Supplementary Online Content

Rabbani C, Saltagi MZ, Ye MJ, et al. Association of obstructive sleep apnea with calvarial and skull base thinning [published online May 3, 2018]. *JAMA Otolaryngol Head Neck Surg*.
doi:10.1001/jamaoto.2018.0347

eMethods.

This supplementary material has been provided by the authors to give readers additional information about their work.

Online-Only Supplemental Material

1. eMethods

eMethods

Calvaria Measurements
Calvarial thickness was measured beginning just anterior to the foramen rotundum in the coronal plane: 1) Measurements began by selecting and highlighting 15 mm (in height) of the thinnest part of the calvarium within 4 cm of the skull-base. A threshold of 400 Hounsfield units was applied for highlighting bone. 2) Moving in a posterior direction, 15 mm (in height) portions of bone were sequentially highlighted while avoiding air cells, posteriorly to the level of the superior extent of the superior semicircular canal (SCC). 3) This length of bone measurement was calculated using distances provided by 3D slicer. 4) Volumes were obtained of the highlighted bone using 3D slicer's volume analysis tool. 5) Measurements were performed bilaterally, yielding a total of 348 initial measurements (N=348) on 174 patients. 6) With the volume, length, and height known, the following calculation was applied to determine the average calvarial thickness on each side: Calvarial Thickness = Volume / [Height x Length]. These values were averaged to obtain the overall average calvarial thickness.

Zygoma Measurements
The extracranial zygoma was then measured with the same 400 Hounsfield unit threshold along a 5 mm anterior-posterior segment of the zygomatic process just anterior to its attachment to the temporal bone, as seen on coronal images. The zygoma was measured as an internal imaging control as it is a consistent extracranial bone in all images. After highlighting the appropriate number of slices needed to reach approximately 5 mm in length, the volume was obtained. Length was calculated by multiplying the number of slices by the thickness of each slice, and this value was approximately 5 mm consistently. Finally, by treating our coronal zygoma cross-sections as a cylinder, we were able to use the following formula to determine zygoma thickness: Zygoma thickness = $2 * (\sqrt{(\text{Volume} / (\text{length} * \pi))}$.

Internal Auditory Canal Measurements
In addition, the height of the internal auditory canal (IAC) was measured and the incidence of tegmen dehiscence was calculated. IAC height measurements were performed as follows: 1) A coronal view was obtained at the central-most slice of the IAC. 2) A single height measurement was obtained using the ruler function at the mid-point of the IAC. 3) Measurements were performed bilaterally. To assess tegmen dehiscence, coronal views of the temporal bone were evaluated for the presence of bone overlying the mastoid cavity and the middle ear. If the tegmen had an obvious bony defect measuring at least 4 mm across, this was considered evidence of tegmen dehiscence. Images that did not include the mastoid tegmen or the IAC were not included in this analysis.

Correction Factor Applied to CT IAC Scans
To account for differences between CT Maxillofacial studies, the predominant type of study ordered for OSA and non-OSA patients, and CT Internal Auditory Canal (IAC), the predominant study ordered for sCSF-L patients, we determined the measurement differences between the two scans in identical patients. This resulted in a correction factor which was applied to calvarial and zygoma thickness in CT IAC scans. This was based on the consistent observation that CT Maxillofacial studies yielded slightly higher calvarial and zygoma thickness measurements than CT IAC studies when these two scans were available for the same patient. To calculate the correction factor, five patients with both CT Maxillofacial and CT IAC scans within a six-month period were identified, and calvarial and zygoma measurements were performed on these patients using 3D slicer. The values were averaged and the differences between CT Maxillofacial and CT IAC scans were determined. On average, the CT Maxillofacial measured 0.265 mm thicker than the CT IAC scan in absolute terms for calvarial thickness. This translated into an average percent difference of 15.5%. The average absolute difference in zygoma thickness between CT Maxillofacial and CT IAC scans was 0.383 mm, which translated into an average percent difference of 5.05%. The discrepancy between the percent differences is explained by the fact that zygoma thickness measurements are much higher at baseline, leading to a lower percent difference despite a higher absolute difference in zygoma measurements between the scans. Ultimately, our correction factor was 15.5% for calvarial thickness measurements and 5.05% for zygoma thickness measurements. This was applied to all CT IAC scans in our initial patient group

and in the subgroup of whites ages 40 to 60. These two types of scans were the predominant scans used in our analysis.