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Estimating femoral nail length in bilateral comminuted fractures using fibular and femoral head referencing

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Summary

Objective: Femoral nail length can be estimated preoperatively by several methods, but this usually requires an intact contralateral femur. The aim of this study was to determine an alternative method using fibula and femoral head as references.
Materials and methods: Digital radiographic views of the lower limbs of 102 healthy volunteers were used to compare femoral medullary length with the sum of fibular length and transverse head diameter.
Results: Femoral medullary length and the estimated length were highly correlated ($r = 0.942$, $p < 0.0001$). Paired samples t-testing has produced a high significance ($p < 0.002$).
Conclusion: The formula provides a simple and accurate estimation of femoral medullary length, and may be used in nailing, particularly of bilateral comminuted femoral fractures.

Introduction

Femoral intramedullary nailing, initially described by Kuntscher in 1940, was accepted as the standard treatment of stable diaphyseal femoral fractures.[3,4,10,13,14,17] In the following period, imaging methods have provided detailed medullary morphology of the femur. With the progress of metallurgical sciences, design techniques have also improved. These advances have made possible the use of intramedullary nailing even in bilateral comminuted fractures of the femoral diaphysis.[1,6,7,9,11,12,15,16]

After more than 60 years, this technique still has significant shortcomings such as limb length

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discrepancy or malreduction. The typical error on a radiolucent table is failure to restore full limb length, whereas on a fracture table excessive length is a common mistake.[17,16] Furthermore, radiological methods that are generally used to determine the optimal length of the intramedullary nail require an intact contralateral femur for measurement, so these techniques are inadequate in bilateral comminuted femoral fractures. Therefore it is not always possible to restore the original femoral length.[17] In such cases, alternative approaches are used to estimate the actual length and to ensure that the correct range of nails is available in the operating theatre.[2]

In this study, the objective was to find a simple radiological method that might be used preoperatively to determine optimal intramedullary femoral nail length in bilateral comminuted fractures.

Materials and methods

The study population comprised 102 healthy volunteers (48 men and 54 women) with no systemic illness nor congenital or traumatic pelvic or lower extremity disorder. The age of the volunteers ranged from 18 to 68 years (mean 41.1 years, S.D. 15.0 years), and equal numbers of participants were recruited for every 10-year period.

All participants were fully informed about the purpose and method of the study, and their written consents were obtained. The study was approved by the institutional ethical board.

Anteroposterior digital radiographic views of both lower extremities in the supine position were obtained using a CT scanner (Tomoscan Secura, Philips, Best, Netherlands). Radiographic views were hard-copied onto standard video films on which measurements were performed. The study

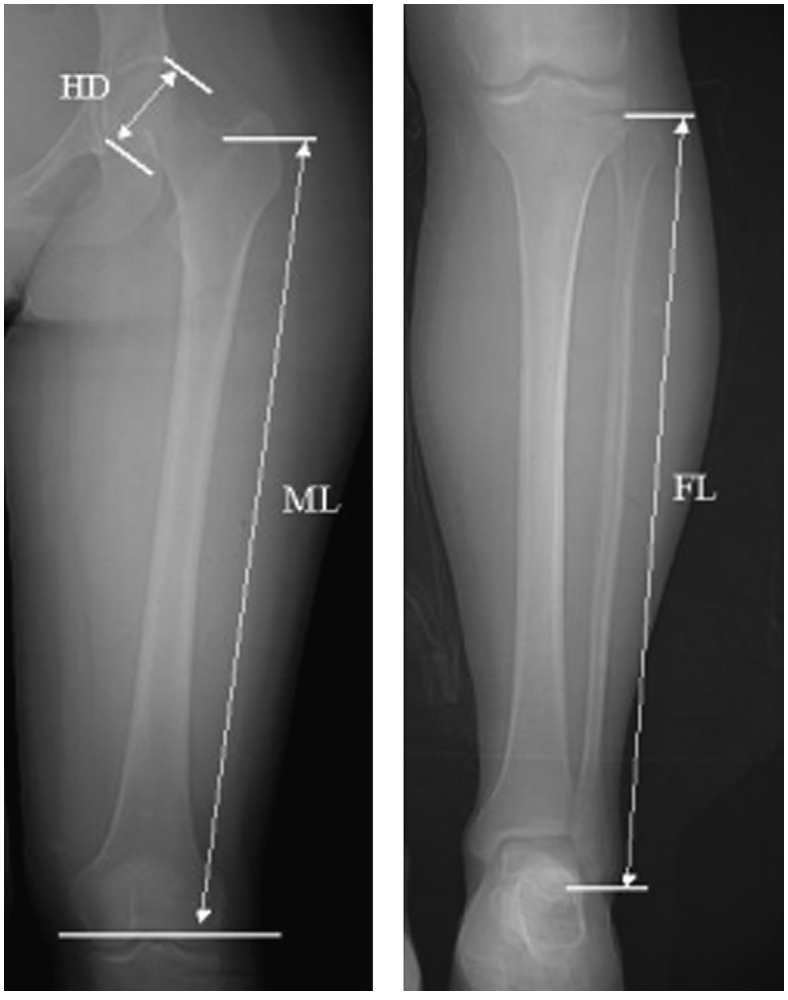

Figure 1 A representative digital radiographic view (CT topogram) on which measurements were carried out. Femoral head diameter (HD), femoral medullary length (ML) and fibular length (FL) measurements were performed on the left lower extremity.

group was also involved in a previous study, which necessitated the positioning of the right hip in 40–45° of flexion; therefore, only left femoral measurements were taken into consideration.

