ESTIMATION OF SKULL CORTICAL THICKNESS FROM CLINICAL CT

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INTRODUCTION

In the United States traumatic brain injuries contributed to 30.5% of all injury related deaths from 2002 to 2006 [1]. The human cranial vault serves as the main mechanism of protection for the brain from these contact injuries. Despite the important role the skull plays in protecting the cranium, more needs to be known about its anatomy. Cortical thickness of bone is difficult to quantify due to the resolution limitation on clinical computed tomography (CT) scans. Thickness measurements of structures thinner than 3 mm are overestimated using the standard full width half max (FWHM) technique [2]. A better understanding of the physical properties of the skull would provide further insight into the mechanism of head injury. In this paper we present a technique that has been adapted from Treece et al to accurately interpret cranial vault cortical thickness from clinical CT scans [3]. With a large repository of clinical CT scans it would be advantageous to be able to evaluate thickness variations across the population by age and skull location.

METHODS

Two male cadavers (age 49 and 56) were used to evaluate the cortical thickness of the skull. Clinical CT scans of the head were collected at 0.625 mm isometric resolution for both specimens (GE 64-slice PET/CT Discovery VCT Scanner, Center for Biomolecular Imaging, Wake Forest University). The skulls were removed using a surgical saw at the base of the foramen magnum and cleaned by removing all skin and soft tissue.

One-quarter inch diameter sections of the skull were collected using neurosurgical equipment. These samples were then scanned using a GE CT-120 CT scanner (Biomedical Research Imaging Center, University of North Carolina at Chapel Hill) to evaluate the actual cortical thickness. The scans were collected at 25 micron resolution with isometric voxels and reconstructed at a 50 micron resolution. The FWHM technique was used to evaluate the actual cortical thickness from the microCT.

The software program Stradwin was used to estimate the cortical thickness of the skull from clinical CT scans [3]. The cortical density of the cadaver skull was measured and reported in Hounsfield Units and used to map cortical thickness estimates over a 3 dimensional (3D) surface of the bone [3, 4]. The location sampled for microCT was identified on the 3D reconstruction of the skull and the skull was then cropped to the appropriate size. Three dimensional volumes were calculated for both the microCT and the cropped clinical CT. The clinical CT was aligned to the microCT using both Geomagic Studio (Geomagic, Research Triangle Park, NC) and 3D Slicer (National Alliance for Medical Image Computing). The 3D volume from the clinical CT scan was converted to a point cloud and sub-selected to only contain points in contact with the surface of the microCT volume. The transforms created from the alignment were used to match the cortical thickness measurements from Stradwin between the clinical CT and the microCT. The thickness measurements corresponding with the surface label map of the clinical CT were then compared to the nearest thickness measurement from the microCT.

RESULTS AND DISCUSSION

A sample from the frontal bone of the 46 year old cadaver was selected for the validation of Stradwin.
for the skull. This sample contained the frontal suture which can be identified as a section of cortical bone from the outer to inner cortex as opposed to the two cortical tables separated by the diploe layer. The actual thickness measurements for the outer table of the frontal bone are shown in Figure 1A. The suture was determined to exceed 4 mm while much of the outer table fell between 1.5 to 2 mm. The thickness measurements calculated from the clinical CT scans are shown in Figure 1B. Qualitatively the thickness measurements between the microCT and the clinical CT were comparable (Figure 1C).

![Figure 1](image1.png)

**Figure 1:** Thickness measurements from Stradwin represented as color maps over the 3D volume’s outer surface for A) microCT, B) clinical CT, and C) microCT aligned with the clinical CT. The thickness scale is located on the right.

For a more quantitative analysis the thickness, calculations from the clinical CT that were associated with points on the surface label map were compared to the thickness of the nearest landmark on the microCT. In evaluating the difference in matched thickness calculations, 96% of all selected points fell within ±0.9 mm (Figure 2). The clinical CT thickness measurement overestimated actual thickness on average only 0.25 mm where the median actual thickness was 1.55 mm.

![Figure 2](image2.png)

**Figure 2:** Distribution of difference in thickness measurements between the clinical CT and the thickness of the microCT.

**CONCLUSIONS**

With the exception of the suture within the sample, cortical thickness measurements on the skull were well below 3 mm and accurate thickness could not be calculated using FWHM on a clinical CT scan. The actual thickness of the skull has been shown to be more accurately determined from clinical CT scans using a cortical density based approach, facilitating the study of populations to assess skull table thickness by age and anatomical location.

**REFERENCES**


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