1 Sonographic indicators of isolated fetal sagittal craniosynostosis during pregnancy.

2 Short Title: isolated fetal sagittal craniosynostosis

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SONOGRAPHIC INDICATORS OF ISOLATED FETAL SAGITTAL CRANIOSYNOSTOSIS DURING PREGNANCY.

ABSTRACT.

INTRODUCTION.

The antenatal diagnosis of sagittal craniosynostosis can be challenging, but there are several published papers describing a traumatic outcome to both the affected fetus and the mother during delivery of a scaphocephalic child. The antenatal imaging from affected children was collected along with the mother's obstetric history. The aim of this study was to identify antenatal ultrasound features that may assist the diagnosis of sagittal synostosis before birth, to enable appropriate delivery planning and avoid both maternal and fetal trauma during birth.

METHOD.

Antenatal ultrasound scans in both the second and third trimesters were traced for 36 children with sagittal synostosis. The initially diagnostic CT scans were also sourced. A delivery history was collected from the hospital case notes where available.

RESULTS.

The affected group showed a statistically significant reduction in cephalic index during the second half of pregnancy compared with the normal population which became slightly more brachycephalic ($p = 0.001$). Regression analysis showed an average reduction in cephalic index of 0.57 units per month. There was also a much higher rate of malpresentation and surgical deliveries in the affected group than the normal population. There was a relationship between sagittal craniosynostosis and breech presentation and an associated higher rate of surgical deliveries.

CONCLUSION.

It is possible to detect sagittal synostosis in the third trimester of pregnancy which may assist with delivery planning.

KEYWORDS.

Craniosynostosis, fetus, perinatal complication, skull, ultrasonography

INTRODUCTION.

Sagittal craniosynostosis is the most common isolated premature sutural fusion, affecting around 1 in every 5 000 live births¹. The condition is usually diagnosed in the first year of life, with the child's head shape being noticeably scaphocephalic. The treatment is surgical with cranial vault reshaping done early in the child's life. This is done to obtain a normal cranial shape, and to prevent complications which include raised intracranial pressure. Craniosynostosis is rarely diagnosed antenatally, and usually only when there are multiple sutural fusions as part of a syndrome, which may include associated limb anomalies.

There are an increasing number of reports in the literature describing maternal and fetal birth trauma where children are later diagnosed with craniosynostosis¹⁻⁶. Some of these reports are anecdotal, and the diagnosis of craniosynostosis is usually made postnatally. Antenatal diagnosis remains difficult, as the fetal head is deformable due to the open fontanelles and patent sutures. The resulting deformability creates significant variability in the normal fetal head shape, but suture function is critical for delivery as the fetal skull needs to mould to permit passage through the maternal pelvis.

The age of onset of sutural fusion remains uncertain in craniosynostosis⁷. Only multi-sutural syndromic forms are able to be reliably diagnosed at the mid-trimester morphology scan. In current Australian obstetric practice, not all pregnancies undergo an ultrasound scan in the third trimester. There is now strong evidence that the clinical diagnosis of intrauterine growth restriction in the third trimester is unreliable⁸⁻¹¹, and it is possible that growth scanning will become routine in late pregnancy within a short time period. This may provide an opportunity to detect craniosynostosis prior to delivery. A progressive reduction in fetal cephalic index (CI) and deflection in the biparietal diameter (BPD) curve have been described previously as indicators of sagittal synostosis^{5, 6}. The normal fetal cephalic index in the second half of pregnancy has recently been determined¹². This information may assist in the recognition of

unusually scaphocephalic fetal skulls in those undergoing scanning in the third trimester.

The aim of this study was to compare the antenatal ultrasound imaging between affected and non-affected children to identify features that may assist with the antenatal diagnosis of sagittal synostosis. This may help identify affected fetuses in the future, to assist with delivery planning. We also compared our cohort of children diagnosed with sagittal synostosis with the background population to determine if there are differences relating to childbirth between the two groups.

MATERIALS AND METHODS.

