Determination of the Chronological Age of Skull Base Suture Closure Using Computed Tomography

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Abstract: The aim of this study was to determine the postnatal chronological age of central and posterior skull base suture closure using computed tomography. The central and posterior skull base suture of pediatric brain CT's obtained from 75 girls and 125 boys of varying ages (newborn to 18 years) were evaluated for this purpose. Premature infants of less than 38 weeks gestation, cases of congenital skull base malformations, and cranial anomalies were excluded. All brain CT studies were performed using 3 mm axial slice thickness at the skull base level. The central and posterior skull base sutures, synchondroses and ossification centers were all assessed for normal appearance and age of closure. The age of initial and completed fusion for the 12 main sutures in the occipital and sphenoid bones, were determined.

Data obtained during the study provides CT scans standard for normal age of closure of the central and posterior skull base sutures that may assist in the future evaluation of skull base fractures, dysplasia and deformities.

Keywords: Skull Base, Suture, Closure, Computed Tomography (CT).

INTRODUCTION

The central and posterior skull base is a platform at the bottom of the cranium. It provides support and protection for the brain and serves as the entrance and exit for major vascular and neural structures. It separates the neurocranium from the cervical spine, deep neck spaces and facial viscerocranium (i.e. orbits, nasal cavities, oral cavities, muscles of mastication and face). It is named chondrocranium since most of its bones are made up of cartilage and ossify by the process of endochondral ossification [1].

The central and posterior skull base undergoes changes throughout the first 18 years of life as its sutures and synchondroses fuse. Most of the skull base foramina, pseudoforamina and clefts are located along the lines of suture or synchondrosal closure [2].

This work was conducted to study the postnatal progression of suture and synchondrosal closure and to illustrate normal development and progression in the chondrocranium suture lines throughout the first 18 years of life using 3 mm axial CT cuts with bone definition algorithm [3].

MATERIAL AND METHODS

Pediatric brain CT's for 75 girls and 125 boys of varying ages (from newborn to 18 years) were evaluated prospectively (Table **1**). Premature infants (< 38 weeks gestation), cases of congenital skull base malformations, cranial anomalies, hydrocephalus and head trauma were excluded. The study population included children with acute non-traumatic neurological disorders (e.g. seizures, stroke, asphyxia, meningitis, developmental delay). The skull base sutures, synchondroses and ossification centers were all assessed by the author for normal appearance and degree of suture closure.

Table 1: The Number of Children Included in the Study and their Ages

No. of children	Age
3	Newborn to 1 month
21	1-12 months
24	1-2 years
41	2-4 years
39	4-6 years
41	6-10 years
31	10-18 years

All examinations were performed using 3 mm axial slice thickness with contiguous sections from the foramen magnum to the skull vertex. The cuts were obtained parallel to the canthomeatal line and reconstructed using bone algorithm with window setting of 4000 HU and a field of view of 12-18 cm. Scanning was performed using 120 KV and 130 mA and images were reviewed using standard bone window settings. The images were analyzed with regard to developmental anatomic features and the timing and characteristics of suture or synchondrosal closure.

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Table 2: Age of Initial and Complete Fusion of Skull Base Sutures

	Suture name	Age of initial fusion	Age of completed fusion
Occipital bone sutures			
1	Kerckring ossicle	34% at birth	100% at 3 months
2	Posterior intraoccipital synchondrosis	78% at 1.5 years	100% at 10 years
3	Anterior intraoccipital synchondrosis	92% at 3.5 years	100% at 12 years
4	Sphenooccipital synchondrosis	68% at 7.5 years	100% at 15 years
5	Petrooccipital fissure	52% at 7.5 years	97.5% remained unfused
6	Occipitomastoid suture	80.5% at 9 years	100% at 16.5 years
Sphenoid bone sutures			
1	Intersphenoidal synchondrosis	94% at birth	100% at 3 months
2	Intrapostsphenodial synchondrosis	94% at birth	100% at 3 months
3	Rostrum ossicle of Bertin synchondrosis	92% at birth	100% at 2 years
4	Interplanum sphenoidal suture	84% at 2 years	100% at 5 years
5	Sphenosquamosal suture	88% at 2 years	100% at 6 years
6	Sphenoethmoid suture	31% at 4 years	100% at 16 years

RESULTS

A. Assessment of Occipital Bone Suture Closure

In a full-term newborn, six unfused occipital bone sutures can be recognized on CT. These are: (1) the Kerckring ossicle (ko), (2) posterior intraoccipital synchondrosis (pio), (3) anterior intraoccipital synchondrosis (aio), (4) sphenooccipital synchondrosis (sos), (5) petrooccipital fissure (pof) and (6) occipitomastoid suture (oms). These sutures and their normal progression of fusion are clearly demonstrated in skull base CT performed in the neonatal period (Table **2**).