The femoral length referencing method involves the calculation of fibular length and femoral head diameter. Fibular length was defined as the distance between the proximal and distal ends of the bone. Femoral head diameter was defined as the longest distance between the inferomedial and superolateral margins of the head. Femoral medullary length was defined as the vertical distance between the fossa priformis and the intercondylar notch (Fig. 1).

Measurements were performed by H.M.K. on the printed films, using the scale bar printed next to the images. We preferred not to use electronic measurement methods on diagnostic workstations, in order to simulate basic clinical conditions in which only hard copies might be available. Statistical analysis of data was carried out using SPSS 13.0. Actual femoral medullary length was compared with the sum of the fibular length and the femoral head diameter. Paired samples *t*-testing was applied to the statistical differences, and their correlation was tested with Pearson's moment correlation coefficients.

Results

Femoral medullary length ranged from 34.4 to 49.5 cm (mean 39.9 cm, S.D. 2.7 cm). When the volunteers were divided according to gender, femoral medullary length ranged from 37.3 to 45.0 cm (mean 41.2 cm, S.D. 1.9 cm) among the men, and 34.4 to 49.5 cm (mean 38.6 cm, S.D. 2.8 cm) among the women.

Referring to the whole group, the sum of fibular length and femoral head diameter ranged from 34.6 to 49.8 cm (mean 40.1 cm, S.D. 2.9 cm). There was no difference between femoral medullary length and the above formula (paired samples *t*-test, $p < 0.002$). When volunteers were divided according to gender, the sum ranged from 37.4 to 44.9 cm (mean 41.6 cm, S.D. 1.9 cm) among the men, and from 34.6 to 49.8 cm (mean 38.8 cm, S.D. 2.9 cm) among the women. The significance level was unchanged for men ($p < 0.009$), whereas women had an insignificant level of difference.

Actual femoral medullary length and the length that was estimated by the above formula were highly correlated (Pearson's moment correlation coefficients, $r = 0.942$, $p < 0.0001$) (Fig. 2). When volunteers were divided according to gender, the correlation was $r = 0.842$, $p < 0.0001$ for men, and $r = 0.956$, $p < 0.0001$ for women.

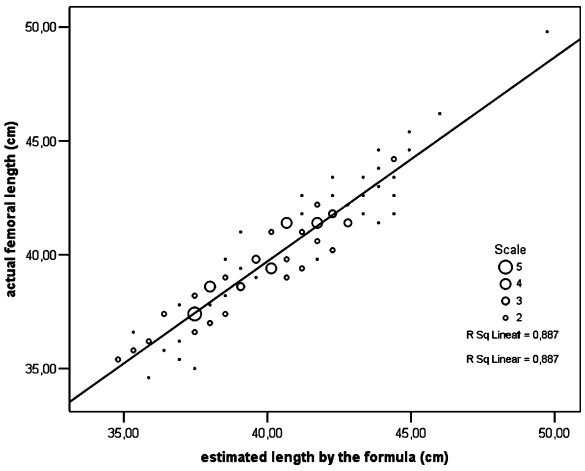

Figure 2 Scatter plot showing the relationship between actual femoral medullary length and the sum of fibular length and femoral head diameter.

Discussion

Good preoperative planning is essential to restore original femoral length by intramedullary nailing. Several methods have been developed for that purpose. Nail templates are available to determine the appropriate nail length.[8] A radio-opaque ruler also helps to determine the size of the contralateral intact femur on radiographs. Alternatively, the most suitable nail may be identified by placing different nails next to the intact femur, using perioperative radiography. A Kuntscher ossimeter can measure the length of the intact contralateral femur also.[5,17] All of these methods depend on the presence of an intact contralateral femur. In bilateral comminuted fractures, the measurement becomes very complicated. In these cases, measurements are performed on the less comminuted side, and identical nails are implanted on both sides.[17] However, even the most rigorous applications may result in underestimation or overestimation of limb length.

Our method depends on the availability of an anteroposterior radiograph of the femur, an additional anteroposterior radiograph of the ipsilateral lower leg, and an incorporated scale such as a radio-opaque ruler. Digital radiography and CT are better alternatives, as they permit direct measurements by placing electronic cursors on the screen. The ideal length may be determined by measuring fibular length and femoral head diameter on the images. In addition to its radiographic simplicity, this method has the advantage of having objective reference points, and it provides highly accurate values. In the present study, CT was used to image the bones. In the scanogram mode, these scanners have the capability to obtain a continuous digital image up to 180 cm or more. Their field of view is

much larger than that reached by current flat panel detectors, which is usually up to 40 cm; a greater field of view is necessary to image femora. In the actual clinical setting there is no need to obtain a full femoral view, and one may use digital radiography instead of CT; the latter may yield slightly higher measurements caused by the magnification factor. This magnification is due to the presence of a divergent beam and the distance between the object (i.e. bones) and the detector. This effect is minimised by the relatively minor object-to-detector distance for bones, and it may further be improved by the use of higher source-to-object distance and the availability of built-in magnification correction algorithms.

Following estimation of medullary length, the length of nail is determined. Ideally, the tip must be located at a given distance from the intercondylar notch, and far from the fracture level. The distance between the intercondylar notch and distal tip of the nail is subtracted from the estimated medullary length. The resulting figure is used as the optimal length of the nail in antegrade nailing. A similar formula may also be used in retrograde nailing.

Conclusion

The formula *fibular length + femoral head diameter* may serve as a simple and highly accurate method of estimating actual femoral medullary length where the contralateral femur cannot be used to do so. Therefore it may be used in nailing, particularly in cases of bilateral comminuted femoral fractures.

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