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Placement of Tibial Intraosseous Infusion Devices

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ABSTRACT Post-mortem preautopsy multidetector computed tomography was used to assess the placement of tibial intraosseous infusion needles in 52 cases of battlefield trauma deaths for which medical intervention included the use of the technique. In 58 (95%) of 61 needles, the tip was positioned in medullary bone. All 3 (5%) unsuccessful placements were in the left leg, and the needle was not directed perpendicular to the medial tibial cortex as recommended. Considering the nature of military trauma and the environmental conditions under which care is rendered, military medical personnel appear to be highly successful in the placement of tibial intraosseous infusion needles.

INTRODUCTION

Intraosseous (IO) vascular access has been an option used by the military in battlefield casualty resuscitation since World War II.[1–5] Presently, IO infusion devices are available to U.S. military medical providers at all echelons of care. U.S. Army medics are trained in the placement of a sternal IO device, and more advanced providers such as physicians, physician assistants, and nurses are taught both sternal and tibal IO placements. During the performance of autopsies on combat casualties who received medical intervention, the presence of IO infusion devices is readily recognized. However, the precise location of a needle tip is not easy to determine with 2-dimensional radiographs or during autopsy without tedious targeted dissection. In contrast, the use of multidetector computed tomography (MDCT) as a preliminary step to autopsy (known as radiology-assisted or virtual autopsy) produces cross-sectional images that clearly indicate the location of the tip of the tibial IO infusion needle. This report is an assessment of tibial IO needle placement based upon the preautopsy MDCT imaging.

METHODS AND MATERIALS

The study was performed with the approval of the Institutional Review Board of the Armed Forces Institute of Pathology and was compliant with the Health Insurance Portability and Accountability Act. The Armed Forces Medical Examiner Tracking System was used to identify a series of 58 consecutive military deaths for which medical intervention included placement of a tibial IO infusion needle. Six cases were excluded: five because computed tomography was not done or was unretrievable and one because the IO needle was in the distal femur. The final study population consisted of 52 subjects.

Total-body MDCT scans were obtained on a GE Lightspeed 16 (General Electric Medical Systems, Milwaukee, WI) within 2 to 4 days after death. Subjects were scanned with a collimation of 16×5 mm^2, pitch 0.938:1, rotation speed of 0.5 seconds, and table speed of 9.37 mm/rotation. Axial sections were acquired at 0.625 mm thickness and 0.625 mm interval to allow isotropic voxal reconstructions. No contrast material was administered. Images were viewed on a GE Advantage Workstation (software version 4.2; General Electric Medical Systems) using 2-dimensional axial, coronal, oblique, and sagittal data sets and 3-dimensional reconstructions as needed. Criteria for acceptable IO placement were (1) placement within the proximal tibia and (2) location of the tip of the needle in an intramedullary position.

RESULTS

The 52 subjects had a total of 61 tibial IO needles. Forty-four cases had a single needle, 7 cases had 2 needles (1 in each tibia), and 1 case had 3 needles (2 in one tibia and 1 in the other tibia). Twenty-four needles were placed in the right tibia, and 37 were placed in the left tibia.

All the right tibial IO needle placements passed through the medial cortex and were in the medullary portion of the bone (Figs. 1–3). In 34 of 37 left tibia placements, the needle passed through the medial cortex with the tip in medullary bone. Three needles did not enter bone, but resided in soft tissue with the needle not directed perpendicular to the medial cortex. In 2 cases, the needle entry and direction were from the lateral aspect of the leg (Figs. 4 and 5). In the third case, the needle was angled superiorly and anteriorly from a medial approach.

In summary, an intramedullary location of the tibial IO needle tip was observed in 58 of 61 placements (95%).

