceptable. Reproducibility was further assessed by computing Cohen's intra- and inter-class kappa values with their 95%CIs.

Values of *p* smaller than 0.05 were taken to indicate significant differences. The statistical analysis was performed using SAS 9.13 software (SAS Institute, Cary, NC, USA).

Results

Descriptive data (Table 1)

Secondary displacement occurred in 22/49 (45%) patients. Mean time from the fracture to secondary displacement was 13 days (range, 1-51 days). Mean follow-up was 4.1 months (range, 3-6 months).

Posterior tilt angle (PTA) and impaction angle (IA)

The PTA was not significantly different between patients with vs. without secondary displacement (*p*=0.62). Consequently, the PTA was not assessed as a possible predictor of secondary displacement.

The IA was significantly smaller in the patients with vs. without secondary displacement (*p*=0.0011). The potential of the IA for predicting secondary displacement was therefore evaluated. The IA cut-off that best discriminated between patients with vs. without secondary displacement was 135° (Figure 3). Compared to the group with an IA>135°, the group with an IA ≤135° had an OR of 11.73 (95%CI, 3.04-45.28) of experiencing secondary displacement (*p*=0.004). An IA value ≤135° had 72.73% sensitivity, 81.48% specificity, 76.29% PPV, and 78.57% NPV for secondary displacement.

Bland-Altman plots were used to assess the intra-observer (Figure 4) and inter-observer (Figure 5) reproducibility of IA measurement. The 10° difference defined as acceptable for this study fell within the limits of agreement. Observers 1 and 2 obtained different values for only 5 (10%) measurements. During the intra-observer assessment, observer 1 obtained different values for only 6 (12%) measurements. In addition, only 4 (8%) patients were classified differently by observers 1 and 3 during the assessment of inter-observer reproducibility, and only 3 (6%) patients were classified differently by observer 1 during the assessment of intra-observer reproducibility. The mean of the differences was close to 0 (-0.62 and -0.43), indicating no tendency to over- or underestimate the angle values between observers 1 and 3 or by observer 1 at two different points in time. Cohen's kappa was 0.94 (95%CI, 0.90-0.97) for the intra-class correlation and 0.90 (95%CI, 0.83-0.94) for the inter-class correlation.

Discussion

The main findings from our study of Garden I hip fractures in patients aged 65 years or over are that secondary displacement is common after non-operative treatment (45%) and that the PTA measured on CT images fails to predict secondary displacement, in contrast to the IA, which is associated with secondary displacement when ≤135°. Thus, the IA may hold promise for guiding the choice between non-operative and operative treatment in elderly patients with Garden I fractures. In addition, IA measurement on CT views showed good inter-observer and intra-observer reproducibility.

Strong points of the study

IA measurement could be used to identify elderly patients with Garden I fractures in whom non-operative treatment is unlikely to be followed by secondary displacement. Non-operative treatment is not associated with higher rates of avascular necrosis (11.3%) (4) or non-union (2.3%) (12) compared to internal fixation. In a multicentre prospective study, internal fixation and non-operative treatment were followed by similar levels of patient self-sufficiency (Parker score, 5 and 5.5, respectively). Thus, selecting non-operative treatment in patients whose IA is ≤135° avoids the morbidity and mortality associated with surgery while providing fracture healing and self-sufficiency rates similar to those seen after surgical treatment.

Limitations of the study

Mean follow-up was only 4.1 months, with a range of 3 to 8 months. However, secondary displacement has never been reported more than 68 days after non-operative treatment of Garden I fractures (13). Reproducibility of IA measurement on CT views was good in our study but might nevertheless be further improved by having a radiologist perform the measurements on native CT views. Finally, the statistical power of the study is limited due to the small number of patients. A further study in a larger sample size would improve the reliability of the statistical findings.

External validity

The mean age of 84.8 years in our study is slightly higher than in similar reports (82.8 years in (14)). The sex ratio indicated a marked female bias (0.11), as reported previously (0.15 (14)). The secondary displacement rate of 45% in our study was higher than in work by Xu et al. (30% (2)) but comparable to the rate reported by Vereyen et al. (47.7% (15)).

Palm et al. (8) reported that the PTA predicted secondary displacement after internal fixation of Garden I fractures. However, Lapidus et al. (16) failed to replicate this finding, and the PTA was not associated with secondary displacement in our study of patients managed non-operatively.