Ethics approval was obtained for this retrospective study from the Women's and Children's Health Network Human Research Ethics Committee and the University of Adelaide Human Research Ethics Committee, both of which waived consent. Children born in South Australia (SA) or the Northern Territory (NT) from January 1, 2000 to December 31, 2018 with a diagnosis of craniosynostosis affecting the sagittal suture were identified through the Australian Craniofacial Unit Database and the Radiology Information System of the Women's and Children's Hospital in SA. The antenatal ultrasound scans, delivery details and initial cranial computed tomography (CT) scans after birth were collected where available. All available scans were electronically archived, many earlier scans were only produced in hard copy format and were therefore not available. The biparietal diameter (BPD), occipitofrontal diameter (OFD) and head circumference (HC – ultrasound only) were measured and the cephalic index calculated for each scan via the equation: $CI = 100 \times BPD/OFD$. Measurements used were performed either at the time of ultrasound scanning, or retrospectively using computer software to obtain accurate measurements from the original imaging data. All ultrasound scans were performed at accredited imaging practices by qualified sonographers, images obtained by non-qualified personnel at the bedside were not included. All antenatal ultrasound scans included standard fetal biometry consistent with the Australian Society of Ultrasound in Medicine Guidelines¹³. All images used were determined to be of good quality by the first author.

The data obtained were compared with the local population data obtained from the Pregnancy Outcomes Unit, SA Health (Pregnancy Outcomes in South Australia (2003 – 2016)¹⁴, the Northern Territory Government, Department of Health (NT Midwives' Collection, Mothers and Babies 2003 – 15)¹⁵ and the Fetal Cephalic Index Study¹².

STATISTICAL ANALYSIS.

All data analyses were performed in the statistical software R v.3.5.2 (R Core Team, 2018). Associations between the sagittal synostosis group and the population with respect to gender, delivery, and presentation were investigated using two-way tables and the Chi-squared test, using Monte Carlo simulated P-values using 2000 'replicates'. As population statistics were only presented one variable at a time, regrettably, more complex analyses, taking into account more than one variable, were not possible.

The change in CI between growth and morphology scans was calculated for normal fetuses¹² and those with sagittal synostosis. The difference in average CI between the two groups was assessed at each scan using Welch's t-test, as was the average change in CI. In addition, a linear regression, taking into account the temporal separation between the second and third trimester scans, was fitted to the change in CI, allowing for differences between the two groups. The average CI at growth ultrasound was also compared with the CI at first diagnostic CT scan using Welch's t-test.

RESULTS.

152 children were born in South Australia or the Northern Territory between 2000 and 2018 that have come to the attention of the Australian Craniofacial Unit with sagittal synostosis. 128 of those children (84.2%) had an isolated sagittal synostosis at presentation, and 1 child (0.7%) had a combined sagittal and metopic synostosis. Of those 129 children with midline fusions seven were diagnosed as syndromic. Three were diagnosed with Crouzon Syndrome, two with Saethre-Chotzen Syndrome, one with Pfeiffer Syndrome and one with Antley-Bixler Syndrome – these were excluded from the analysis. The proportion of male babies was significantly higher in the sagittal

synostosis group compared with the normal population ($p < 0.001$) which may lead to confounding of some of the following effects.

Nine children (7.4%) were diagnosed with isolated sagittal synostosis without scaphocephaly. Six of these children had CT scans for other clinical cranial abnormalities and three children had CT scans for unrelated reasons.

The details of the birth of the children with sagittal synostosis was collected and compared with the normal population. The data are summarized in Table 1. The median gestational age for delivery was 39 weeks' gestation (range 24 – 42 weeks, gestation unknown in 2 cases). This is very similar to the general population¹⁴. There is a statistically significant difference between the deliveries for the 2 groups, due to the higher rate of Caesarean deliveries and the lower rate of unassisted vaginal deliveries in the sagittal synostosis group ($\chi^2 = 20.1$, $p = 0.001$). This is also demonstrated in Figure 1. There was also a statistically significant difference between the presentation at delivery between the babies with sagittal synostosis and the normal population ($\chi^2 = 13.0$, $p = 0.003$). There were a lower number of vertex presentations amongst the babies with sagittal synostosis (Figure 2).

Serious perineal tears (third and fourth degree) were recorded in 3.8% of vaginal deliveries of infants later diagnosed with sagittal synostosis compared with 2.7% of vaginal deliveries in the population. There was no statistically significant difference in relative occurrence of tears associated with the delivery of an infant later diagnosed with sagittal synostosis compared with the normal population ($\chi^2 = 0.25$, $p = 0.65$).

Second trimester morphology ultrasound scans were traced for 91 children (74.6%) and third trimester growth scans were performed in 36 pregnancies (29.5%). Fifteen of these children (41.7%) had multiple third trimester scans during pregnancy – only the scan closest to 32 weeks was used for this study. Scans in both trimesters were available in 21 pregnancies (23.0%).

