PICTORIAL ESSAY Neuro/Head and Neck Radiology

Overview of craniosynostosis

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ABSTRACT

Although craniosynostosis is a well-described entity, advances in genetics and radiology equipment have brought to light new evidence, which can possibly change the imaging approach. A number of genes and mutations related to the disorder have been indentified, whereas foetal MRI appears to be quite reliable in the clarification of fetal ultrasound findings. This article includes the latest medical literature data on craniosynostosis with emphasis to those concerning or even affecting diagnostic imaging. It appears that cranial ultrasound and foetal MRI, along with specific MRI techniques for the skull, will be the future in the imaging of craniosynostosis. Literature data on the normal sutures' anatomy, as well as on the disorder's classification, aetiology and treatment, have also been included.

Introduction

Craniosynostosis is a pathological condition of infancy, characterised by partial or complete premature fusion of one or multiple cranial sutures (vault and/or base), resulting in characteristic skull shape deformities and facial asymmetry. The term was first used by Virchow, who also attempted to explain the cranial deformities [1]. "Virchow's law", which still remains valid, proposes that cranial deformities arise when growth of the skull is interrupted perpendicular to the affected suture, resulting in a skull growth which is parallel to this suture. Nevertheless, the severity of the resulting de-

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formities does not reflect the severity or the extent of synostosis [2, 3].

The prevalence of this entity in the general population is estimated to be 3-6 infants per 10,000 live births [4-7] and is reported as the most frequent craniofacial anomaly [8]. The most commonly affected sutures are the sagittal (40-56%) [9, 10] and the coronal (20-25%), the latter being reported more frequently in females [11]. The main causes of morbidity in craniosynostosis are increased intracranial pressure, headaches, neurodevelopmental delay [12-15], visual defects and cosmetic deformities [6, 16, 17].

Normal cranial sutures are distinguished into major and minor. Major sutures are the single sagittal, separating the two parietal bones, the single metopic, formed between the frontal bones, a pair of coronal sutures, between the frontal and the parietal bones and a pair of lambdoid sutures, between the parietal and the occipital bones. Minor sutures include the pair of the squamosal sutures, formed between the parietals and the temporal bones, the pair of the lateral mendosal sutures, the single transverse occipital suture and others. Cranial sutures are fused from back to front and from lateral to medial, except for the metopic suture, which fuses from front to back [18].

The exact time of fusion is not the same for each suture. Normally, the metopic suture is the first to be fused, at the age of two years, a process beginning at the age of nine months. However, there are studies reporting earlier closure; Vu et al. [19] set the process of metopic suture fusion between three and nine months and Weinzweig et al. [20] suggested the ages between four and eight months. Regarding the sagittal suture, fusion initiates after the age of 22 years, whereas the coronal sutures follow, two years later. Finally, the lambdoid sutures begin to fuse after the age of 26 years. All these sutures do not normally close before the age of 40 years [21, 22]. Unfortunately, in cases of craniosynostosis, fusion initiates at the prenatal period, perinatally or even during early infancy [17, 23].

Based on aetiology, craniosynostosis can be divided into idiopathic or primary and secondary. Idiopathic craniosynostosis is attributed to a possible developmental error, taking place during embryogenesis, for instance defective dural-mesenchymal signaling issues [24] or shortly after birth, resulting in an intrinsic structure defect [25], even though genetic causes are increasingly being indentified [24]. Spontaneous mutation of a syndromic gene has also been reported [26].

On the other hand, the secondary form of craniosynostosis can be attributed to various causes. First, to mechanical causes, including intrauterine compression of the foetal skull against the bones of the maternal pelvis or conditions that diminish growth stretch at sutures, such as microcephaly, encephalocoele and shunted hydrocephalus. Second, to metabolic causes, such as hypophosphataemic vitamin D-resistant rickets, hypercalcaemia, hyperthyroidism, renal osteodystrophy, Hurler's syndrome, mucopolysaccharidoses and mucolipidoses, haematological diseases like sickle cell disease and thalassaemia, as well as bony dysplasia. Similarly, there are studies associating craniosynostosis with specific medications, such as clomiphene citrate used for infertility [27], fluconazole [28], sodium valproate [29] and citalopram [30], along with other iatrogenic factors, such as early postnatal shunt in hydrocephalus and early craniofacial irradiation for tumour control [24]. Finally, the secondary form of craniosynostosis can be attributed to positive family history, advanced parental age [11, 31], certain habits and the use of teratogens [4, 18, 24, 27, 32, 33].

Moreover, idiopathic craniosynostosis can be divided into nonsyndromic or syndromic type. Nonsyndromic craniosynostosis refers to an isolated fusion of one or two sutures and is the commonest type of the disorder (80-90%) [34]. Specifically, isolated coronal synostosis indicates a strong genetic background, compared to other craniosynostoses, as in 1/3 of infants carrying this phaenotype, a single gene mutation can be detected [35, 36]. Therefore, Wilkie et al. [35] suggested that genetic testing in nonsyndromic craniosynostosis may be targeted only to infants with coronal or multisutural synostoses.