Possible clinical implications

Our findings suggest that the IA may hold promise for selecting those patients with Garden I fractures most likely to benefit from non-operative treatment. The IA may also prove useful for determining the indications of internal fixation in patients with Garden I or II fractures. Primary arthroplasty may be preferable in patients at high risk for secondary displacement (IA≤135°) to avoid both secondary displacement after non-operative treatment and failure of internal fixation. This strategy would decrease the risk of salvage arthroplasty, which carries high mortality and morbidity rates (6).

The cost of the CT evaluation and close patient monitoring required to use the IA must be weighed against the cost of managing failures of non-operative therapy or internal fixation, both of which are associated with longer hospital stays and more complex surgical procedures. Although hip hemi-arthroplasty is relatively inexpensive due to the shorter follow-up, routine arthroplasty treatment of all Garden I fractures does not seem warranted, given the non-negligible surgical risks. A cost-effectiveness study is needed.

Conclusion

IA measurement on CT views is useful for specifying the indications of non-operative treatment in patients aged 65 years or over who have Garden I hip fractures. In patients whose IA is >135°, non-operative therapy is likely to produce favourable outcomes, thereby avoiding unnecessary surgery and the attendant complications. In contrast, an IA ≤135 is associated with a high risk of secondary displacement that indicates either internal fixation or hemi-arthroplasty.

Disclosure of interest

None of the authors has any conflicts of interest to declare.

Funding

None

Contributions of each author

All authors contributed equally to all the actions involved in performing and reporting this work.

Table 1. Demographic features, secondary displacements, and computed tomography findings in the study patients

	Secondary displacement	**No secondary displacement**	**Total**
Age, years, mean (range)	84.5 (65 to 95)	85 (65 to 95)	84.8 (65 to 95)
Males/Females	0/22	5/22	5/44
FN-IA, degrees, mean (range)	129.8 (95 to 180)	150 (101 to 190)	141.66 (95 to 190)
≤135°, n (%)	16 (72%)	5 (19%)	21 (43%)
>135°, n (%)	6 (28%)	22 (81%)	28 (57%)
FN-PTA, degrees, mean (range)	9.7 (-29 to 8)	8.7 (-42 to 9)	9.21 (-41 to 9)

FN-IA, femoral neck impaction angle; FN-PTA, femoral neck posterior tilt angle

FIGURE LEGENDS

Figure 1: Measurement of the posterior tilt angle (PTA)

Left: the PTA is 8.8°

Right: the PTA is 41°

Figure 2: Measurement of the impaction angle (IA)

Left: the IA is 123.3°

Right: the IA is 167.5°

Figure 3: Receiving Operator Characteristic curve used to determine the best impaction angle cut-off for discriminating between fractures with and without a risk of secondary displacement. The cut-off indicated by the point located above and farthest from the line of no discrimination is 135°.

Figure 4: Bland-Altman plot for intra-observer agreement

Figure 5: Bland-Altman plot for inter-observer agreement

References

1. Brutel C, Omalek L. Demographic projections for France, its regions and departments on the horizon in 2030. INSEE 2003 data, insee.fr/fr/ffc/docs ffc/irsoc016.pdf.

2. Xu DF, Bi FG, Ma CY, Wen ZF, Cai XZ. Systematic review of undisplaced femoral neck fracture treatments for patients over 65 years of age, with a focus on union rates and avascular necrosis. J Orthop Surg Res 2017;12:28

3. Conn KS, Parker MJ. Undisplaced intracapsular hip fractures: results of internal fixation in 375 patients. Clin Orthop Relat Res 2004;421:249–54.

4. Raaymakers EL, Marti RK. Non-operative treatment of impacted femoral neck fractures. A prospective study of 170 cases. J Bone Joint Surg Br 1991;73(6):950–4.

5. Hui AC, Anderson GH, Choudhry R, Boyle J, Gregg PJ. Internal fixation or hemiarthroplasty for undisplaced fractures of the femoral neck in octogenarians. J Bone Joint Surg Br 1994;76:891–4.

6. **McKinley JC, Robinson CM.** Treatment of displaced intracapsular hip fractures with total hip arthroplasty: comparison of primary arthroplasty with early salvage arthroplasty after failed internal fixation. J Bone Joint Surg Am 2002;84:2010–5.