The mean CI at morphology scan was 76.0 (standard deviation (SD) 4.3) and at growth scan was 74.5 (SD 4.5) (Table 2). This compares to a mean CI in the normal population

of 75.9 (SD 3.7) at morphology scan and 77.8 (SD 3.5) at growth scan. The difference in mean CI was not statistically significant ($p = 0.77$) at the morphology scan but was statistically significantly different at the growth scan ($p = 0.001$). For those where both scans were available, the average change in CI between the second and third trimester scans in fetuses with sagittal synostosis was -1.6 (SD 5.0). There is a statistically significant difference between the change in CI of the babies with sagittal synostosis compared with the normal population, who showed an average change in CI of +1.9, SD 4.3 ($p = 0.001$). This is shown in Figure 3, which shows the density curves of the change in CI between the two scans for the two groups of fetuses. A linear regression analysis was performed, as there was some variability in the time period between the second and third trimester scans in both the normal population¹² and the sagittal synostosis group. This is shown in Figure 4, which shows a scatter plot of the change in CI versus time difference between scans for both groups, including the least squares regression lines. From this plot it is evident that the change in CI in sagittal synostosis fetuses is more likely to be negative compared with the normal population¹², that is, the head shape is more likely to become more scaphocephalic than the normal population which tends to become slightly more brachycephalic, although this effect tends to reduce the further the scans are apart. In addition, there were two potential outliers, where a relatively large positive change was observed given the time difference between scan (both of these had scans that were separated by 12 weeks or less). The two regression lines are statistically significantly different, both in intercept ($p < 0.001$ at 12 weeks separation between scans) and gradient ($p = 0.02$).

The cephalic index at growth ultrasound was also compared with the CI at the first diagnostic CT scan performed post-natally in 29 children who had a third trimester ultrasound and a CT in the first two years of life. There was a statistically significant difference between the CI calculated at growth scan and the CI calculated at CT scanning, with an average difference in CI of -5.1 ($p < 0.001$). When taking into account the time difference between these two scans in individual children, the regression analysis shows an average reduction of 0.57 units per month.

DISCUSSION.

The findings of a significantly higher rate of Caesarean sections amongst the sagittal synostosis group is consistent with the previous studies. Over 50% of affected children in the study group were delivered by Caesarean section compared with a rate of 32% in the background population. This is much higher than the rates reported by Weber et al³ (26% vs 24%) and Swanson et al⁴ (33% vs 24%) who examined all craniosynostoses, and Heliovaara et al¹ (31% vs 17%) and Cornelissen et al⁶ (28% vs 12%) who looked only at sagittal synostosis. The background rate of surgical deliveries is also higher in the Australian population compared to the numbers reported in these studies. There were more than double the proportion of breech presentations in the study group (12.1%) compared with the background population (4.7%). This is similar to the study by Weber et al³ (12% vs 5.4%), although the Swanson et al⁴ and Cornelissen et al⁶ studies reported lower rates of breech presentation (5.8% and 3%). The sagittal synostosis group had a higher rate of both elective and emergency Caesarean sections than the background population, but especially elective Caesarean sections. This may be due to the higher incidence of breech presentations, although in both the study and background population groups there are often multiple reasons given for a surgical delivery.

The reported rate of serious (third and fourth degree) perineal tears was not statistically significantly higher in mothers who deliver infants later diagnosed with sagittal synostosis. The limited ability of the scaphocephalic head to mould normally during delivery and the increased rate of malpresentation may be leading to more Caesarean sections deliveries, and thus the rate of serious perineal tears is not elevated as might be expected. Previous studies have reported an increase in vaginal tearing³ in pregnancies of children later diagnosed with sagittal synostosis. Statistics on vaginal tearing were not available in the study population or background population groups.

