Research Article

Skull Abnormalities in Cadavers in the Gross Anatomy Lab

Jessica De Rose, 1 Brian Laing, 1 and Maha Ahmad 2

1 University of Detroit Mercy School of Dentistry, USA
2 Division of Integrated Biomedical and Diagnostic Sciences, University of Detroit Mercy School of Dentistry, USA

Correspondence should be addressed to Maha Ahmad; ahmadmk1@udmercy.edu

Received 26 September 2019; Revised 17 December 2019; Accepted 4 February 2020; Published 21 February 2020

1. Introduction

Mechanical stimulation influences the process of remodeling, and it has been documented that there is a decrease in cortical bone and an increase in trabecular porosity as adults age [1]. In addition, evidence suggests that with age the greatest loss in gray matter density occurs in the frontal and parietal regions of the brain and may correlate with thickness in the frontal and parietal bones as an attempt to balance the intracranial pressure [1]. Thus, a combination of both age and mechanical stimulation can influence the process of bone stimulation and structural changes seen in these populations.

In addition to external factors, there are internal factors that may influence the health and homeostasis of bone remodeling. Studies have also suggested a link between Alzheimer’s disease and bone density. In a study performed by
Loskutova et al. [2], it has been suggested that low bone mineral density can be correlated with Alzheimer’s disease when compared to a group of healthy females of the same age. Many factors can be taken into account to explain the association, but some evidence suggests that the hypothalamus, a structure affected in Alzheimer’s disease, regulates bone health and may play a larger role in the destruction of the bone density of the skull in said patients [2].

Furthermore, experimental data suggests that in an aging population there is a decline in one’s motor adaptability, performance, and learning capabilities [3]. Thus, studies have been conducted to determine if an aging human brain has the same abilities to change its structural neuroplasticity in response to learning and/or practicing just as a 20-year-old does [3]. Given that any changes in the brain structure will consequentially result in changes in the structure of the skull to maintain intracranial pressure, the skull in postmortem cadavers can be interrupted to understand what factors may have caused such changes. The hippocampus, a structure involved in lifelong neurogenesis, has showed plasticity similar to the nucleus accumbens [3]. Physical activity and an enriched environment have the ability to improve neurogenisis in an older population and maintain the new neurons produced. Thus, differences seen in cadaver skulls in said areas may be due to how active the person was prior to death.

Research has also suggested a strong correlation between the thickening of the skull, particularly the frontal lobe, and the appearance of irregular undulations with hypostosis frontalis interna (HFI). Structural abnormalities can occur in the frontal lobe and more commonly occurs in women than in men [4]. HFI affects females 9 times more than it affects males and is mostly present among the middle-aged and elderly population [5]. The underlying mechanisms are not well known; however, there have been case reports where HFI is accompanied by endocrinopathies and/or neuropsychiatric abnormalities [4].

In addition, a thickening of the skull has been associated with Paget’s disease. Paget’s disease is characterized by the destruction of the bone followed by reparative changes [6]. This disease often causes a boney enlargement of the skull and commonly involves the frontal and basal regions [7]. The new bone is laid down in a haphazard fashion and begins at the outer table of the skull; later, the differentiation between the inner and outer portions of the skull is lost and becomes thickened [7]. Paget’s disease is often diagnosed in up to 8% of those over the age of 60 and affects both sexes; however, there is a slight male predominance [8]. Paget’s disease patients with skull involvements have a 50% chance of developing a hearing loss.

Lastly, an infection that is often characterized by brain dysfunction is sepsis, which is associated with inflammation that may induce significant alterations to areas of the brain [9]. Specific areas that have been susceptible to ischemia in septic shock include the frontal junctional cortex, the dentate nucleus, hypothalamic nuclei, the amygdala, and the medullary autonomic nuclei [9]. Thus, in cadavers that have died of sepsis, one could expect abnormalities to occur in these respective areas of the skull.

The goal of this study is to observe the frequency of skull abnormalities in the cadavers that we have in the Gross Anatomy Laboratory. Furthermore, to correlate these abnormalities to age and sex of the specimens.

2. Materials and Methods

The Gross Anatomy Laboratory at the University of Detroit Mercy, School of Dentistry collected data from 65 cadavers through 2016–2019, which were formalin embalmed. Out of the 65 cadavers, there were 34 females and 31 males. Reciprocating saws and mallets were used to separate the calvaria, approximating a sagittal plane above the superior orbital ridge in the anterior and external occipital protuberance posteriorly. All dura was removed on most specimens to get a better visualization of the inner surface of the frontal bone. Age and sex of each specimen containing the characteristic thickening of the frontal bone were recorded. Chief medical issues and cause of death of each cadaver were collected to determine presence of accompanying possible neuropsychiatric changes to the brain.