7. Heetveld MJ, Raaymakers EL, Luitse JS, Nijhof M, Gouma DJ. Femoral neck fractures: can physiologic status determine treatment choice? Clin Orthop 2007;461:203–12.

8. Parker MJ, Dynan Y. Is Pauwels classification still valid? Injury 1998;29:521–3.

9. Palm H, Gosvig K, Krasheninnikoff M, Jacobsen S, Gebuhr P. A new measurement for posterior tilt predicts reoperation in undisplaced femoral neck fractures: 113 consecutive patients treated by internal fixation and followed for 1 year. Acta Orthop 2009;80:303–307

10. Simon P, Gouin F, Veillard D, et al. Femoral neck fractures in patients over 50 years old. Rev Chir Orthop Reparatrice Appar Mot. 2008;94:S108–32.

11. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1: 307–10.

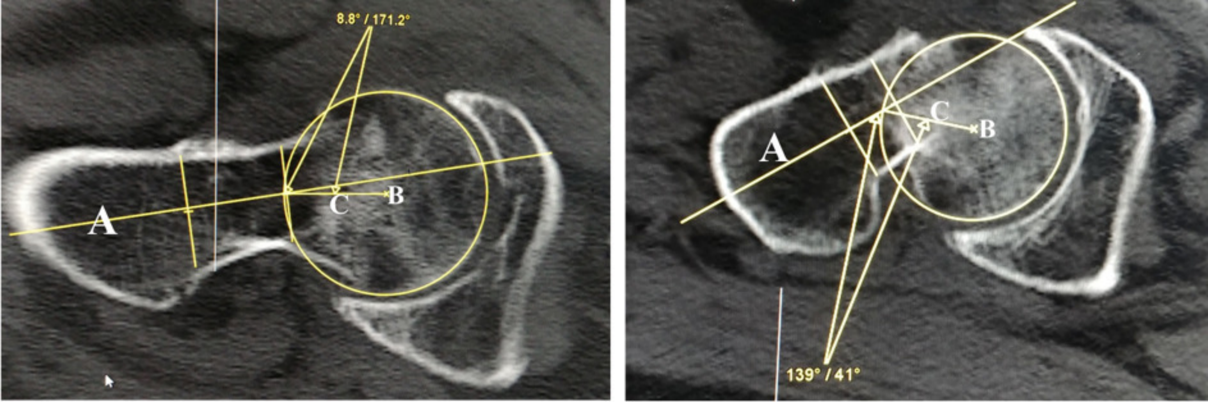
12. Bentley G. Treatment of non-displaced fractures of the femoral-neck. Clin Orthop Relat Res 1980;152:93–101.

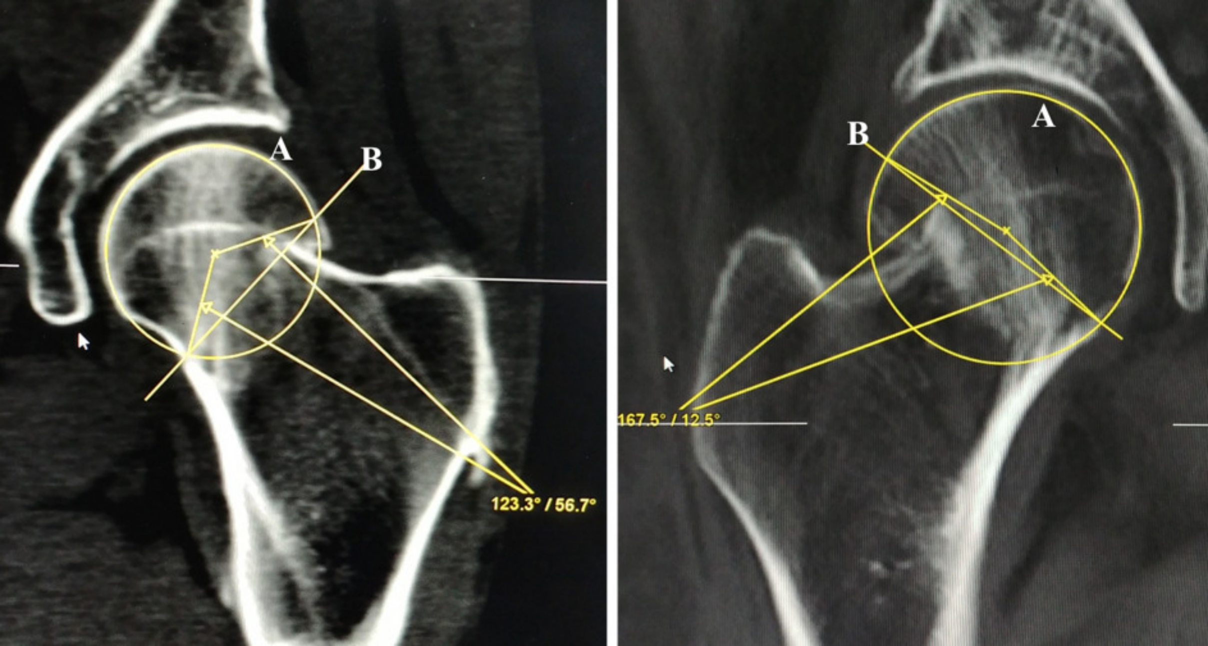
13. Shugiang M, Kunzheng W, Zhichao T, Mingyu Z, Wei W. Outcome of non-operative management in Garden I femoral neck fractures. Injury. 2006;37:974–8.