At birth the Kerckring center was identified as an ossicle completely separated from the supraoccipital bone in 132 newborns (66%). Partial ossicular fusion was found in 48 cases (24%), and complete fusion was detected in 20 cases (10%) (Figure **1**, **2**). Complete ossicular fusion was identified in all cases by the age of 3 months.

The posterior intraoccipital synchondrosis began to show CT evidence of fusion (grade 2) by 18 months in 156 cases (78%). The suture was completely fused in all children older than 10 years in all cases (Figure **1**, **2**).

The anterior intraoccipital suture showed evidence of early fusion (grade 2) by the age of 3 years and 6 months in 184 cases (92%). The suture was completely fused in all patients by the age of 12 years (Figure **2**, **3**).

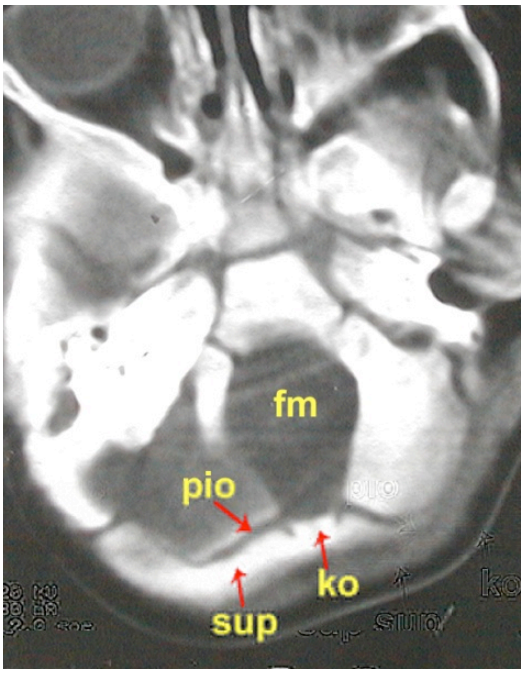

Figure 1: Axial CT image of the skull base of a three-month-old infant showing open posterior intraoccipital synchondrosis (pio) and Kerckring ossicle (ko). Also note the supraocciput (sup) part of the occipital bone and foramen magnum (fm).

The sphenooccipital suture showed CT evidence of the beginning of fusion at a mean age of 7.5 years in 136 cases (68%) and reached complete fusion in all cases by the age of 15 years (Figure **4**, **5**).

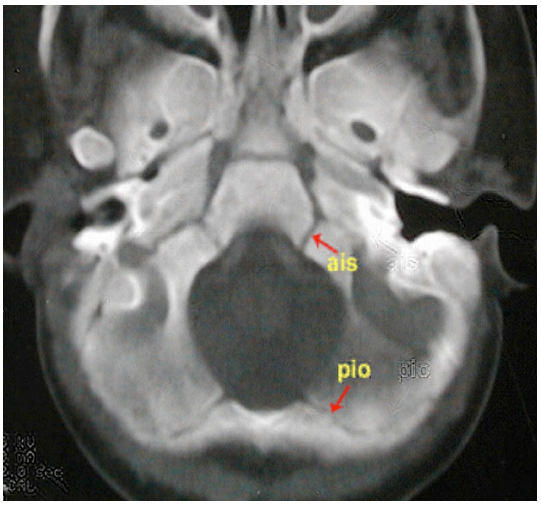

Figure 2: Axial CT image of the skull base of an 18-month-old infant showing open anterior intraoccipital synchondrosis (ais) which is of a slightly delayed closure compared with posterior intraoccipital (pio) and fused Kerckring ossicle (ko).

