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Original article

Preoperative determination of tibial nail length: An anthropometric study

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ABSTRACT

Objective: To assess the correlation between five anthropometric parameters and the distance from tibial tuberosity to medial malleolus in 100 volunteers.

Methods: Six anthropometric parameters were measured in 50 male and 50 female medical students using a metallic scale: medial knee joint line to ankle joint line (K-A), medial knee joint line to medial malleolus (K-MM), tibial tuberosity to ankle joint (TT-A), tibial tuberosity to medial malleolus (TT- MM), olecranon to 5th metacarpal head (O-MH) and body height (BH). Nail size predicted based upon TT-MM measurement was chosen as ideal nail size. A constant was derived for each of the six anthropometric parameters which was either added or subtracted to each measurement to derive nail size. A regression equation was applied to BH measurements. Nail sizes calculated were compared with that obtained from TT-MM measurement and accuracy was evaluated. Accuracy of O-MH and BH regression equations recommended by other authors were calculated in our data.

Results: Adding 11 mm to TT-A distance had highest accuracy (81%) and correlation (0.966) in predicting nails correctly. Subtracting 33 mm from K-MM measurement and 25 mm from K-A distance derived accurate sizes in 69% and 76% respectively. Adding 6 mm to O-MH distance had a poor accuracy of 51%. Nail size prediction based upon body height regression equation derived correct nail sizes in only 34% of the cases. Regression equation analysis by other authors based on O-MH and BH distances yielded correct sizes in 11% and 5% of the cases respectively.

Conclusion: TT-A, K-A and K-MM measurements can be used simultaneously to increase accuracy of nail size prediction. This method would be helpful in determining nail size preoperatively especially when one anatomic landmark is difficult to palpate.

Introduction

Tibial shaft fractures comprise 2% of all adult fractures.[1] Intramedullary interlocking nailing is the gold standard in the treatment of tibial shaft fractures in adults.[2] Insertion of the correct-sized nail is essential to obtain satisfactory outcomes. A shorter nail results in malreduction and inadequate working length, leading to failure of the implant. A longer nail would distract the fracture site and impinge on the patellar tendon, causing pain. Forceful insertion of a longer nail could cause the penetration of the nail into the tibiotalar joint.

Various methods have been mentioned in literature to estimate the accurate nail size. The intraoperative methods used are the two guide wires technique, nail-against-limb technique and using a radiographic ruler.[3–5] The two guide wires technique cannot be used when unreamed nails are used.[6] The preoperative radiological methods described are krammer splint technique, templating, scanograms, spotograms and direct measurement from radiographs of the contralateral limb.[5,7]

Anthropometric measurements described for the preoperative estimation of tibial nail length are knee joint line to ankle joint line (K-A), knee joint line to medial malleolus (K-MM), tibial tuberosity to ankle joint line (TT-A), tibial tuberosity to medial malleolus (TT-MM), olecranon to fifth metacarpal head (O-MH) and body height (BH).[6–10]

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Intraoperative techniques consume valuable operating time and add radiation exposure of both the patient and the operating room personnel. So if the tibial nail length can be determined accurately preoperatively, we could avoid these problems. This also avoids wastage of inaccurate nails which are discarded during the operative procedure.[8] Exchanging an incorrect length nail increases the operative time, X-ray irradiation and causes the frustration of the surgeon. Preoperative methods which rely on conventional radiography can cause inaccuracies due to malrotation in positioning the patient, inadequate exposure and variation in magnification.[7] Anthropometric measurements provide an easy way to preoperatively estimate tibial nail lengths accurately.[8] Existing literature provides varying and contrasting accuracies to each anthropometric parameter used currently and investigates their interrelationship.

This study aimed to compare the different anthropometric measurements so as to explore the interrelationship between them for predicting nail size and determining their accuracy.