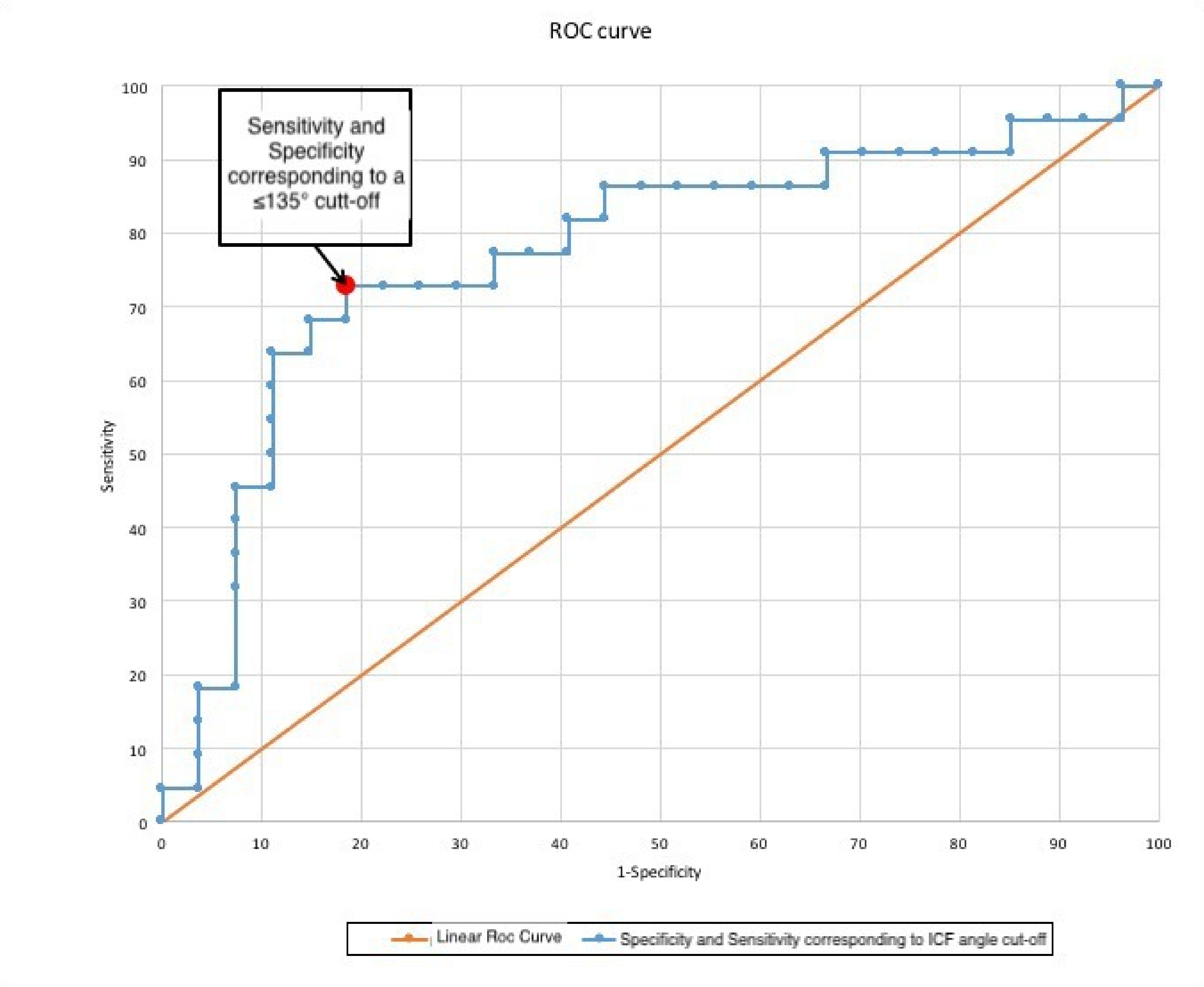
14. Buord JM, Flecher X, Parratte S, Boyer L, Aubaniac JM, Argenson JN. Garden I femoral neck fractures in patients 65 years old and older: is conservative functional treatment a viable option? Orthop Traumatol 2010;96:228–34.