The “breech head” was first reported in 1979 by Haberkern et al¹⁶. They noted scaphocephaly in eight infants with breech presentation and commented on the

potential for birth injury during vaginal delivery. None of the affected infants had craniosynostosis diagnosed post-natally. Kasby and Poll¹⁷ also noted the “breech head” in at least one third of breech babies, and commented on the reduced cephalic index in this group. Bader et al¹⁸ found similar results. This raises an interesting question in the sagittal synostosis population: Does the presence of scaphocephaly relate to a breech presentation, and why? It is likely that in many cases the elongated fetal head does not fit in the maternal pelvis, with a breech presentation allowing the fetus to descend in the later weeks of pregnancy. While other studies¹⁹⁻²¹ neither prove nor disprove that a breech presentation plays a role in the development of sagittal synostosis, this warrants further investigation. The mean cephalic index in the sagittal synostosis group was not significantly different from that of the normal population at second trimester morphology scan. This has two important implications in craniosynostosis diagnosis. Firstly, the morphology scan alone is of no value in the diagnosis of sagittal craniosynostosis. The lack of a difference in the CI between the two groups on a single scan gives no indication that a sutural fusion may be present. Secondly, the lack of any difference in CI between the two groups at morphology scan, but a statistically significant difference at third trimester growth scan suggests that in the majority of affected fetuses, the sutural fusion occurs in the third trimester or later. An example of this is shown in Figure 5. It has been shown previously that a progressive reduction in the growth of the BPD compared with the HC is often seen in the second half of pregnancy in affected fetuses^{5, 22}.

It has previously been reported that the onset of craniosynostosis can be delayed and progressive^{23, 24}. Fusion may be pre- or post-natal^{1, 7}, and the earlier the onset, the more significant the effect on skull shape⁷. Three of the children in this study had an incidental diagnosis of sagittal craniosynostosis (without scaphocephaly) made when CT scans were performed for unrelated reasons. A further six children had a diagnosis made when scans were performed for cranial abnormalities other than scaphocephaly. Only one of these nine children had a CI more than one standard deviation below the mean at morphology scan. An abnormal head shape is detected in 2 – 3% of pregnancies at routine anatomy scanning²⁵. In a 2007 study, 72 fetuses with

dolichocephaly at morphology ultrasound were followed, and none developed craniosynostosis. Eight of these fetuses were eventually diagnosed with a genetic/chromosomal disorder²⁶. Gray et al²⁷ found a wide variation in the normal cephalic index during pregnancy, as did Kurmanavicius et al²⁸ and Constantine et al¹², who both examined a large number of normal fetuses. This contributes to the explanation as to why craniosynostosis is rarely diagnosed in the second trimester, unless there are other abnormalities present^{3, 5, 25, 29}.

The difference in the cephalic index measured antenatally compared with that postnatally was very significant. The average difference in CI between the scans was - 5.1 units, with 25 of the 29 children demonstrating a reduction in CI. This is not unexpected as the head continues to grow during this time and becomes progressively more scaphocephalic due to the advancing sagittal sutural fusion. This also lends some validity to the ultrasound calculation of the CI, as all children were more scaphocephalic postnatally compared with antenatally. The underestimation of cranial measurements by fetal ultrasound has previously been reported³⁰. It may be that the ultrasound measurements under or over-estimate the CI in some individual cases depending on fetal head position and gestation, whereas CT scanning provides very accurate measurements.

The incidence of isolated sagittal synostosis is approximately 1 in 5000 live births¹ and while our data shows a higher rate of surgical deliveries in this group, many infants still deliver without incident. Our data does not support the use of 3D ultrasound scanning in every fetus with a reduced CI in the third trimester. It would be neither time nor cost effective when many normal fetuses have a low CI in the third trimester and the incidence of isolated craniosynostosis is low. However, if a progressive reduction in fetal CI is observed in the third trimester and a vaginal delivery is planned, 3D ultrasound scanning to visualize the sagittal suture could be of benefit to detect sutural fusion⁵.

STUDY LIMITATIONS.

The main limitation of this study relates to the small numbers in the sagittal synostosis group. Only a small number of affected children had multiple antenatal scans (as per obstetric practice at the time) to allow the CI to be calculated. Third trimester imaging was performed in only 36 pregnancies. There is also a discrepancy between the gender distribution in the sagittal synostosis group compared with the background population, with a male to female ratio of 2.2:1 compared with 1:1 in the background population. This is a reflection that sagittal synostosis is more common in males, which has been previously well-established. There were also some differences in the methods of data collection and terminology relating to pregnancy and childbirth between South Australia and the Northern Territory that made comparison with the study group difficult. However, the Northern Territory only contributed 13% to the population data and hence any (minor?) differences in reporting methodology between the two jurisdictions are likely to have only a small effect. Where possible, stillbirths were excluded from the comparison data.

CONCLUSION.