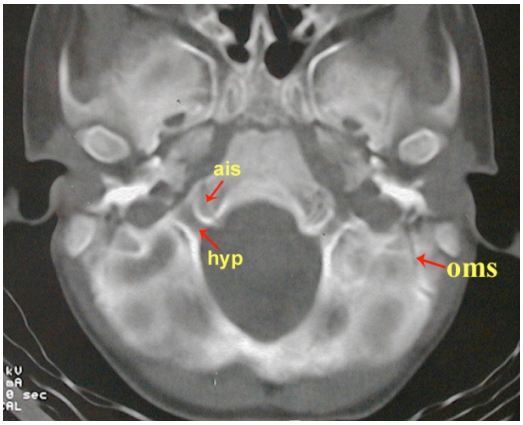

Figure 3: Axial CT image of the skull base of a four-year-old child showing only remnants of the anterior intraoccipital synchondrosis (ais). The hypoglossal canals (hyp) appear posterior to the anterior intraoccipital synchondrosis and are now more prominent. Also notice the clear visualization of the occipitomastoid suture (oms).

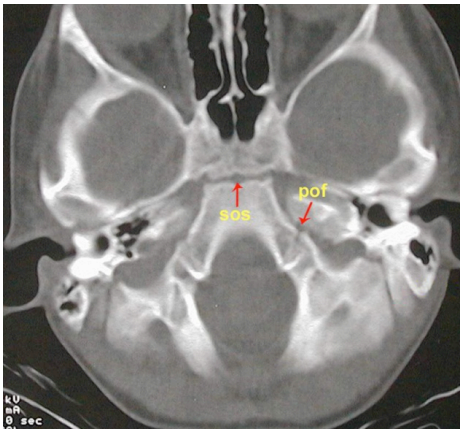

Figure 4: Axial CT image of the skull base of a five-year-old child showing sphenooccipital synchondrosis (sos), petrooccipital fissure (pof) and occipitomastoid suture (oms) with no signs of fusion (grade 1).

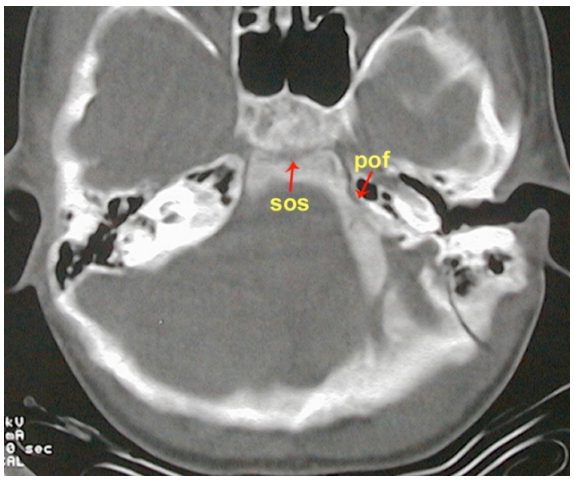

Figure 5: Axial CT image of skull base of a nine-year-old child demonstrating sphenooccipital synchondrosis (sos) and petrooccipital fissure (pof) both showing early signs of fusion (grade 2). Also notice the clear visualization of the occipitomastoid suture (oms).

The petrooccipital suture began to fuse by the age of 7.5 years in 104 cases (52%). Only 5 cases (2.5%) reached grade 4 at the age of 18. (Figure **5**). The remaining 195 cases (97.5%) showed persistent suture patency.

The occipitomastoid suture started showing evidence of progressive fusion by the age of 9 years in 161 cases (80.5%) and reached complete fusion in all cases by the age of 16.5 years. (Figure **4**, **5**).

B. Assessment of Sphenoid Bone Suture Closure

In a full-term newborn, six sphenoid bone sutures can be recognized on CT. These are: (1) the intersphenoidal synchondrosis (iss), (2) intrapostsphenodial synchondrosis (its), (3) rostrum ossicle of Bertin synchondrosis, (4) interplanum sphenoidal suture, (5) sphenoethmoid suture, and (6) sphenosquamosal suture (Table **2**).

The intersphenoidal (iss) and the intrapostsphenodial synchondroses (its) showed complete fusion at birth in 188 cases (94%) and in all cases above the age of 3 months, but a sclerotic remnant is more commonly seen in the intersphenoid synchondrosis (Figure **6**).

The rostrum ossicle of the Bertin synchondrosis was partially fused by 6 months of life in 184 cases (92%). After the age of 2 years the synchondrosis showed complete fusion in all cases (Figure **6**).

The interplanum sphenoidal suture showed signs of early fusion by 3 months in 168 cases (84%) and grade

4 level of fusion at the age of 5 years in all cases (Figure **7**).