3. Results

Various skull disparities were observed among measurements in the 65 specimens collected. Out of the sixty-five cadavers obtained, nineteen specimens (29%) contained irregular, undulating, thickening on the internal surface of the frontal bone as shown in Figure 1. This finding closely resembled the gross anatomic appearance of HFI. Twelve of the nineteen specimens (63%) exhibiting frontal bone skull abnormalities were female ranging from 68 to 95 years old (35% of female cadaver sample). Seven of the nineteen

Figure 1: (a) Internal surface of the cadaver’s frontal bone in a female skull, 68 years old. Note the bilateral thickening of the bone along both sides of the midline. (b) Internal surface of skull specimen’s frontal bone with normal anatomical features.
specimens (37%) that showed a thickened skull with possible HFI were males ranging from 70 to 103 years old (23% of male cadaver sample).

The percentage of specimens exhibiting bone abnormalities in our study was much higher than the overall HFI prevalence observed in previous studies [7, 10] (Table 1). The average age of cadavers showing the skull abnormalities was $84.53 \pm 9.29$, which is similar to the average age of the overall female and male cadaver samples. The average age seems to be similar between males ($82.14 \pm 6.00$) and females ($85.92 \pm 8.70$). It is important to note that a great deal of variation was found between specimens.

In addition, five of the nineteen samples (26%) that presented with suspicions of HFI and a thickened skull had some form of neuropsychiatric abnormalities listed as the cadavers' chief medical concerns, including Alzheimer’s, dementia, depression, and Parkinson’s disease; four out of these five specimens belonged to female cadavers. However, in the remaining sample, there were 10 cadavers (Table 1) diagnosed with neuropsychiatric abnormalities that had normal skull appearance. Thus, further monitoring for skull abnormalities in the Detroit Mercy Dental cadaver lab is planned.

### Table 1: Prevalence, sex, and age of affected cadavers exhibiting frontal bone skull abnormalities and exhibiting neuropsychiatric disorders in our study.

<table>
<thead>
<tr>
<th>Percentage of skull anomaly in the cadaver group</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(%)</td>
<td>22.6%</td>
<td>35.2%</td>
<td>29%</td>
</tr>
<tr>
<td>(7 out of 31)</td>
<td>(12 out of 34)</td>
<td>(19 out of 65)</td>
<td></td>
</tr>
<tr>
<td>Average age of cadavers</td>
<td>79.7 ± 12.6</td>
<td>85.2 ± 10.6</td>
<td>82.6 ± 11.8</td>
</tr>
<tr>
<td>$n = 31$</td>
<td>$n = 34$</td>
<td>$n = 65$</td>
<td></td>
</tr>
<tr>
<td>Average age of affected cadavers</td>
<td>82.1 ± 6.0</td>
<td>85.9 ± 8.7</td>
<td>84.5 ± 9.3</td>
</tr>
<tr>
<td>$n = 7$</td>
<td>$n = 12$</td>
<td>$n = 19$</td>
<td></td>
</tr>
<tr>
<td>Sex of affected skulls</td>
<td>36.8%</td>
<td>63.2%</td>
<td>100%</td>
</tr>
<tr>
<td>$n = 7$</td>
<td>$n = 12$</td>
<td>$n = 19$</td>
<td></td>
</tr>
<tr>
<td>Overall prevalence of neuropsychiatric abnormalities</td>
<td>22.5%</td>
<td>23.5%</td>
<td>23.1%</td>
</tr>
<tr>
<td>(7 out of 31)</td>
<td>(8 out of 34)</td>
<td>(15 out of 65)</td>
<td></td>
</tr>
<tr>
<td>Prevalence of neuropsychiatric abnormalities in affected cadavers</td>
<td>14.2%</td>
<td>33.3%</td>
<td>26%</td>
</tr>
<tr>
<td>(1 out of 7)</td>
<td>(4 out of 12)</td>
<td>(5 out of 19)</td>
<td></td>
</tr>
<tr>
<td>Prevalence of neuropsychiatric abnormalities in remaining cadavers</td>
<td>25%</td>
<td>18%</td>
<td>22%</td>
</tr>
<tr>
<td>(6 out of 24)</td>
<td>(4 out of 22)</td>
<td>(10 out of 46)</td>
<td></td>
</tr>
</tbody>
</table>