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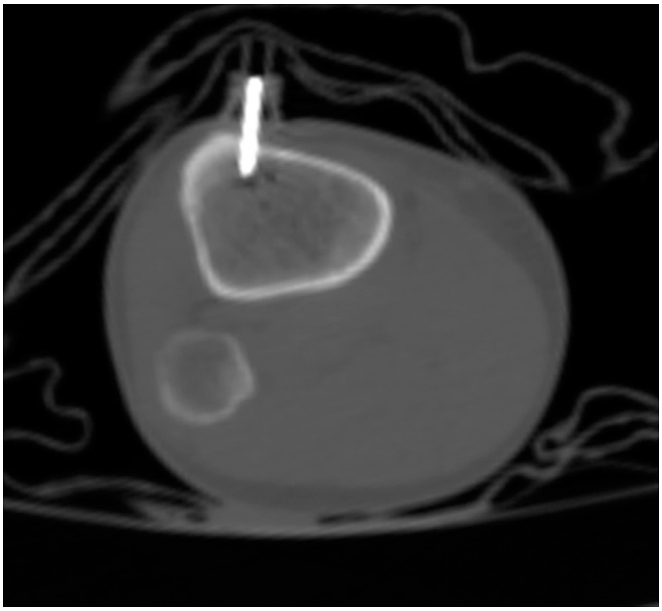

FIGURE 1. Correct placement of a right tibial IO needle. Axial MDCT shows the needle perpendicular to the medial cortex and tip in the medullary cavity.

FIGURE 2. Coronal MDCT shows the needle perpendicular to the medial cortex and tip in the medullary cavity.

The 3 unsuccessful placements (5%) were all in the left tibia and the needle was in soft tissue with no evidence of having entered bone.

DISCUSSION

Vascular access is a critical element in the emergency treatment of critically ill patients. IO access is a rapid and safe alternative

FIGURE 3. Three-dimensional MDCT reconstruction using a bone algorithm shows the surface position of the needle seen in Figures 1 and 2.

when central or peripheral access cannot be obtained.[6] The sternum and proximal tibia are the primary sites utilized because relatively thin overlying soft tissue affords access to flat cortical bone. Other sites such as the humeral head, distal radius and ulna, iliac crest, distal femur, and distal tibia have also been used successfully.[7]

The medial aspect of the proximal tibia with its flat surface and relatively thin layer of soft tissue covering the bone is the preferred site for IO access in children under 6 years of age, but in adults it has been, until recently, considered one of the least desirable locations.[7] Recent advent of spring-loaded devices such as the Bone Injection Gun (BIG; Waismed, Yokneam, Israel) and the battery-powered drill handle for the EZ-IO (Vida-Care, San Antonio, TX) have made penetrating the thicker bone in the adult tibia much easier. This, combined with easily identifiable landmarks, has made the proximal tibia the preferred site for military providers in the Battalion Aid Stations (BAS). The U.S. Army has added the EZ-IO to the BAS Medical Equipment Set. All deploying medical providers are required to attend the Tactical Combat Medical Care course where they are given hands-on training with these devices.

In the battlefield environment, use of IO infusion is particularly relevant because of the type of trauma encountered, the evacuation process, and the need for rapid access in austere

