Abnormal Cranial Shape Preceding Radiographic Evidence of Craniosynostosis

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Summary: Premature fusion of a cranial suture is known to result in characteristic changes in the head shape, even when the synostosis involves only part of the suture. We report an unusual case of a patient seen at the age of 2 months for an abnormal head shape that was present at birth. The phenotype was consistent with an isolated fusion of the frontosphenoidal suture, but the suture was open on a high-resolution computed tomography scan finding. There was no improvement in cranial form after 6 months of helmet therapy, and a follow-up computed tomography scan image taken at age 10 months showed the development of bilateral isolated frontosphenoidal synostosis. This case highlights that an abnormal head shape may, in some patients, predate radiographic evidence of craniosynostosis. (Plast Reconstr Surg Glob Open 2020;8:e3127; doi: 10.1097/GOX.0000000000003127; Published online 17 September 2020.)

Craniosynostosis, or premature fusion of one or more cranial sutures, results in relatively predictable alterations of cranial growth and shape. The characteristic changes are typically recognized at birth and draw clinical awareness to the presence of a sutural fusion. Latent forms of postnatal craniosynostosis have been described1,2 and typically present with a normal or near normal cranial shape. However, there are few reports of patients in whom the cranial shape changes predate radiographic evidence of craniosynostosis. Herein, we describe a patient who was born with the characteristic phenotype of isolated frontosphenoidal (FS) craniosynostosis but had patent sutures on initial computed tomography (CT). The patient was unsuccessfully treated with a cranial orthotic for deformational flattening and a subsequent CT finding revealed a new onset fusion of both FS sutures.

CASE REPORT
An otherwise healthy 2-month-old girl was referred to our clinic for a cranial shape abnormality that was evident at birth. The patient was born at term to a 31-year-old mother via an uneventful vaginal delivery, and the abnormal form of the head was initially thought to be a result of normal cephalic molding. On physical examination, the patient was developmentally appropriate for her age. Her head circumference (HC) was in the 98th percentile, with a cross diagonal difference of 15 mm. Head examination revealed relative bossing of the left frontal bone, flattening of the right frontal bone and superior orbital rim, mild anterior displacement of left ear, flattening of the left occipital bone, but no nasal root or lower facial asymmetry. Although some of these features were consistent with deformational plagiocephaly, the degree of frontal retrusion was not. A high-resolution CT scan was performed, whose findings demonstrated narrowed, but patent, right FS, and the remaining sutures were normal in appearance and patent (Figs. 1 and 2). A diagnosis of deformation plagiocephaly was made, and the patient underwent management with a custom cranial orthotic and physical therapy.

At the age of 10 months, the patient showed only limited improvement of the cranial asymmetry and had a cross diagonal difference of 10 mm. The frontal-orbital asymmetry persisted and promoted a follow-up CT scan that revealed definitive fusion of the right FS suture, and severe narrowing and probable fusion of the left FS suture (Fig. 3). After consultation with the parents, the patient had a bilateral orbital advancement at the age of 1 year. Genetic testing failed to reveal any known mutations associated with craniosynostosis. At the age of 6 years, the patient is developmentally normal and has subtle right frontotemporal retrusion with no signs of increased intracranial pressure.

DISCUSSION
The diagnosis of most forms of craniosynostosis relies on recognizing the characteristic changes in craniofacial form, which occur as a result of the premature suture fusion. The...
predictable patterns of cranial shape were first cataloged in the sentinel work of Virchow and established the foundation of accurate clinical diagnosis. Although often performed, radiographic studies are only used to confirm clinical suspicions of sutural pathology. In our patient, the presence of a phenotype consistent with one of the rarest forms of craniosynostosis, isolated frontosphenoidal craniosynostosis, prompted an early CT scan to clinch the clinical diagnosis. While the right FS suture was narrowed compared with the suture of the contralateral side, the treating physician (S.N.M.) was surprised that all cranial sutures were patent. This finding was reviewed with 2 neuroradiologists. This finding is reminiscent of the so-called sticky suture, which was used to describe children with functional lambdoid synostosis. This phenomenon has also been reported rarely in patients with nonsynostotic scaphocephaly. Baumgartner et al reported a series of patients with deformational scaphocephaly and patent sagittal suture. In his series, one patient presented with a persistent scaphocephalic phenotype after completing the helmet molding therapy. This prompted performing a CT scan, whose findings revealed a radiographic fusion of the sagittal suture that was treated surgically. Similar to what occurred in our patient, the latent suture fusion was only identified because there was a persistent phenotypic abnormality despite months of helmet therapy and observation. These cases highlight that suture fusions can occur in previously patent sutures, and that characteristic head shape changes can predate radiographic craniosynostosis. Moreover, the persistence of an abnormal cranial shape (especially one that is characteristic of a specific suture fusion) should raise suspicions of a suture fusion and prompt a CT evaluation, even if a prior CT evaluation was deemed normal.

The underlying etiology of this unusual craniosynostosis in our patients is unknown. Genetic testing failed to identify a mutation associated with any of the more common syndromic forms of craniosynostosis. This is consistent with the literature, and none of the described cases of isolated frontosphenoidal synostosis had an identifiable genetic etiology. Given the rarity of this form of craniosynostosis, and the latent development of fusion, we ponder whether our patient’s fusion may have arisen as a result of intrauterine mechanical forces. The proposal that fetal constraint can induce craniosynostosis stems from its well-described association with factors that increase the risk of gestational crowding, such as plurality, twinning, nulliparity, macrosomia, and early fetal descent. A number of animal studies have produced compelling evidence that suture activity and patency can change in response to external mechanical forces, a process termed mechanotransduction. Southard and Forbes showed that the application of mechanical force to murine cranial sutures yielded significant histological changes, including increased suture width, vascularity, size, and the number of cells, amount of osseous production, and even alterations in suture morphology. These changes are associated with alterations in molecular signaling in the peri-sutural environment.

![Fig. 1. Axial and three-dimensional computed tomographic image at the age of 2 months demonstrating (A) patent but narrow right frontosphenoidal suture (white arrows), and patency of the right sphenosquamosal (black arrowhead) and coronal (black arrow) sutures. B, Patent left fronto-sphenoidal suture (white arrow).](image1)

![Fig. 2. Three-dimensional computed tomographic reconstruction at the age of 2 months: A, patent left frontosphenoidal suture (black arrow), B, narrow but patent sutures of the right hemicranium (black arrow).](image2)

![Fig. 3. Three-dimensional computed tomographic reconstruction at the age of 10 months: A, Anterior-posterior view showing right frontal flattening and mild deviation of the nasal root. B and C, Lateral views of left and right hemicranium showing isolated fusions of the frontosphenoidal sutures (black arrows).](image3)
environment and arise as early as the first day of force. Intraterine mechanical forces on the forehead may have resulted in focal compression of the involved sutures, and initiation of a molecular cascade that ultimately led to the closure of the initial patent suture. It is, however, equally possible that unknown genetic or epigenetic influences were already acting on the suture even before birth.

**CONCLUSIONS**

This case provides a cause for clinicians to closely monitor patients with an abnormal head shape despite sutural patency on initial CT scan. In this case, the presence of a head shape abnormality preceded sutural closure, perhaps as a result of mechanical forces exerted in utero.

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