Methods

A hundred medical students (fifty males and fifty females) were included in the study. This study was approved by the ethics committee and informed written consents were taken. All participants had an age more than 18 years and the patients with previous fractures of the tibia, forearm and metacarpals were excluded. The following anthropometric parameters were measured using a metallic scale in each participant: K-A, K-MM, TT-A, TT-MM, O-MH and BH (Fig.1). The anatomical landmarks used for measurement of each parameter were defined based upon previous studies in literature.[6–9]

K-A was measured from a point on the medial knee joint line 3 cm medial to the medial edge of patellar tendon to another point on the medial ankle joint line felt as a depression just medial to the tibialis anterior tendon at the medial corner of the ankle joint.[6,8] K-MM was measured from the medial knee joint line 3 cm medial to the medial edge of patellar tendon to the most prominent point on the medial malleolus.[6] TT-A was determined by measuring the distance between the most prominent point on the tibial tuberosity and the medial ankle joint line. TT-MM was defined as the distance between the most prominent points on the tibial tuberosity and medial malleolus.[6,7] These parameters were measured when the participant was in the supine position with the knee flexed to 90°, the ankle dorsiflexed and the leg externally rotated. Distance between the tip of olecranon to the 5th metacarpal head constituted O-MH.[6,9] This measurement was taken with the elbow and metacarpophalangeal joints at 90°of flexion and the wrist in neutral position. Body height was measured in a standing position.

Nail size predicted from the TT-MM measurement was chosen as the ideal nail size. If the predicted nail length fell between available nail sizes, the shorter nail size was selected except if it was within 5 mm of the available larger sized nail. In that situation, the higher sized nail was chosen. For example, if the TT-MM measurement was 350 mm, 345 mm was chosen as the nail size for that method. However, if the measurement was 355 mm, 360 mm was selected.

Statistical analysis was done using Microsoft Excel Software. The mean value of the differences between the TT-MM measurement and each anthropometric parameter was calculated. By this method and based upon the highest degree of correlation calculated by Pearson's correlation coefficient, a constant was derived which was either added or subtracted from each anthropometric measurement to calculate the predicted nail size. To predict nail size based on BH measurements, a regression equation was derived using linear regression analysis (BH equation).

The nail size predicted based upon each anthropometric parameter was compared with that derived from the TT-MM measurement. Accuracy of the nail size calculation based upon each anthropometric parameter measurement was evaluated as a percentage and the 95% confidence interval (CI) was calculated. Nail size calculation applying the regression equations recommended by Fischmeister et al[10] (nail length $= -5.05729 + 0.222 \times$ BH) and Blair[9] (nail length $= 9.1 + 0.93 \times$ O-MH) was also done. This was compared with the ideal nail size calculated from the TT-MM distance to measure the accuracy of these two methods in our study population.

Results

Nail size derived from each anthropometric parameter was compared with the ideal nail size calculated from the TT-MM measurement. The results are summarized in Table 1. The average of the differences between TT-MM and TT-A distance was 11 mm. Adding 11 mm to the TT-A distance gave the highest correlation ($r = 0.989$) to the TT-MM measurement (Table 2). So adding 11 mm to each TT-A measurement derived the nail size predicted by that method.

Similar calculations were done with the K-MM, K-A and O-MH parameters too (Table 2). Nail sizes were predicted by subtracting 33 mm from each K-MM measurement and 25 mm from each K-A measurement. The 6 mm was added to the O-MH distance to arrive at a nail size. The regression equation calculated for BH measurement was as follows: TT-MM $= 4.498 + 2.107 \times$ BH.

Among all the anthropometric parameters, TT-A distance was the most accurate (accuracy of 81%, 95% CI 0.73–0.89) in predicting the nail size (Table 3). Correlation to the ideal nail size was also the