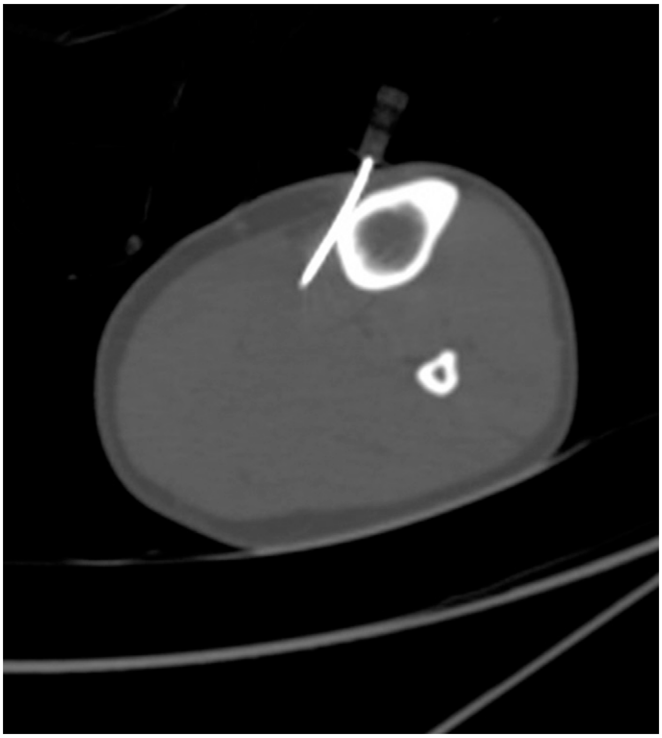

FIGURE 4. Incorrect placement of a left tibial IO needle. Axial MDCT shows a nonperpendicular needle angle with respect to the medial cortex and the needle failing to enter bone.

FIGURE 5. Coronal MDCT shows a nonperpendicular needle angle with respect to the medial cortex and the needle failing to enter bone.

conditions. To evaluate the effectiveness of tibial IO devices, we examined a sample of consecutive deaths in theater where medical care rendered included use of a tibial IO infusion device. We observed that 95% of the placements were into the medullary bone. This observation compares favorably with that in the study by Calkins et al., where 3 types of devices were placed in the tibia with 94 to 97% success by Special Operations medical personnel in a laboratory setting.[8]

In the civilian medical community, successful IO insertion has been consistently found to exceed 94% on first try for all types of providers, both in hospital and prehospital settings.[9–13]

For those experienced in cross-sectional imaging, needle placement is accurately assessed by axial MDCT images alone. In all our cases, the radiologist could confirm the position from the images alone. Axial images can be augmented by coronal and sagittal images if there is a question or confirmation needed. Three-dimensional images have become popular, particularly to provide better understanding for those who are not trained in interpreting cross-sectional images.

A limitation of this report is the sample being taken from only autopsy cases. We are not able to say if our accuracy estimation holds for the entire casualty pool of dead and wounded. The more severe casualties seem most likely to receive IO access as resuscitative attempts were made. Also, we have no knowledge of unsuccessful placement attempts in which the needle was removed.

This report does not specify the device manufacturer, echelon of care where the device was placed, or training level of the person who placed the device. It is important to note that in the civilian literature, placement has predominantly been performed with powered devices. The military has access to both manual and powered devices, and we do not know which were used in our cases.

Although it is impossible to know each of the individual circumstances where an IO was placed, it is most likely that tibial IO devices are being inserted by providers at the BAS and echelons above. Combat medics do not routinely carry tibal IO devices, nor are they trained to insert a tibial IO. With the EZ-IO being added to the BAS equipment set and with deploying medical officers being trained in its use, we will gain more experience with its use. Although this study examines IO placement in post-mortem cases and does not capture living patient data where an IO attempt failed, an accuracy rate of 95% suggests that training has been effective.

Finally, the information presented speaks only of the success of device placement in the medullary space of the tibia. It in no way addresses what was administered or how the device functioned. We noted variability in tibial locations ranging from the needle being in the tibial plateau or epiphyseal part of the bone, to placement at the metaphyseal/diaphyseal junction. It is our intent to study variation in tibial IO placement and its effect on function. For example, a case contained in this series (Figs. 6–8) showed the needle passing through one cortex and coming to rest at the margin of the opposite cortex. We do not know if flow would be compromised at this location.