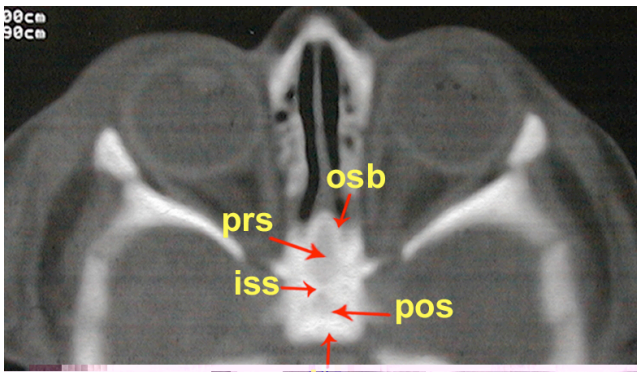

Figure 6: Axial CT image of the skull base of a three-month-old infant showing the centers of the pre-sphenoid (prs) and post-sphenoid (pos) portions of the sphenoid body. Intrapostsphenoid synchondrosis (its) and intersphenoid suture (iss) all have grade 4 fusion. Also note the fused ossicle of Bertin (osb).

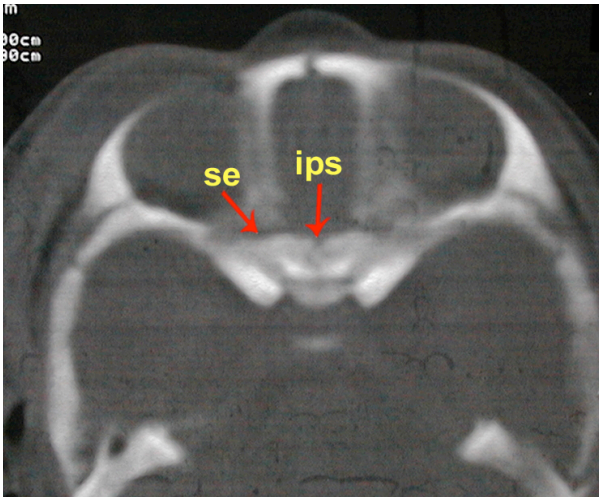

Figure 7: Axial CT image of the skull base of a three-month-old infant showing non-fused interplanum sphenoidal (ips) and sphenoethmoid suture (se).

The sphenoethmoid suture shows early signs of fusion (grade 2) at the mean age of 4 years in 176 cases (88%). Complete fusion is seen at the mean age of 16 in all cases (Figure **7**).

The sphenosquamosal suture began to close at the age of 2 years in 62 cases (31%). All children above the age of 6 showed a grade 4 level of fusion (Figure **8**).

DISCUSSION

This study assessed the timing of skull base suture/synchondrosal closure depending on CT findings. The suture grading system was based on the Madeline and Elster system (Table **3**) [4].

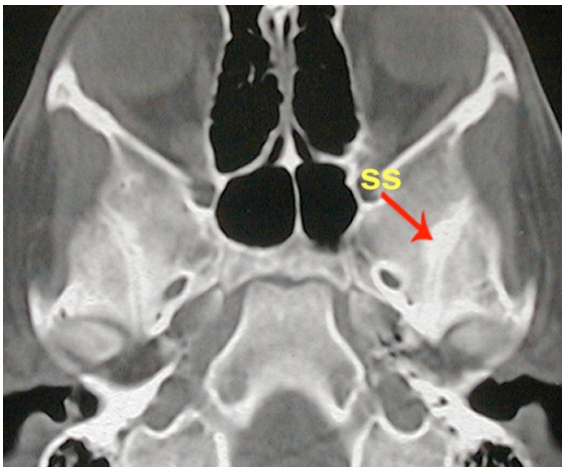

Figure 8: Axial CT image of the skull base of an 11-year-old child showing grade 4 closure of the sphenosquamosal suture (ss) with sclerotic remnant.

