Two hyperostotic non-metric traits, caroticoclinoid foramen and pterygospinous foramen, which appear at an early developmental stage in the human cranium

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Abstract  Hyperostotic non-metric traits of the human cranium are characterized by excessive ossification over the non-anomalous condition. Although hyperostotic traits are considered age-progressive, the appearance of two hyperostotic traits, hypoglossal canal bridging and jugular foramen bridging, has been reported in fetal crania. In the present study, we show the detection of a pterygospinous foramen and two caroticoclinoid foramina in Japanese fetal crania. These findings suggest that these two types of foramen can appear at an early stage of craniofacial development. Analysis of the Spitalfields skeletal collection (London) has shown that the frequencies of both foramina in adults older than 20 years of age were slightly higher than those of children aged 0–6 years. However, statistical analyses did not show significant differences between children and adults. This suggests that these non-metric cranial traits may also be useful for anthropological population studies of juveniles.

Key words: hyperostotic traits, developmental anomaly, fetus, juvenile, Spitalfields collection

Introduction

Ossenberg (1969, 1970) proposed a dichotomy between hypostotic and hyperostotic traits within the analytical framework of non-metric traits of the human cranium: hyperostotic traits are characterized by excessive ossification over the non-anomalous condition, such as the ossification of structures normally consisting of cartilage, ligament, or dura. Although this type of ossification is considered an age-progressive phenomenon, Dodo (1980, 1986) observed two hyperostotic traits, hypoglossal canal bridging and jugular foramen bridging, in fetal crania in the Japanese population.

Preliminary investigations on non-metric traits in fetal crania in Japan and infant/early childhood crania of the Spitalfields collection in London showed the occurrence of two additional hyperostotic traits, caroticoclinoid foramen (CCF) and pterygospinous foramen (PSF), in these samples of an early developmental stage. According to Davis (1967), CCF is formed by an excess of ossification of the ligament stretching between the anterior and middle clinoid processes of the sphenoid bone (Figure 1), whereas PSF develops as a consequence of excessive ossification of the ligament extending between the spine of the sphenoid bone and the upper part of the lateral pterygoid plate (Figure 2). Therefore, both types of foramen have been regarded as hyperostotic traits derived from postnatal changes and their existence in fetal bones has not been reported, with the exception of the description of CCF in a 30-week fetus (Kiel, 1966).

In the present study, we described these two hyperostotic traits in crania of an early developmental stage in some detail and examined the possible age-related changes of these hyperostotic traits by comparing their frequencies of occurrence between child and adult cranial series from the Spitalfields collection. Their implications for future population studies are also discussed.

Materials and Methods

Fetal specimens consisted of 162 Japanese crania ranging in age from 6 months to term housed at the Tohoku University School of Medicine and five Japanese crania aged 10 months kept at the Saga Medical School.

From the crypt of Christ Church, Spitalfields, London, 968 skeletons including 215 juvenile specimens from individuals who had died in the 17–19th centuries AD were recovered (‘crypt sample’). For 387 of these skeletons (‘named sample’), coffin plates providing details of name, age, and date of death were available (Molleson and Cox, 1993). We recorded the presence or absence of non-metric cranial traits only for the crania available from the named sample (48 juveniles and 140 adults). However, observations of the CCF and PSF were extended to some of the unspecified juvenile crania from the unnamed crypt sample.

Observations were made by the naked eye using a check light with a flexible mirror. When the CCF or PSF was detected, the structure was photographed. Differences in occurrence of these traits between the child crania of 0–6 years
and the adult crania (>20 years old) of the Spitalfields named sample were tested by calculating Fisher’s exact probabilities using the software package HALWIN (Gendaisugakusha).

**Results**

**Caroticoclinoid foramen in fetal and infant/young child crania**

According to Davis (1967), the anterior, middle, and posterior clinoid processes of the sphenoid bone are connected by ligaments and are occasionally ossified to form the CCF and posterior interclinoiold foramen. However, we only detected the bony bridge between the anterior and middle clinoid processes in the fetal and infant/early childhood crania examined, with the exception of a 6-year-old cranium from the Spitalfields collection.

Figure 3 shows two cases of CCF in fetal crania of Japanese subjects. The sphenoid bone of a fetal cranium aged 7 months from the Tohoku University School of Medicine is shown in Figure 3a. The presphenoid and postsphe-

Figure 1. The caroticoclinoid foramen is observed on the right side of the sphenoid bone in a Japanese young adult cranium. CCF, caroticoclinoid foramen; OPC, optic canal; LW, lesser wing; ST, sella turcica.