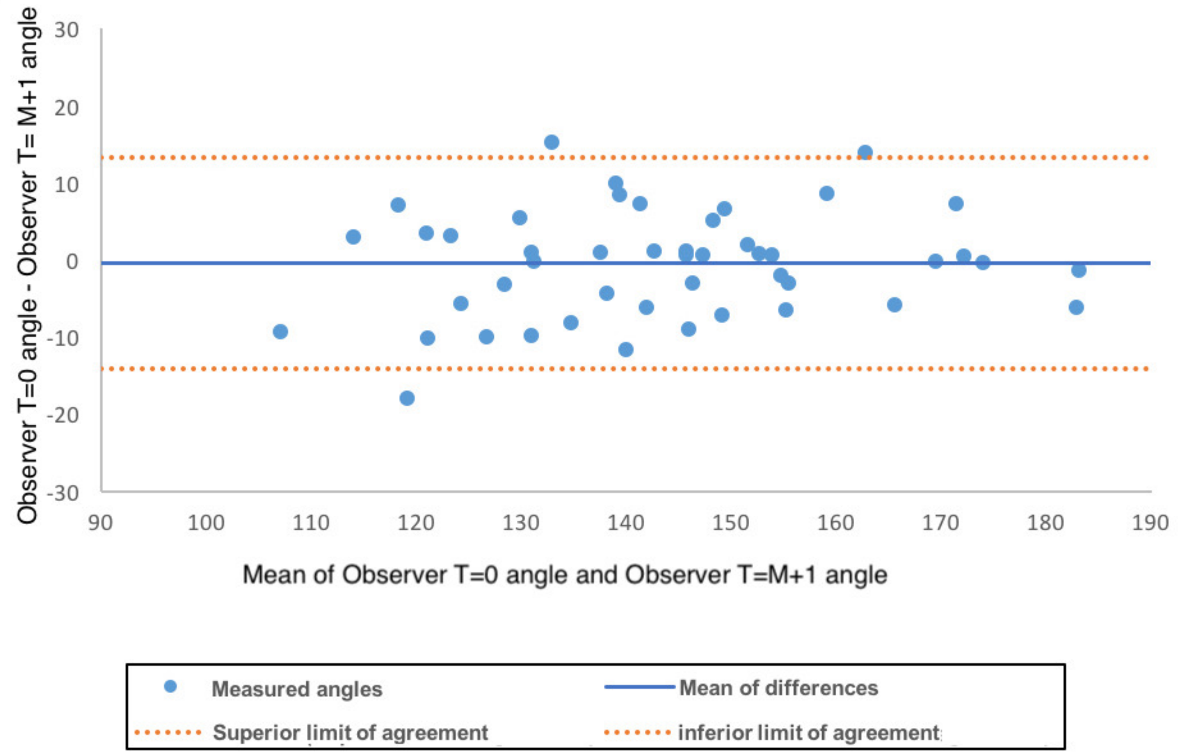
15. Verheyen CC, Smulders TC, van Walsum AD. High secondary displacement rate in the conservative treatment of impacted femoral neck fractures in 105 patients. Arch Orthop Trauma Surg 2005;125:166–8.

