Technique Report

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Extracorporeal measurement of femoral nail length in the treatment of trochanteric hip fractures: the “box” technique

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Abstract

Intramedullary nails, long and short, are widely used for fixation of trochanteric femur fractures. In theory, long nails may be able to protect the entire length of the femur from a future periprosthetic fracture, providing that the nail spans the length of the entire femoral canal. The described technique for long nail insertion calls for the use of an intramedullary guidewire and depth gauge for premeasurement of the length of the canal, as well as the use of a reamer. However, compared with short nails, this technique may add cost, operating time, and blood loss. We describe a safe technique for long nail measurement that reliably spans the length of the femur while potentially reducing surgical cost, time, and blood loss. We also describe 21 cases in which the technique was applied.

Keywords: femoral nail, intramedullary canal, nail length, trochanteric fracture

1. Introduction

Trochanteric fractures comprise almost 50% of all hip fractures[1] and are among the most common types of fracture in the elderly.[2] Intramedullary nailing has emerged as the most common treatment for trochanteric fractures in North America.[3] Choosing the length of the intramedullary nail to be inserted is a subject of controversy[4–8] with no clear difference demonstrated so far.[8] Long nail proponents argue that long nails span the length of the entire femoral canal, leading to greater protection from periprosthetic fractures and increasing mechanical advantage.[6,9–11] Short nail proponents argue that long nails increase surgical time and blood loss,[9,11] as well as the potential for anterior cortical perforation or inability to properly position the hip screw.[12–14] It is therefore incumbent upon surgeons using long nails to minimize surgical time and blood loss while spanning as much of the length of the femur as possible.

Insertion of long femoral nails currently calls for use of an intramedullary guidewire that is inserted into the femoral canal, followed by the use of a depth gauge over the guidewire to accurately measure canal length.[15] However, the guidewire technique is not always correct,[16] and the added surgical time associated with reaming may contribute to the observed increase in blood loss.[9,11] Furthermore, the single-use intramedullary guidewires may increase surgical costs.[17]

Inspired by ideas and techniques from as early as 1945,[18] we describe a novel technique for long nail measurement that has the potential to reduce surgical time and cost while accurately spanning the entire length of the femoral canal.

2. Surgical technique

2.1. Required instruments

- Intramedullary nailing system with nail still packaged
- C-arm image intensifier

2.2. The “Box” technique

The patient is placed supine on a radiolucent fracture table. C-arm fluoroscopy is set up in the operating room with the C-arm base contralateral to the fractured hip. A packaged nail of 10 mm diameter is superpositioned over the patient’s femur and fluoroscopically imaged to preoperatively assess the appropriate nail length (Fig. 1).

Under fluoroscopy with C-arm at 0 degrees anteroposterior, the proximal end of the packaged nail is aligned over the proximal femur, between the greater trochanter and the femoral neck at femoral neck notch (Fig. 2A). Ensuring that the location of the lag screw hole site in the packaged nail is in line with the inferior border of the femoral neck allows estimation of the eventual position of the lag screw, and thus allows proper positioning of the proximal end of the packaged nail. With the proximal end of the packaged nail properly aligned, an anteroposterior image of the knee is obtained and the distance of the nail tip to the intercondylar notch is assessed. This process is repeated with nails of different lengths until the distance from the distal end of the nail to the intercondylar notch is between 1

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Figure 1. Superimpositioning of packaged nail of 10 mm diameter over the patient's femur and fluoroscopically imaged to preoperatively assess the appropriate nail length.

and 3 nail diameters (Fig. 2B). This will be the chosen nail length. It is important to maintain a fixed distance between the patient's skin and the image intensifier during this nail selection process. To limit fluoroscopic image distortion, the C-arm image intensifier[19] should be positioned directly over the hip and knee. Next, the nail is assembled and inserted in a standard technique,[20] without the use of an intramedullary guidewire and without reaming. If the nail does not easily slide into its intended position without the need for more than gentle tapping, the nail is removed and the canal is reamed over a guidewire in a standard technique.

2.3. Assessment of nail spanning length of femur

The authors consider the nail to have spanned the length of the femoral canal if at least one of the following the criteria is met based off of postoperative x-rays of the knee in lateral view: the distal tip of the nail is advanced to fit within the triangle formed by Blumensaat's line or if the distal tip of the nail is advanced to the distal 1/3 of the joint line of the patella when leg is in full extension (Fig. 3).

3. Statistical analysis

The accuracy of the "box" technique was determined using Fisher exact test. The "box" technique was used to make a femoral length spanning prediction (yes/no) and the final postoperative x-rays of the knee in the lateral view were used to determine whether the prediction was successful or not. Descriptive statistics were used to describe other variables. Statistical analyses were performed with IBM SPSS Statistics, version 26.