There is a clear relationship between the presence of sagittal craniosynostosis and breech presentation at delivery in affected fetuses. There is also a marked increase in the rate surgical deliveries in this group of infants. Our data supports the notion that isolated sagittal synostosis is rarely detectable antenatally at the mid trimester morphology scan. It is possible to diagnose sagittal synostosis in the third trimester by noting a progressive decrease in the fetal cephalic index, which should provoke 3D scanning of the fetal skull to examine the sagittal suture. A breech presentation in the late third trimester should increase suspicion of sagittal synostosis when the other ultrasound markers are present.

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REFERENCES.

1. Heliovaara A, Vuola P, Hukki J and Leikola J. Perinatal features and rate of cesarean section in newborns with non-syndromic sagittal synostosis. *Child's Nerv Syst.* 2016 Jul;32(7):1289-92. DOI: 10.1007/s00381-016-3078-2.
2. Anderson PJ, McLean NR and David DJ. Craniosynostosis and childbirth. *Eur J Plast Surg.* 2005;28(2):94-8. DOI: 10.1007/s00238-005-0753-z.
3. Weber B, Schwabegger AH, Oberaigner W, Rumer-Moser A and Steiner H. Incidence of perinatal complications in children with premature craniosynostosis. *J Perinat Med.* 2010 May;38(3):319-25. DOI: 10.1515/JPM.2010.028.
4. Swanson J, Oppenheimer A, Al-Mufarrej F, Pet M, Arakawa C, Cunningham M, et al. Maternofetal Trauma in Craniosynostosis. *Plast Reconstr Surg.* 2015 Aug;136(2):214e-22e. DOI: 10.1097/PRS.0000000000001468.
5. Constantine S, David D and Anderson P. The use of obstetric ultrasound in the antenatal diagnosis of craniosynostosis: We need to do better. *Australas J Ultrasound Med.* 2016;19(3):91-8. DOI: 10.1002/ajum.12016.
6. Cornelissen MJ, Softeland M, Apon I, Ladfors L, Mathijssen IMJ, Cohen-Overbeek TE, et al. Perinatal complications in patients with unisutural craniosynostosis: An international multicentre retrospective cohort study. *J Craniomaxillofac Surg.* 2017 Nov;45(11):1809-14. DOI: 10.1016/j.jcms.2017.08.012.

- 316 7. Cohen MM. Sutural Biology and the Correlates of Craniosynostosis. Am J Med
317 Genet. 1993 Oct 1;47(5):581 - 616. DOI: 10.1002/ajmg.1320470507.
- 318 8. Sovio U, White, I. R., Dacey, A., Pasupathy, D., Smith, G. C. S. Screening for fetal
319 growth restriction with universal third trimester ultrasonography in nulliparous
320 women in the Pregnancy Outcome Prediction (POP) study: a prospective cohort
321 study. Lancet. 2015 Nov 21 2015;386(10008):2089 - 97. DOI: 10.1016/S0140-
322 6736(15)00131-2.
- 323 9. Khalil A and Thilaganathan B. Role of uteroplacental and fetal Doppler in
324 identifying fetal growth restriction at term. Best Pract Res Clin Obstet Gynaecol.
325 2017 Jan;38:38-47. DOI: 10.1016/j.bpobgyn.2016.09.003.
- 326 10. Williams M, Turner, S., Butler, E., Gardosi, J. Fetal growth surveillance – Current
327 guidelines, practices and challenges. Ultrasound. 2018 May 1 2018;26(2):69-79.
328 DOI: 10.1177/1742271X18760657.
- 329 11. Sparks TN, Cheng YW, McLaughlin B, Esakoff TF and Caughey AB. Fundal height:
330 a useful screening tool for fetal growth? J Matern Fetal Neonatal Med. 2011
331 May;24(5):708-12. DOI: 10.3109/14767058.2010.516285.
- 332 12. Constantine S, Keirmeier, A., Anderson, P. The Normal Fetal Cephalic Index in
333 the Second and Third Trimesters of Pregnancy. Ultrasound Q. 2019;Published
334 Ahead of Print. DOI: 10.1097/ruq.0000000000000444.
- 335 13. Australasian Society for Ultrasound in Medicine Policies and Statements. D7.
336 ASUM. NSW. 2007.
337 [www.asum.com.au/files/public/SoP/Current/Obstetrics and Gynaecology/Nor](http://www.asum.com.au/files/public/SoP/Current/Obstetrics%20and%20Gynaecology/Normal-Ultrasonic-Fetal-Measurements-Standard-D7.pdf)
338 [mal-Ultrasonic-Fetal-Measurements-Standard-D7.pdf](http://www.asum.com.au/files/public/SoP/Current/Obstetrics and Gynaecology/Normal-Ultrasonic-Fetal-Measurements-Standard-D7.pdf).
- 339 14. Pregnancy Outcome in South Australia. Adelaide, South Australia: Pregnancy
340 Outcome Unit, SA Health, Prevention and Population Health Branch,
341 Government of South Australia; 2003 - 2016. Report No.: ISSN 0819-3835
342 Contract No.: Public-I2-A1.