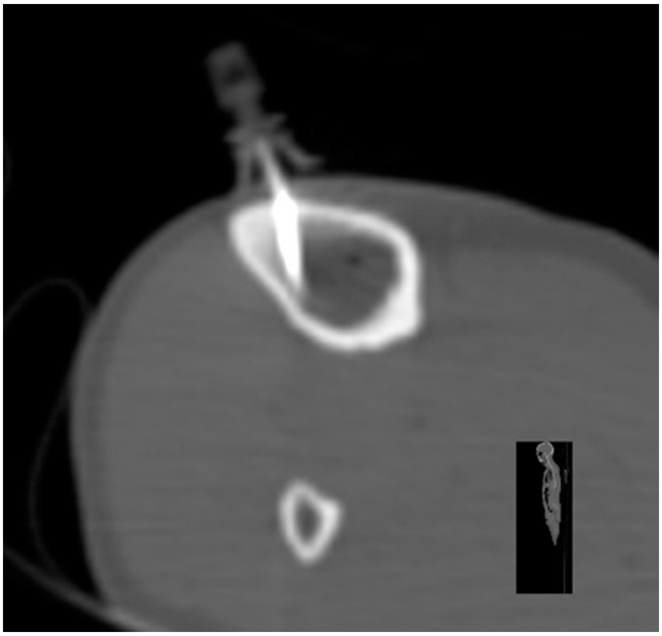

FIGURE 6. Placement of a right tibial IO needle with tip at the inner cortical margin; it is uncertain how this position would affect infusion. Axial MDCT shows the needle passing through the medial cortex into the medullary cavity with the tip at the inner margin of the lateral cortex.

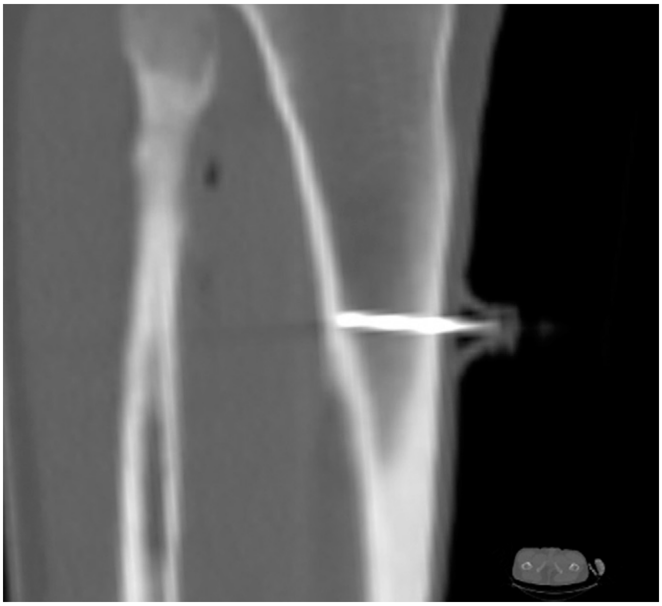

FIGURE 7. Sagittal MDCT shows the needle passing through the medial cortex into the medullary cavity with the tip at the inner margin of the lateral cortex.

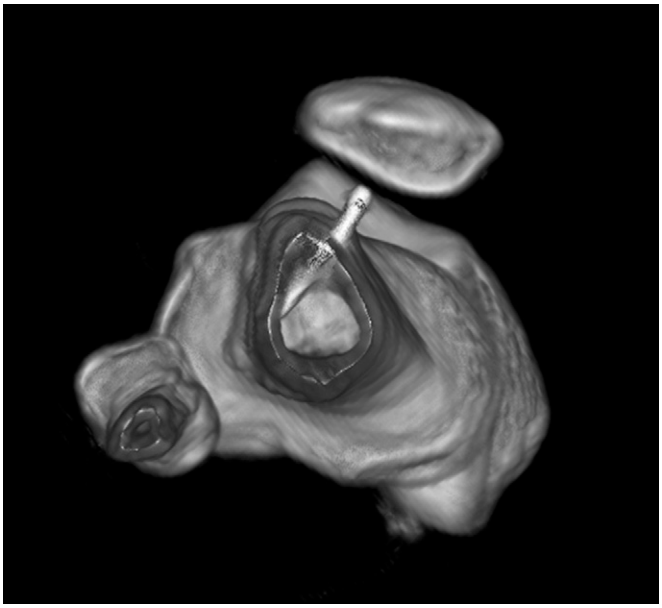

FIGURE 8. Three-dimensional MDCT reconstruction using a bone algorithm shows a cut-away view of needle seen in Figures 6 and 7 within the medullary cavity. Note tip position at inner cortical margin.

CONCLUSIONS

Our study sample shows that military medical personnel are highly successful in the placement of tibial IO infusion needles. Considering the nature of military trauma and the environmental conditions under which care is rendered, this technique for rapid vascular access appears reliable in the hands of those performing the procedure.

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