Figure 2. The pterygospinous foramen is observed on the right side of a Japanese adult cranium. PSF, pterygospinous foramen; LPP, lateral pterygoid plate.
Medical School is shown in Figure 3b. The presphenoid and postsphenoid portions are firmly fused, with the exception of the central portion of the sphenoid body, and the fusion of the anterior and middle clinoid processes forms a complete CCF on the right side.

Figure 4a shows the CCF observed in an infant cranium aged approximately 1.5 years from the Spitalfields unnamed crypt sample. In this specimen, the CCF is on the left side, although the posterior strut segment of the optic canal (Kier, 1966) is not yet formed. Figure 4b shows a typical CCF seen on the right side of a 3.6-year-old infant cranium (no. 2456) from the Spitalfields named sample.

Figure 5 shows the cranium of a young child of approximately 6 years of age from the Spitalfields unnamed crypt sample. On both the left (Figure 5a) and right (Figure 5b) sides of the sphenoid bone, the anterior, middle, and posterior clinoid processes are joined by solid bony bars, thus forming the CCF and posterior interclinoid foramen.

Pterygospinous foramen in fetal and infant/young child crania

Figure 6 shows the sphenoid bone of a 10-month Japanese fetal cranium from the Tohoku University School of Medicine. On the right side, a backward projection (pterygospinous process) extends from the posterior border of the lateral pterygoid plate to the spine of the sphenoid, and an almost complete PSF is formed (Figure 6a). On the left side, an indication of the PSF is noted (Figure 6b).

Figure 7a shows the left lateral aspect of the sphenoid bone of a 1.6-year-old infant cranium (no. 2578) from the Spitalfields named sample. A stout bony bridge between the posterior border of the lateral pterygoid plate and the spine of the sphenoid bone forms the typical PSF. Figure 7b shows the inferolateral view of the right lateral pterygoid plate and greater wing of no. 2441 cranium aged 3.4 years from the Spitalfields named sample. The PSF is formed by a thin bony bridge stretching between the posterior margin of the...
lateral pterygoid plate and the spine of the sphenoid. According to Molleson (personal communication), no. 2441 is an elder brother of no. 2578.

Figure 8a is an inferolateral view of the right lateral pterygoid plate and the right-sided sphenoid body of an approximately 3-year-old infant cranium from the Spitalfields unnamed crypt sample. The right greater wing is missing. A backward extension of the lateral pterygoid plate forms the typical PSF. Figure 8b shows the lateral view of the right lateral pterygoid plate and greater wing of an approximately 4-year-old infant cranium from the Spitalfields unnamed crypt sample. A stout bony bridge between the posterior border of the lateral pterygoid plate and the spine of the sphenoid bone forms the typical PSF.

Comparison of trait frequencies between child and adult cranial series

The frequency of occurrence of the CCF was 1/25 (4.0%) in the infant/young child crania ranging in age from 0 to 6 years and 9/109 (8.3%) in the adult crania aged >20 years (Table 1). Although a higher frequency of the CCF is observed in the adult series than in the child series, Fisher’s exact probability (0.6874) did not show a significant difference between the two cranial series. The frequency of occurrence of the PSF in the child and adult cranial series was 2/28 (7.1%) and 15/119 (12.6%), respectively (Table 1). Again, a higher frequency of the PSF was observed in the adult series, although Fisher’s exact probability (0.5291) did not indicate a significant difference between these two cranial series.
Figure 5. The caroticoclinoid foramina on both sides of an approximately 6-year-old Spitalfields child cranium. (a) Left view. (b) Right view. In addition to the CCF, posterior interclinoid foramina are noted on both sides. CCB, caroticoclinoid bridging; ICB, interclinoid bridging.

Figure 6. The pterygospinous foramen and its indication in a 10-month-old Japanese fetal sphenoid bone. (a) Right lateral view. (b) Left lateral view. In (a), an almost complete pterygospinous foramen is shown, and in (b), an indication of the pterygospinous foramen is observed. PSF, pterygospinous foramen; LPP, lateral pterygoid plate; GW, greater wing.
Caroticoclinoid foramen