- 343 [https://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+](https://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/resources/pregnancy+outcome+in+south+australia)
 344 [internet/resources/pregnancy+outcome+in+south+australia](https://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/resources/pregnancy+outcome+in+south+australia)
- 345 15. Mothers and Babies: Northern Territory Midwives' Collection. Darwin,
 346 Northern Territory: Department of Health, Darwin, Department of Health NT;
 347 2003 - 2015. Report No: ISBN 978 0 9804235 9 4.
 348 [https://digitallibrary.health.nt.gov.au/prodispui/simple-](https://digitallibrary.health.nt.gov.au/prodispui/simple-search?location=%2F&query=mother+and+babies&rpp=10&sort_by=score&order=desc)
 349 [search?location=%2F&query=mother+and+babies&rpp=10&sort_by=score&or](https://digitallibrary.health.nt.gov.au/prodispui/simple-search?location=%2F&query=mother+and+babies&rpp=10&sort_by=score&order=desc)
 350 [der=desc](https://digitallibrary.health.nt.gov.au/prodispui/simple-search?location=%2F&query=mother+and+babies&rpp=10&sort_by=score&order=desc)
- 351 16. Haberkern CM, Smith, David W., Jones, Kenneth J. The 'Breech Head' and Its
 352 Relevance. Arch Pediat Adolesc Med. 1979;133(2):154-6. DOI:
 353 10.1001/archpedi.1979.02130020044009.
- 354 17. Kasby CB and Poll V. The breech head and its ultrasound significance. Br J
 355 Obstet Gynaecol. 1982 Feb;89(2):106-10. DOI: doi:10.1111/j.1471-
 356 0528.1982.tb04674.x.
- 357 18. Bader B, Graham D and Stinson S. Significance of ultrasound measurements of
 358 the head of the breech fetus. J Ultrasound Med. 1987 Aug;6(8):437-9.
- 359 19. Graham JM, Jr., deSaxe M and Smith DW. Sagittal craniostenosis: fetal head
 360 constraint as one possible cause. J Pediatr. 1979 Nov;95(5 Pt 1):747-50. DOI:
 361 10.1016/s0022-3476(79)80728-3.
- 362 20. Higginbottom MC, Jones KL and James HE. Intrauterine constraint and
 363 craniosynostosis. Neurosurgery. 1980 Jan;6(1):39-44. DOI: 10.1227/00006123-
 364 198001000-00005.
- 365 21. Sanchez-Lara PA, Carmichael SL, Graham Jr JM, Lammer EJ, Shaw GM, Ma C, et
 366 al. Fetal constraint as a potential risk factor for craniosynostosis. Am J Med
 367 Genet Part A. 2010;152(2):394-400.
- 368 22. Cornelissen MJ, Apon I, van der Meulen J, Groenenberg IAL, Kraan-van der Est
 369 MN, Mathijssen IMJ, et al. Prenatal ultrasound parameters in single-suture