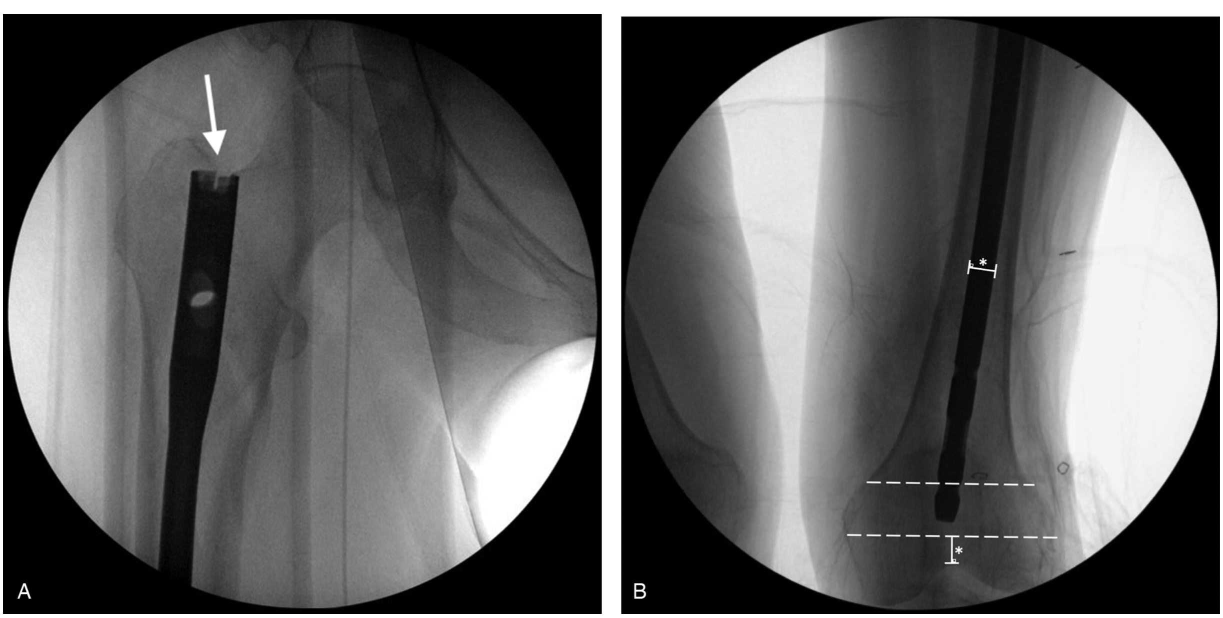

Figure 2. (A) Under fluoroscopy with C-arm at 0 degrees anteroposterior, the proximal end of the packaged nail is aligned over the proximal femur, between the greater trochanter and the femoral neck at femoral neck notch (see white arrow). Ensuring that the location of the lag screw hole site in the packaged nail is in line with the inferior border of the femoral neck allows estimation of the eventual position of the lag screw, and thus allows proper positioning of the proximal end of the packaged nail. (B) With the proximal end of the packaged nail properly aligned, an anteroposterior image of the knee is obtained and the distance of the nail tip to the intercondylar notch is assessed. This process is repeated with nails of different lengths until the distance from the distal end of the nail to the intercondylar notch is between 1 and 3 nail diameters, represented here as the lower and upper dashed white lines, respectively. This will be the chosen nail length. It is important to maintain a fixed distance between the patient's skin and the image intensifier during this nail selection process.

Figure 3. The authors consider the nail to have spanned the length of the femoral canal if at least one of the following criteria are met: the distal tip of the nail is advanced to fit within the triangle formed by Blumensaat's line or if the distal tip of the nail is advanced to the distal one-third of the joint line of the patella when leg is in full extension (see white line).

4. Case series

After obtaining Institutional Review Board approval, trochanteric fracture nailings performed by the senior author between October 2015 and April 2020 were reviewed. Twenty-three cases were available for analysis. Two cases were excluded. One due to a previous total knee arthroplasty that altered radiographic landmarks, and the other had specific documentation stating that the patient had distorted femur anatomy. Nail dimensions and patient-specific information were obtained from the medical records. Fluoroscopy images were analyzed to determine accuracy of the described technique.

Average age of the patients was 78 ± 16 years, with an average BMI of 23 ± 4.2 kg/m^2. Seven participants were male and 14 were female. Median and mode nail length was 380 mm (range 320 mm to 440 mm). Nail diameters were 9 mm (n = 2), 10 mm (n = 14), 11 mm (n = 3), and 12 mm (n = 2), with an average nail diameter of 10.2 mm. Neck shaft angle was either 125 or 130 degrees.