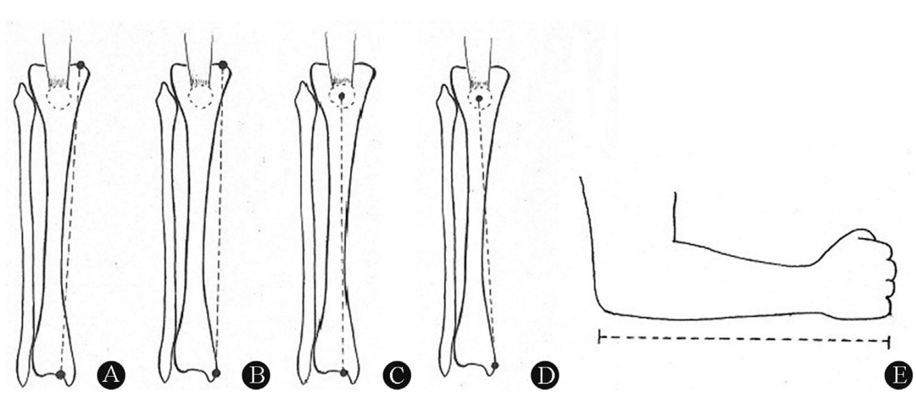

Fig. 1. Anthropometric measurements. A: K-A; B: K-MM; C: TT-A; D: TT-MM; E: O-MH.

Table 1
Various anthropometric measurements with their corrections and nail size measurements.

Measurement	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard deviation
TT-MM	295	415	349.7	23.6
TT-MM nail	300	420	349.7	24.7
TT-A	290	400	338.9	22.0
(TT-A) +11 mm	301	411	349.9	22.0
(TT-A) +11 nail	300	405	349.2	22.5
K-MM	315	460	382.7	26.8
(K-MM) −33 mm	282	427	349.7	26.8
(K-MM) −33 nail	285	420	348.0	27.0
K-A	305	450	374.5	26.6
(K-A) −25 mm	280	425	349.5	26.6
(K-A) −25 nail	285	420	350.0	26.4
O-MH	290	405	343.9	24.2
(O-MH) +6 mm	296	411	349.9	24.2
(O-MH) +6 nail	300	405	348.9	24.6
BH	148	187	163.8	8.8
BH(equation)	316	399	349.7	19.7
BH(equation) nail	315	390	346.5	19.6

Table 2
Correlation of the corrected anthropometric measurements to TT-MM distance.

Measurement	Correlation with TT-MM distance	*p* value
(TT-A) + 11 mm	0.989	0.01
(K-MM) −33 mm	0.973	0.01
(K-A) − 25 mm	0.971	0.01
(O-MH)+6 mm	0.867	0.01
BH (equation)	0.790	0.01

highest with TT-A distance (Table 3). A similar linear correlation was noted with K-MM and K-A nails too. TT-A distance predicted incorrect nails in 19% of the cases (95% CI 0.11–0.27). A longer incorrect nail was predicted in only 8% of the cases (95% CI 0.03–0.13). The next accurate method was K-A measurement which predicted correct nail size in 76% of the cases (95% CI 0.68–0.84). K-MM distance was also reasonably accurate, predicting a longer nails in only 10% of the cases (95% CI 0.04–0.16). O-MH and BH (equation) measurements fared poorly with correct nail sizes predicted in only 51% (95% CI 0.41–0.61) and 34% (95% CI 0.25–0.43) of the cases respectively (Table 3). Nail size calculation based upon the regression equations used by Fischmeister et al and Blair yielded inaccurate nails in 95% (95% CI 0.91–0.99) and 89% (95% CI 0.83–0.95) of the cases respectively.

Discussion

Several anthropometric methods have been described for the preoperative estimation of tibial nail length. A simple and accurate method is the direct or indirect measurement of the distance between the tibial tuberosity and medial malleolus.[7,9,11,12] Our study aimed to compare the common anthropometric measurements with the TT-MM distance for preoperative determination of tibial nail size.

Conventional radiographic techniques pose the problem of errors due to magnification. Krettek et al[13] reported a magnification of 7% in standard tibial radiographs and found templates unreliable in selecting implant length.[13] Magnification would depend on the splint used and the position of the limb. Scannograms are not routinely done in the trauma setting. Some authors recommended the routine use of radiographic ruler or marker at the level of the tibia for each anterioposterior radiograph of the leg when a fractured tibia was suspected.[6] The feasibility of such a practice, especially in a poly trauma situation, is questionable. Moreover, the radiographic marker if not kept at the level of tibia could result in poor accuracy in determining correct nail length.[6]