- 370 cranosynostosis. J Matern Fetal Neonatal Med. 2017 Jun 14:1-8. DOI:
371 10.1080/14767058.2017.1335706.
- 372 23. Moore JM, Molloy C and Anderson PJ. A complicated case of plagiocephaly
373 followed by delayed cranosynostosis. Child's Nerv Syst. 2013 August
374 01;29(8):1395-6. DOI: 10.1007/s00381-013-2102-z.
- 375 24. Reddy K, Hoffman H and Armstrong D. Delayed and Progressive Multiple Suture
376 Craniosynostosis. Neurosurgery. 1990;26(3):442-8.
- 377 25. Petersen OB and Chitty LS. Prenatal Diagnosis of Craniosynostosis. In: Hayward
378 R, Dunaway D and Jones BM, editors. Clinical Management of Craniosynostosis,
379 The. London, UNITED KINGDOM: Mac Keith Press; 2010. p. 85-97.
- 380 26. Petersen OB, David A, Thomasson L and Chitty LS. OC240: Abnormal fetal head
381 shape: etiology and management. Ultrasound Obstet Gynecol. 2007;30(4):441.
382 DOI: 10.1002/uog.4346.
- 383 27. Gray DL, Songster GS, Parvin CA and Crane JP. Cephalic index: a gestational age-
384 dependent biometric parameter. Obstet Gynecol. 1989 Oct;74(4):600-3.
- 385 28. Kurmanavicius J, Wright EM, Royston P, Wisser J, Huch R, Huch A, et al. Fetal
386 ultrasound biometry: 1. Head reference values. Br J Obstet Gynaecol. 1999
387 Feb;106(2):126-35.
- 388 29. Harada A, Miyashita S, Nagai R, Makino S and Murotsuki J. Prenatal
389 sonographic findings and prognosis of cranosynostosis diagnosed during the
390 fetal and neonatal periods. Congenit Anom. 2019;59(4):132-41. DOI:
391 10.1111/cga.12308.
- 392 30. Melamed N, Yogev Y, Danon D, Mashiach R, Meizner I and Ben-Haroush A.
393 Sonographic estimation of fetal head circumference: how accurate are we?
394 Ultrasound Obstet Gynecol. 2011 Jan;37(1):65-71. DOI:
395 10.1002/uog.7760.

Figure 1. Bar chart comparing the method of delivery between the group with sagittal synostosis (SS) and the population (Pop).

Figure 2. Bar chart comparing the presentation at delivery between the group with sagittal synostosis (SS) and the population (Pop). Births where presentation is unknown have been excluded.

Figure 3. Density plots of the change in cephalic index between the morphology and growth scans for fetuses with sagittal synostosis (SS) compared with the normal population (Pop).

Figure 4. Scatter plot of the change in CI between the second and third trimester scans versus the corresponding difference in time between the scans. The grey dots represent the normal population (Pop) and the red triangles represent the fetuses with sagittal synostosis (SS). The dashed lines in corresponding colours represent the linear regression lines for the 2 groups.

Figure 5. Head circumference (HC) and biparietal diameter (BPD) plots and cranial images of a fetus that was diagnosed with sagittal synostosis after birth. The HC remains close to the same percentile throughout the third trimester, whereas the BPD growth drops off over the same time period.

Table 1. Presentation and method of delivery for non-syndromic babies with sagittal synostosis compared with the population.

Number (%)	Vertex presentation	Breech presentation	Other eg transverse, compound, mobile	Normal vaginal delivery	Caesarean delivery	Elective section	Emergency section	Instrumental delivery	Other/unknown
Sagittal synostosis	106 (86.9)	14 (11.5)	2 (1.6)	52 (42.6)	62 (50.8)	33 (27.0)	27 (23.8)	7 (5.7)	1 (0.8)
SA/NT population 2003 – 15 ^{15, 16}	284782 (94.2)	14143 (4.7)	3497 (1.2)	167819 (56.2)	96524 (32.3)	45561 (15.3)	50963 (17.1)	33010 (11.1)	1037 (0.3)

Table 2. Summary of the CI at the second and third trimester antenatal ultrasound scans (observed data) and the normal distribution for children diagnosed with sagittal craniosynostosis.

	n	Mean	SD	2.5%	5%	10%	25%	50%	75%	90%	95%	97.5%
2 nd Trimester scan observed	91	76.0	4.3	66.9	69.5	70.2	73.2	76.4	78.8	81.0	82.2	84.9
2 nd Trimester normal distribution				67.6	69.0	70.5	73.1	76.0	78.9	81.5	83.0	84.4
3 rd Trimester scan observed	36	74.5	4.5	67.7	68.9	69.6	71.3	74.0	77.4	79.4	82.6	84.1
3 rd Trimester normal distribution				65.6	67.1	68.7	71.5	74.5	77.6	80.4	82.0	83.4
Change in CI observed	28	-1.6	5.0	-9.1	-7.9	-7.5	-4.9	-2.1	2.6	4.6	5.5	7.1
Change in CI normal distribution				-11.5	-9.9	-8.1	-5.0	-1.6	1.8	4.8	6.7	8.2

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