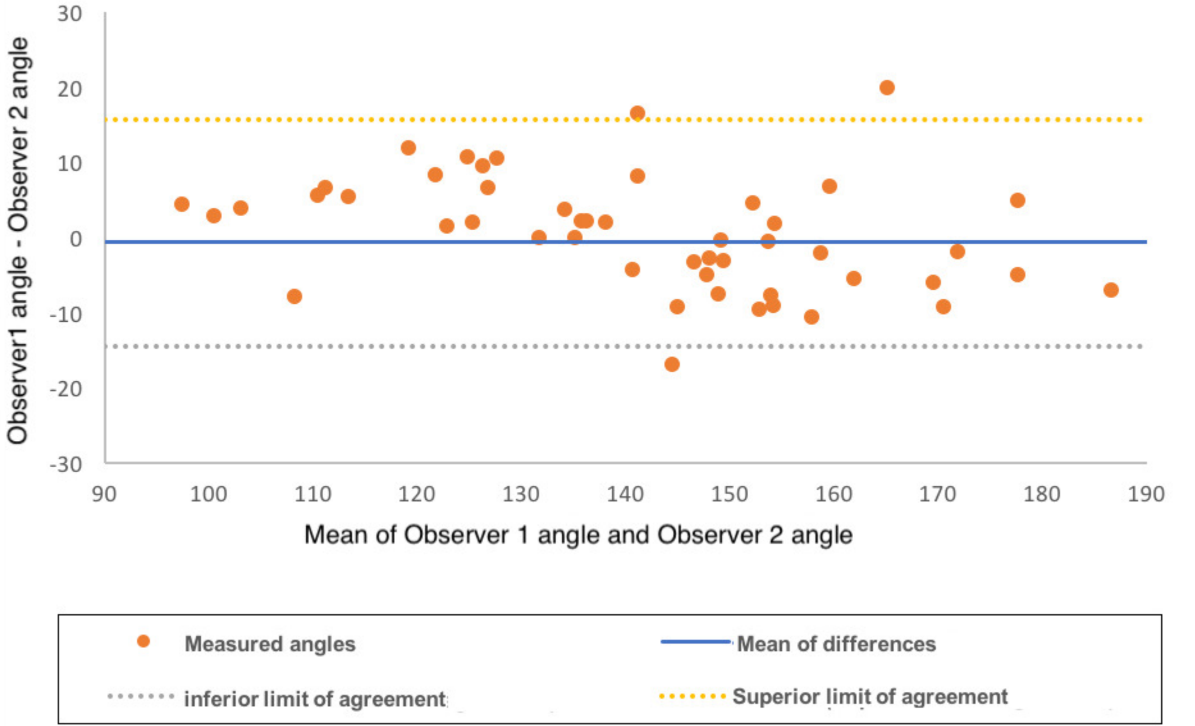
16. Lapidus LJ, Charalampidis A, Rundgren J, Enocson A. Internal fixation of Garden I and II femoral neck fractures: Posterior tilt did not influence the reoperation rate in 382 consecutive hips followed for a minimum of 5 years. J Orthop Trauma 2013;27:386–391


8.8° / 171.2°
A
C
B
A
C
B
139° / 41°


A
B
123.3° / 56.7°
A
B
167.5° / 12.5°


ROC curve
Sensitivity and Specificity corresponding to a ≤135° cutt-off
Sensitivity
1-Specificity
0
10
20
30
40
50
60
70
80
90
100
Linear Roc Curve
Specificity and Sensitivity corresponding to ICF angle cut-off


Observer T=0 angle - Observer T= M+1 angle
30
20
10
0
-10
-20
-30
90
100
110
120
130
140
150
160
170
180
190
Mean of Observer T=0 angle and Observer T=M+1 angle
Measured angles
Mean of differences
Superior limit of agreement
inferior limit of agreement



30
20
10
0
-10
-20
-30
Observer1 angle - Observer 2 angle
90
100
110
120
130
140
150
160
170
180
190
Mean of Observer 1 angle and Observer 2 angle
Measured angles
Mean of differences
inferior limit of agreement
Superior limit of agreement