Intraoperative techniques such as the guide wire method and the radiographic ruler have an excellent accuracy of 94% according to Galbraith et al.[6] Inaccuracies may occur due to eccentric C-arm placement, with the measurement being taken from the lowest exposed part of the guide wire or by not holding the radiographic ruler close and paralleled to the tibia.[6] These techniques cannot be utilized in comminuted fractures of tibia as restoration of normal leg length requires comparison with the opposite side. Intraoperative methods lead to added fluoroscopic exposure to operating room personnel as well as increased operating time. Though they are considered to be the most accurate methods, they provide no scope for preoperative planning and are not recommended in isolation for estimation of tibial nail length.[6,9]

Anthropometric measurements for the preoperative assessment of tibial nail length have been studied previously, with varying accuracies (Table 4). Colen and Prieskorn[7] found the TT-MM distance to be the most accurate (accuracy of 71%) among the four methods tested, including full-length scanograms, spotograms, acrylic template overlays and TT-MM distance. Galbraith et al[6] and Venkateswaran et al[8] reported an accuracy of 38% and 64% respectively using TT-MM measurement. In the study by Venkateswaran et al,[8] the tip of medial malleolus was used as the anatomical landmark. According to Galbraith et al,[6] K-A measurement is the only recommended anatomical measurement for predicting nail size. However, they did not apply any constant to be

Table 3
Comparison of the nail sizes derived from the various anthropometric parameters after correction with the ideal nail size.

Measurement	Correlation to ideal nail [r (*p*)]	Accuracy (%)	Incidence of incorrect nail predicted (%, 95% *CI*)	Incidence of longer than ideal nail (%, 95% *CI*)	Incidence of shorter than ideal nail (%, 95% *CI*)
(TT-A) +11 nail	0.966 ($p = 0.01$)	81	19 (0.11–0.27)	8 (0.03–0.13)	11 (0.05–0.17)
(K-MM) −33 nail	0.953 ($p = 0.01$)	69	31 (0.22–0.40)	10 (0.04–0.16)	21 (0.13–0.29)
(K-A) −25 nail	0.960 ($p = 0.01$)	76	24 (0.16–0.32)	13 (0.06–0.20)	11 (0.05–0.17)
(O-MH) +6 nail	0.853 ($p = 0.01$)	51	49 (0.39–0.59)	20 (0.12–0.28)	29 (0.20–0.38)
BH (equation) nail	0.776 ($p = 0.01$)	34	66 (0.57–0.75)	25 (0.17–0.34)	41 (0.31–0.51)

Table 4
Accuracy (%) of anthropometric measurements in different studies.

References	TT-MM	TT-A	K-MM	K-A	O-MH	BH
Current study		81	69	76	51	34
Venkateswaran et al[8]	64		79	86	57	
Colen and Prieskorn[7]	71					
Galbraith et al[6]	38		50	56	56	13

deducted from their measurements to calculate the ideal nail size. These varying methodologies could be a cause of the different accuracies in their studies.

Based on our study, we found a relationship between the parameters when TT-MM distance was utilized for nail size prediction (Table 3). Adding 11 mm to the TT-A measurement had the highest correlation ($r = 0.966$) with ideal nail size. This method had the highest accuracy with correct nail length being predicted in 81% of the cases. It also predicted the least number of longer nails (8%). No previous study has utilized TT-A distance for tibial nail size calculation. We recommended TT-A measurement as an excellent anthropometric parameter for preoperative planning.

Deducting 25 mm from K-A and 33 mm from K-MM yielded an accuracy rate of 76% and 69% respectively in our study. Venkateswaran et al[8] recommended deducting 20 mm from K-A (accuracy of 86%) and 40 mm from K-MM (accuracy of 79%) in deriving ideal nail size (Table 5). According to these authors, K-A measurement is the most accurate. Our result was consistent with their recommendation to use K-A and K-MM measurements.

method due to a low accuracy rate of 57%. According to Blair,[9] TT-MM did not exceed O-MH. However, in our study, TT-MM measurement was greater than the O-MH distance in 62% of the cases. Applying Blair's regression equation based on O-MH distance in our study population predicted accurate nail sizes in only 11% of the cases.