A. Sutures of the Occipital Bone

In the Kerckring-supraoccipital sutures, the Kerckring center was identified to be completely fused at birth in 10% of cases, partially fused in 24%, and appearing as a separated ossicle in 66%. The ossicle soon thereafter undergoes complete fusion with the occipital bone, as only 9% of children above the age of one month showed partial fusion and all children showed complete fusion of the Kerckring ossicle by the age of 3 months. This is slightly more than, but consistent with, what was reported by Madeline *et al*. [2], who examined 189 CT scans for closure of skull

Table 3: Suture or Synchondrosal Closure CT Grading System [10]

Grade	Character
Grade 1	Margins of the synchondrosis are clearly separated on all sections
Grade 2	Clear separation of the synchondrosis is seen along most sections, except for some areas that are indistinct or suspicious for bony bridging
Grade 3	There is an area of fusion or bridging across a portion of the synchondrosis
Grade 4	Complete fusion of the synchondrosis with remnant sclerotic margin
Grade 5	Complete closure is seen with no apparent vestige remaining

base suture and found that the Kerckring ossicle was completely separate in 42% of the newborns and partially fused in two. In this study, the Kerckring ossicle showed partial fusion in 13% of children older than one month, while the remaining children showed complete fusion.

The posterior intraoccipital synchondrosis showed initial evidence of closure (grade 2) in 78% of the cases from age of 18 months with a mean age of 23 months. Grade 4 fusion occurred in all children older than ten years with a mean age of 4.7 years. These findings are also comparable with those produced by Madeline *et al*. [2], who found that the posterior intraoccipital synchondrosis began to show CT evidence of fusion during the 2nd postnatal year and typically reached grade 4 between 3 and 6 years of age. Similarly, Mann *et al*. [5], reviewed the CT scans of 260 subjects ranging in age from term to 22 years and found that the posterior intraoccipital suture showed great variability, from completely open to completely fused from 2 years up to 4 years.

The anterior intraoccipital synchondrosis showed signs of early fusion (grade 2) starting from the age of 3 years and 6 months with a mean age of four years. Grade 4 fusion was noticed at a mean age of 8 years with the range of 7 to 12 years.

Madeline *et al*. [6], found that fusion of anterior intraoccipital synchondrosis began during the second year and displayed grade 4 level of fusion between the ages of 7 and 10 years. Mann *et al*. [7], also found that the anterior intraoccipital suture remained completely open in all cases during the first year of life and showed great variability in maturation between the ages of 2 and 10 years. In addition, Furuya [3] examined CT scans of 150 normal individuals ranging from birth to 74 years and found that the anterior and posterior intraoccipital synchondroses fused in early childhood but did not specify the ages of closure initiation and end.

The sphenooccipital synchondrosis showed wide variation in the age demonstrating initial CT evidence of fusion (grade 2), ranging from 4-10 years with the mean age of 7.5 years in 68% of cases, and reached grade 4 at a mean age of 15 years. These findings are in disagreement with Mann, [5] who found that the sphenooccipital synchondrosis exhibited partial closure from the second year up to 10 years and showed complete fusion from 11 years onward. The results of the present study are closer to those reported by Madeline, [4] who found that the sphenooccipital synchondrosis showed signs of early fusion by the age of 8 years and reached grade 4 of closure at 16 years. Further data in this regard has been provided by Kiziklilic, [8] who found that the earliest complete closure of the synchondrosis occurred at the age of 13 years, and if a transverse hypodense zone across the clivus is seen on CT scans in individuals with head trauma who are 13 years of age or older, it is more likely to represent a skull base fracture than a persistent synchondrosis. In addition, Wachenheim [9] found that the sphenooccipital synchondrosis usually closes between 12 and 13 years of age but it may persist up to the age of 20 years. As well, Molsted [10] found that children with complete clefts of the lip and palate had a broader sphenooccipital compared to children with incomplete clefts.

In this study the petrooccipital fissure began to fuse from the age of 7.5 years in 52% of cases and reached grade 3 fusion at a mean age of 16 years. 195 cases (97.5%) showed patent fissures at the age of 18 years. Madeline [2] found that the petrooccipital suture underwent a slow progressive union with a definite closure not seen on CT scans until about the age of 16 years. Meanwhile, Mann [5] found that the petrooccipital suture showed infrequent partial closure from the second to the fourth year and increasing percentages of partial closure were seen from the 5th to the 20th year.

The occipitomastoid suture began to show a grade 2 level of fusion starting from the age of 9 years in 80.5% of cases, with a mean age of 11 years, and all cases reached grade 4 at a mean age of 16.5 years, but complete closure was not seen. This matches the results of Mann, [5] who found that the occipitomastoid suture showed greatly variable closure after the 1st postnatal year, but was typically open or partially fused up to 22 years of age.