Hochstetter (1940) described a bilateral CCF formed by cartilage on the right and connective tissue on the left in a 12–13-week fetus (66.02 mm CRL). Kiel (1966) reported a case of ossified CCF on the right side in a 30-week fetus, which was clearly detected in a photograph. The latter case is comparable to our depiction of an ossified CCF in a 7-month-old Japanese fetus shown in Figure 3a. In addition to these reports, several authors described the occurrence of CCF in juvenile crania, including infants aged 21 days, 30 days, 3 months, 7 months, and 15 months (Keyes, 1935); an infant aged 8 months (Kier, 1966); infants/children of 0–11 years (Ossenberg, 1969); and a child of 8 years of age (Lang, 1977). On the basis of these findings, Hochstetter (1940) and Lang (1977) postulated that the CCF is already present as a structure surrounded by a cartilaginously preformed bridge during the embryological development of the cranium, rather than the product of secondary ossification of ligaments or dural folds. Kiel (1966) regarded this structure as a developmental anomaly of the embryonic chondrocranium, and
Scheuer and Black (2000) were in agreement with Kiel’s suggestion.

In the present study, the CCF was observed not only in the crania of infants and young children aged 1.5, 3.6, and 6 years (Figure 4, Figure 5) but also in 7- and 10-month fetal crania (Figure 3). The results of the present study and those of the preceding studies confirm that the CCF formed by a bony bridge between the anterior and middle clinoid processes of the sphenoid bone appears at an earlier stage of cranial development.

**Pterygospinous foramen**

Histological observations made by James et al. (1980) showed the appearance of the pterygosphenous ligament in a fetus aged approximately 17 weeks (120 mm CRL). The bony bridge forming the PSF has been described in the following infants and children: an infant of unknown age (Oetteking, 1930); an infant or child of 0–10 years (Akabori, 1933); infants/children aged 0–11 years (Ossenberg, 1969); and a 5-year-old child (Lang and Hetterich, 1983). On the basis of their findings from a study of postnatal development of the pterygoid process, Lang and Hetterich (1983) claimed that the PSF is formed as a developmental anomaly similar to the CCF, rather than the result of secondary ossification of the pterygosphenous ligament.

In the present study, an almost complete PSF was ob-
served in a 10-month fetal cranium (Figure 6). To our knowledge, the formation of the bony PSF at such an early developmental stage of the human cranium has not been reported previously. Moreover, the complete PSF was detected in the crania of infant/young children aged 1.6, 3, 3.4, and 4 years (Figures 7, Figure 8). Our findings, together with those of previous studies, confirm that the PSF formed by a bony bridge between the spine of the sphenoid and the posterior border of the lateral pterygoid plate appears at an early stage of cranial development.

**Comparison of trait frequencies between children and adults**

Ossenberg (1969) reported side incidences of clinoid bridging (including the CCF) and PSF of 16.3% and 5.6%, respectively, in juvenile Native American crania aged 0–11 years. This author demonstrated that the frequency of clinoid bridging increases slightly with age, while that of the PSF has no significant relation to age. In the present study, frequencies of both the CCF and PSF showed slightly increasing tendencies from the children of 0–6 years to adults >20 years of age (Table 1). However, statistical tests did not show significant differences between children and adults.

The frequencies patterns of the CCF and PSF in fetal/infant/young child and adult cranial series resemble those of the hypoglossal canal bridging and jugular foramen bridging reported previously (Dodo, 1980, 1986). Taken together, these results strongly suggested that these four hyperostotic non-metric traits make their appearance during the fetal or infant stage of cranial development. The occurrence of PSF in two infant siblings from the Spitalfields series may suggest that the appearance of this hyperostotic trait is familial in nature (Figure 7).

Non-metric traits in adult crania are frequently used to measure biological distances between populations (e.g., Laughlin and Jørgensen, 1956; Yamaguchi, 1967; Berry and Berry, 1967; Dodo, 1974; Ossenberg, 1976). The findings of the present study suggest that these non-metric cranial traits might be used effectively even for population studies of juveniles, such as the children of prehistoric Jomon and Yayoi in Japan.

**Table 1. Comparison of trait frequencies between child and adult cranial series of the Spitalfields named sample**

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<thead>
<tr>
<th>Caroticoclinoid foram.</th>
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<tr>
<td>Child (0–6 years)</td>
<td>1 (4.0)</td>
<td>25</td>
</tr>
<tr>
<td>Adult (20 years or more)</td>
<td>9 (8.3)</td>
<td>109</td>
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Fisher’s $P = 0.6874$

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<th>Pterygospinous foram.</th>
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<tbody>
<tr>
<td>Child (0–6 years)</td>
<td>2 (7.1)</td>
<td>28</td>
</tr>
<tr>
<td>Adult (20 years or more)</td>
<td>15 (12.6)</td>
<td>119</td>
</tr>
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Fisher’s $P = 0.5291$

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**References**