The nail sizes calculated based upon the BH regression equation matched with the ideal nail in only 34% of the cases. The nails were more than two sizes longer in five subjects and more than two sizes shorter in ten subjects. We did not recommend using BH measurements in preoperative planning in judging tibial nail size. Accurate nail sizes were derived in only 5% of the cases when the regression equation recommended by Fischmeister et al.[10]

Some authors found measurements involving the tibial tuberosity to be difficult as it was not prominent in females.[8] We did not encounter this difficulty. All the anatomical landmarks could be easily palpated and no obvious difference was noted with regard to gender.

Our study was unique in a lot of ways. Previous work in this field which utilized cadavers has drawn conclusions based on interpretation of measurements on fewer specimens (maximum:16 cadaveric legs).[6] Those studies involving measurements in patients also have included less subjects (maximum:16).[8] Conclusions were derived from O-MH and BH measurements based on data collected from 60 to 59 individuals respectively. The current study involved 100 subjects, the maximum until the date for study in this field. Techniques utilizing CT scan for measurements are much more accurate but are not recommended in routine practice.[6] Taking manual measurements in real subjects would mimic the clinical scenario most closely than from cadavers or by utilizing CT scans. We firstly utilized TT-A measurement for nail size prediction. The limitation of the study would be lack of comparison with radiographic data. Exposing all the participants to radiation would be unethical and this would be a shortcoming of any study in this field involving healthy individuals as study population. Performing a similar study in patients with tibial shaft fractures would have a limitation of a lesser sample size due to practical reasons.

Table 5
Comparison of correction recommended for determining ideal nail size in current and previous studies.

References	TT-MM	TT-A	K-MM	K-A	O-MH	BH
Current study	TT-MM	TT-A +11 mm	K-MM −33 mm	K-A −25 mm	O-MH + 6 mm (not recommended)	4.498 + 2.107 × BH (not recommended)
Venkateswaran et al[8]	TT-MM (not recommended)		K-MM −40 mm	K-A −20 mm	O-MH -5 mm (not recommended)	
Blair[9]	TT-MM				9.1+ (0.93 × O-MH)	
Fischmeister et al[10]						−5.05729 + 0.222 × BH
Colen and Prieskorn[7]	TT-MM					
Galbraith et al[6]				K-A		

When nail sizes calculated by TT-MM, TT-A, K-MM and K-A measurements in each subject were compared, the nail was predicted to be of a single size in 52%, two sizes in 46% and three sizes in 2%. So in 98% of the cases, the nail size could be predicted to be of not more than two sizes in each subject. This would be helpful in predicting the nail sizes which needs to be made available in the operation theatre. When two sizes were predicted, the smaller size corresponded to the ideal nail size in 39% of the cases (18 out of 46 cases). None of the nails were more than one size longer or shorter. We recommended utilizing the smaller nail size when having to choose between two nail sizes especially in proximal fractures of the tibial shaft. Longer nails would cause anterior knee pain, distract the fracture site or perforate the tibiotalar joint, causing complications.

In our study, adding 6 mm to the O-MH measurement derived the ideal nail size in only 51% of the cases. Moreover, the nail size predicted was longer than the ideal nail in 20% of the cases. The size predicted was longer than two nail sizes in seven participants and shorter than two sizes in three participants. We recommended not utilizing the O-MH distance due to the poor accuracy in our series. Venkateswaran et al[8] deducted 5 mm from the O-MH distance in calculating nail size. But they did not recommend this

In conclusion, we found a correlation between the anthropometric parameters measured and the ideal nail size and the highest correlation with the distance between the tibial tuberosity and the ankle joint. The interrelationship between the various measurements involving the multiple anatomical landmarks could be utilized when one area is not easily palpable in a patient. We recommended utilizing TT-MM, TT-A, K-A, K-MM measurements simultaneously in order to increase the accuracy of nail size prediction. We did not recommend using BH and O-MH distances. The smaller nail sizes predicted could be used when nailing proximal and middle third fractures of the tibial shaft. This is an easy, fast and accurate method of preoperative planning before tibial nailing.

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