Per the Fisher exact test, the box technique had an accuracy of 95.2% in its femoral length spanning predictions, with a positive predictive value of 93.8% and a specificity of 83.3% for spanning the length of the femoral canal ($P < .001$). Overall, the "box" technique successfully spanned the length of the femur in 15 of 16 cases. In all 5 of the cases in which the distance from the distal end of the nail to the intercondylar notch was greater than 3 nail diameters (>30.0 mm), the "box" technique successfully predicted that the length of the femur would not be spanned.

5. Discussion

The choice between a long or short nail for treating trochanteric fractures is controversial.[4–8] Due to the increase in surgical time and blood loss, the use of long nails can only be justified if the resulting construct has a mechanical advantage or protects the femoral bone from a future periprosthetic fracture.[6,9–11] The "box" technique is a safe and reliable method for choosing the appropriate nail length to span the length of the entire femoral canal. The technique exhibited an accuracy of 95.2% in its femoral length spanning predictions in 21 consecutive cases.

The "box" technique calls for the measurement of the nail length before commencement of the surgical procedure (while in the box), choice of a low nail diameter (usually 10 mm), and insertion of the intramedullary nail without reaming. In this work, we only describe the accuracy of the technique in spanning the length of the femoral canal. However, the technique has the potential to reduce surgical time by avoiding the insertion of an intramedullary guide, length measurement, and reaming. The technique also avoids the cost of the intramedullary guide and may indirectly reduce cost through reduction in surgical time and nail inventory.

Determination of appropriate nail size in the "box" technique may be limited by the effects of C-arm distortion due to parallax.[21] However, a recent study found that parallax alone affected perceived dimensions of objects by a mere 0.8% when placed 155 mm off-center from an x-ray central beam.[22] Another study found no significant effects on acetabular measurements when modifying x-ray central beam position around the pelvis.[23]

Another potential concern with "box" technique measurements may be a magnification effect in excessively large bodies. When imaging at equal distance from the skin, the femur can appear 19% larger when there is an additional 6 inches of subcutaneous tissue.[22] In the current study, the "box" technique accurately predicted spanning of the length of the femur in 20 of 21 patients, with BMIs ranging from 16.5 to 28.4 kg/m^2. The one patient in whom the prediction was inaccurate had a BMI of 34.1 kg/m^2. This was inconsequential because the nail ended up being shorter than the intended spanning of the femoral length. Although the "box" technique did not overestimate the length of any nail in the case series, we recommend limiting the distance between the nail tip and intercondylar notch to 2 to 3 cm instead of 1 to 3 cm, in obese patients (BMI $\geq$ 30 kg/m^2).

The frequent use of relatively small diameter nails in the "box" technique may raise concern about mechanical disadvantage of the resulting constructs. A recent retrospective study showed 10 mm nails to be of adequate strength, regardless of femoral canal length, to promote healing in 147 patients with femoral shaft fractures.[24] The use of 10 mm diameter nails has also obviated the need for reaming the canal in trochanteric fractures, with no significant difference in perioperative and postoperative outcomes compared with reamed nailing in 37 patients.[25] There were no cases of anterior cortical penetration in the unreamed group.[25]

While our technique calls for the use of 10 mm diameter nails for all cases, there were instances in our cohort of 21 patients where diameter was increased based on surgeon discretion. This was usually due to size availability, exceptionally large patients, or patients with an exceptionally large canal. Although the "box" technique is used primarily to determine appropriate nail length, future study should be conducted on its potential ability to simultaneously assess appropriate nail diameter using the femoral isthmus.

In this study we did not measure surgical time or cost; however, the "box" technique may affect both parameters favorably. Unreamed intramedullary nailing has been demonstrated to save an average of 16.7 minutes of surgical time.[25] Furthermore, the "box" technique saves additional time by avoiding the use of an intramedullary guidewire and depth gage. Reduction of operative time is associated with reduced blood loss and anesthesia time,[26–28] as well as reduced complications,[25] particularly in geriatric patients.[29]

The "box" technique may decrease costs by reducing surgical time as well as avoiding the cost of an intramedullary guidewire (list price $246 with the vendor most commonly used in this study). A recent study has shown operating room costs to be around $16 per minute,[30] but costs have been described to range from $21.80 to $133 per minute in the United States.[31]

Importantly, the fluoroscopic images used to assess appropriate nail length in the "box" technique were obtained preoperatively. Imaging occurred after the patient was intubated, positioned on the fracture table, and reduced, all of which were steps that constituted the vast majority of the preoperative room time. Typically, we first obtained 2 to 3 anteroposterior images to align the proximal end of the packaged nail over the proximal femur, followed by 1 to 2 anteroposterior images of the distal end of the packaged nail and the distal femur. If we found the nail to be too short or too long, then this process was repeated with a nail of a different length. We consider this nail selection process to have an insignificant effect on overall preoperative room time.

6. Conclusions

The "box" technique is a safe and reliable method for choosing the appropriate nail length to span the entire length of the femur. Additional research is needed to assess the potential for reduction in surgical time and cost with this technique.

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