4. Discussion

The current study examined various cadaver skulls over a 3-year data collection sample and noted abnormal thickening in the inner surface of the skulls, particularly the frontal bone. A common reason for said occurrence is hypertosis frontalis interna (HFI). There are other possible causes for thickening to occur in the frontal bone, such as Paget’s disease. In previously conducted studies, the reported rates of HFI are higher in females (20%) than in males (3%) [7]. Another study [10] reported a prevalence of HFI as high as 13% in females compared to 1.3% in males. Thus, one can conclude that HFI is uncommon among males, and a significant difference exists between males and females. Even though both sexes had skull abnormalities present in our current study, the extent to which it occurred varied. Females tended to have more irregularities and thickening in the frontalis compared to males. Thus, it may be plausible to conclude from these differences that HFI is the cause not linked to one specific sex, but its severity is highly correlated to the female gender, with minor cases mostly occurring in males. The etiology of HFI is not well known, but it is suggestive that a hormonal imbalance is a likely cause. Studies have inferred that androgens do not particularly cause HFI to occur, rather the link to androgens and HFI is more related to the estrogen/androgen ratio imbalance, with a surplus of estrogen [11]. This may be a possible link as to why HFI is more prevalent in the female population, since females have an abundance of estrogen premenopause. Such effects that may take place early on in life may cause the thickening of the skull, which remains throughout the entirety of their lives, including postmenopausal females.

The presence of HFI may suggest a decrease in brain volume, which may indicate degenerative processes of the brain [11]. Furthermore, many of the female specimens with an increased severity of HFI had some form of neuropsychiatric abnormalities, including dementia, depression, Parkinson’s, and Alzheimer’s. As mentioned previously, Alzheimer’s is linked to bone density. The extent and severity to which a patient has Alzheimer’s can predispose them to having low bone mineral density [2]. This may suggest that the bodies’ response to loss of brain matter and increased volume in the skull, is to increase bone deposition to minimize the movements of the brain and stabilize it within the capsule.

Some limitations of the study include a small sample size and a slightly higher number of female cadavers than males, which may decrease the statistical power of the study. Thus,
the small sample size does limit the conclusions that may be
drawn from this study. Another limitation is that the results
are obtained from cadavers; thus, conclusions are limited to
hypothesizing possible causes linking sex and HFI, since live
studies cannot be performed on the specimens. Lastly, a
radiological examination and pathology biopsy of the speci-
mens were not available in the study limiting the conclusions
to only suggestive of HFI.

Future studies must be done in order to gather more data
to formulate conclusive results that are statistically signi-
cificant and can be applied to the general population. With that said,
to enhance the results obtained in this study, further research
may be done to look at the relationship not only of sex and
HFI, but HFI and the causes of death of specimens, such as
prostate cancer prevalence and HFI and/or dementia preva-
ience and HFI. Overall, additional research needs to be per-
fomed in order to determine the other mechanisms that
play a role in the structural changes of the skull that were
seen in this study.

5. Conclusions

This study demonstrated the existence of a considerable
number of anatomical abnormalities in the skull of cadavers
of the Gross Anatomy Laboratory. These variations may be
attributed to hypertosis frontalis interna, a condition that
affects the skull of many in the aging population. The major-
ity of skull abnormalities belonged to females. Investigation
is needed for a definitive diagnosis of the found abnormali-
eties. More cadaver studies will help to bolster sex di-
ferences and prevalence data and provide standardized measure-
ments of lesions.

Data Availability

The Data is available upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

Stitzel, “Evaluation of skull cortical thickness changes with
age and sex from computed tomography scans,” Journal of
J. M. Burns, “Bone density and brain atrophy in early Alzhei-
mer’s disease,” Journal of Alzheimer’s Disease, vol. 18, no. 4,
[3] J. Boyke, J. Driemeyer, C. Gaser, C. Buchel, and A. May,
“Training-induced brain structure changes in the elderly,”
T. Mezaki, “Hyperostosis frontalis interna associated with
hypogonadism in an elderly man,” Age and Ageing, vol. 35,
[5] National organization of rare disorders, “Hyperostosis fronta-
hyperostosis-frontalis-interna/.
disease of bone: a review,” Rheumatology International, vol. 28,
[7] D. Cvetkovic, S. Nikolic, V. Brkovic, and V. Zivkovic, “Hyper-
ostosis frontalis interna as an age-related phenomenon – Dif-
fences between males and females and possible use in
identification,” Science & Justice, vol. 59, no. 2, pp. 172–176,
2019.
[8] National organization of rare disorders, “Paget’s Disease,”
brain dysfunction in sepsis,” Annals of Intensive Care, vol. 3,
no. 1, p. 15, 2013.
sis frontalis interna among the aged,” The American Journal of
Roentgenology, Radium Therapy, and Nuclear Medicine,
vol. 73, no. 3, pp. 396-397, 1955.
“Intracranial volume, cranial thickness, and hyperostosis fron-
talis interna in the elderly,” American Journal of Human Biol-