B. Sutures of the Sphenoid

In this study both intersphenoid and intrapostsphenoid synchondroses were completely closed at birth in 188 cases (94%). From the age of three months onward, all cases showed complete closure, but a closure with sclerotic remnant was common with the intersphenoid synchondrosis. This is in accordance with the results reported by Madeline, [2] who found that the intersphenoid and intrapostsphenoid synchondroses all underwent complete closure (grade 4) on CT by three months of

age. Mann [5] also found that no case aged from birth to three months showed an open intersphenoid or intrapostsphenoid synchondrosis. The intrapostsphenoid synchondrosis was open in a few cases in the age group from 0 to 6 months, but this does not contradict the findings of Madeline or Mann.

The rostrum ossicle of Bertin was completely fused in all cases above the age of two years. The majority of cases (92%) demonstrated signs of partial fusion by six months of age. This is similar to Madeline's [2] data indicating that the ossicle of Bertin fused between the first and second years. Mann, [5] however, found that the rostrum ossicle of Bertin may remain partially unfused till the age of 3.

The interplanum sphenoidal suture showed signs of early closure, starting from the age of 2 years in 168 patients (84%). Grade 4 level of fusion was noted at the mean age of 5 years. Madeline, [4] on the other hand, found that the interplanum sphenoidal reaches grade 4 earlier, at 3.3 years.

In the present study the sphenoethmoid suture showed early signs of fusion (grade 2) at a mean age of 4 years in 176 cases (88%), and reached complete fusion at a mean age of 12 years. Complete closure was seen in all cases above the age of 16 years. Madeline, [2] found that the sphenoethmoid suture began to fuse at about the age of 2 years and was completely fused in all individuals older than 15.

The sphenosquamosal suture began to close at a mean age of 2 years and reached grade 4 at the mean age of 6 years. Madeline, [4] similarly found that this suture closed at first medially between the ages of 2 and 6 years, and reached complete fusion with sclerosis by the age of 6 years.

In conclusion, the obtained data should be of assistance to radiologists in the diagnosis of fractures, skeletal dysplasia, and deformities that affect the pediatric chondrocranium. It can also help surgical approaches to the pediatric cranial base, allowing safe implementation while developmental anatomic relationships are considered.

REFERENCES

[1] Willams R, Nemzek, Hilary A, Brodie, Stephen T, Hecht, Brian W, Catherine J. MR, CT, and plain film imaging of the developing skull base in fetal specimens. Am J of Neuroradiol 2000; 21: 1699-706.

[2] Madeline LA, Elster AD. Postnatal development of the central skull base: normal variants. Radiology 1995; 196: 757-63.

[3] Furuya Y, Michael SB, Edwards MD, Charles E. Computerized tomography of cranial sutures part 1: comparison of suture anatomy in children and adults. J Neurosurg 1984; 61: 53-58. http://dx.doi.org/10.3171/jns.1984.61.1.0053

[4] Madeline A, Elster AD. Suture closure in the human chondrocranium: CT assessment. Radiology 1995; 196: 747-56.

[5] Mann SS, Naidich TP, Towbin RB, Doundoulakis SH. Imaging of postnatal maturation of the skull base. Neuroimaging Clin N Am 2000; 10(1): 1-21.

[6] Fiegler W, Stolele E. The fovea pharyngeal-demonstration in conventional tomography and CT. J Neuroradiol Aug 1980; 133(2): 188-91.

[7] Francel PC, Park TS, Marsh JL, Kaufman BA. Frontal plagiocephaly secondary to synostosis of the frontosphenodial suture: Case report. J Neurosurg 1995; 83(4): 733-6. http://dx.doi.org/10.3171/jns.1995.83.4.0733

[8] Kiziklilic O, Yalcin O, Yildirim T, Sener L, Parmaksiz G, Erdogan B. Hypothalamic hamartoma associated with a craniopharyngeal canal. Am J Neuroradiol 2005; 26(1): 65-7.

[9] Wachenheim J. Spheno-occipital syncondrosis in neonates. Acta Radiol 1985; 20(2): 546-63.

[10] Molsted K, Kjaer I, Dahi E. Spheno-occipital syncondrosis in three-month-old children with clefts of the lip and palate: a radiographic study. Cleft palate craniofac. J Nov 1993; 30 (6): 596-73. http://dx.doi.org/10.1597/1545-1569(1993)030<0569:SOSITM>2.3.CO;2

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