On the other hand, syndromic craniosynostosis is rarer (10-20%) [34], involving several sutures, as it is part of a systemic disorder. This type of craniosynostosis is associated with other extra cranial anomalies, such as syndactyly and midface hypoplasia, as well as malformations of the heart, the trachea and the nervous system, which guide differential diagnosis towards a specific syndrome, even though this is not always achievable. Syndromic craniosynostosis is likely to be genetically influenced, either by a single gene disorder or by chromosomal abnormalities [24]. A wide va-
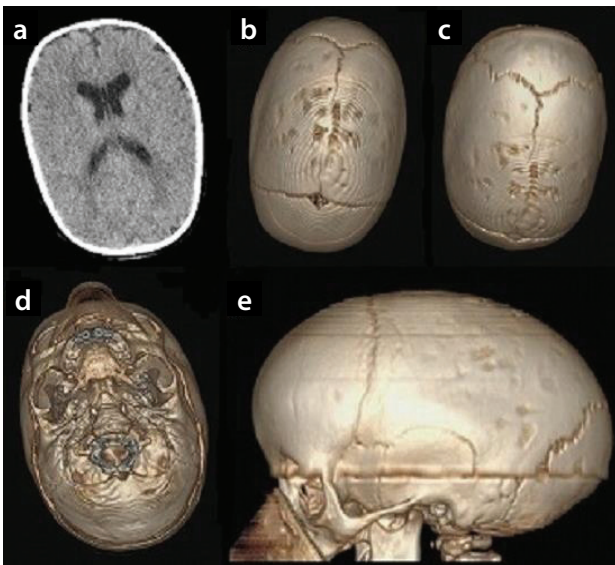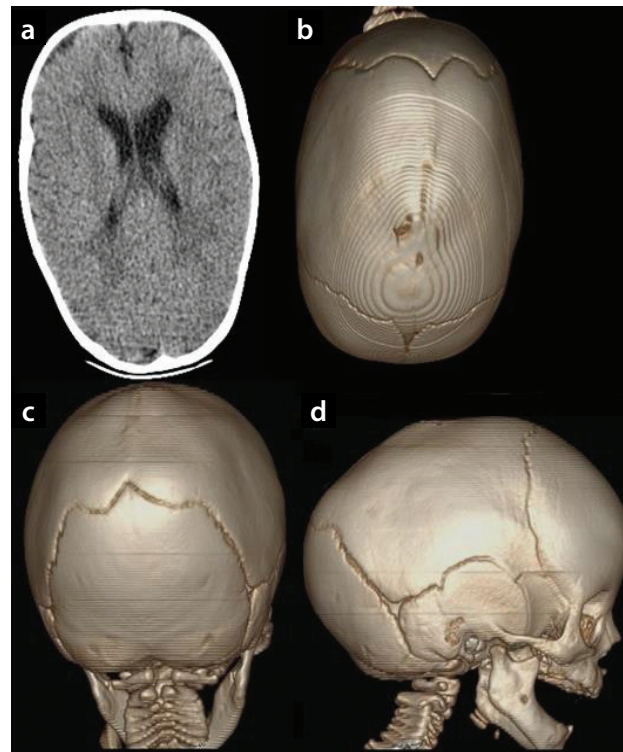
*Fig. 1: Dolichocephaly. **a.** Axial CT scan. **b-e.** 3D CT volume rendered images of a ten months old girl. Partial fusion of the sagittal suture (posterior half) results in increasing anterior-posterior diameter, along with bitemporal narrowing, due to the restriction of biparietal growth.*

riety of mutations in several genes has been implicated, including these in FGFR1, FGFR2, FGFR3, TWIST1, EFNB1, MSX2 and RAB23 genes. All the same, mutations in FBN1, POR, TGFBR1 and TGFBR2 have been correlated to craniosynostosis, despite having an apparently low penetrance and not forming the major clinical feature of the phaenotype. Among the genes described, the FRGR family is the one which plays a central role in the growth and differentiation of the mesenchymal and neuroectodermal cells, as these genes bind to fibroblast growth factor receptor (FRFR) and initiate signal transduction [37]. They also regulate cranial suture fusion on a macroscopic level [9]. The FGFR2 gene is the main gene of this family and its mutations are correlated to multiple syndromic craniosynostoses. The latter cause various and multiple sutures' involvement, as they have variable clinical expressivity [38]. Consequently, the resulting syndromes are exclusively characterised by their extra cranial coexisting abnormalities [9], such as the presence of distinct limb and dermatological features [37].

## Different forms of craniosynostosis

In cases where only one major suture is affected, the terms follow the Greek terminology, describing the morphology of the resulting head deformities. Thus,

*Fig. 2: Dolichocephaly. **a.** Axial CT scan. **b-d.** 3D CT volume rendered images of a six months old boy. Complete fusion of the sagittal suture, increasing the anterior-posterior diameter, while narrowing the bitemporal one. Frontal and occipital bulging is observed.*
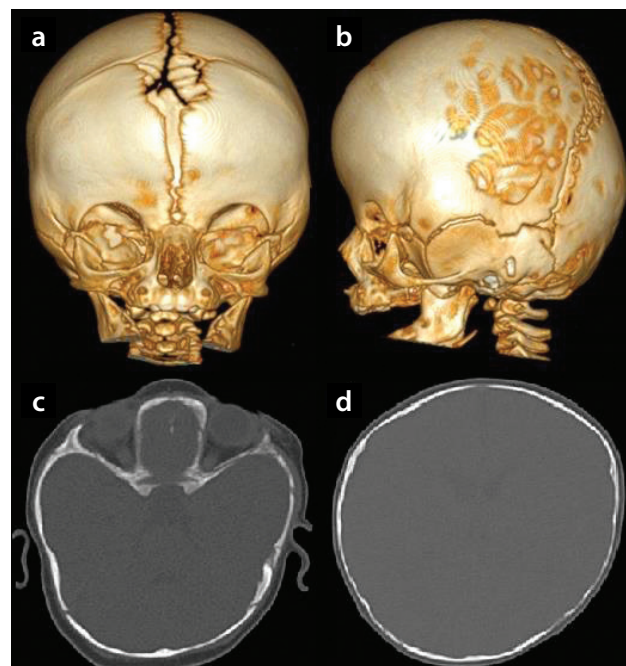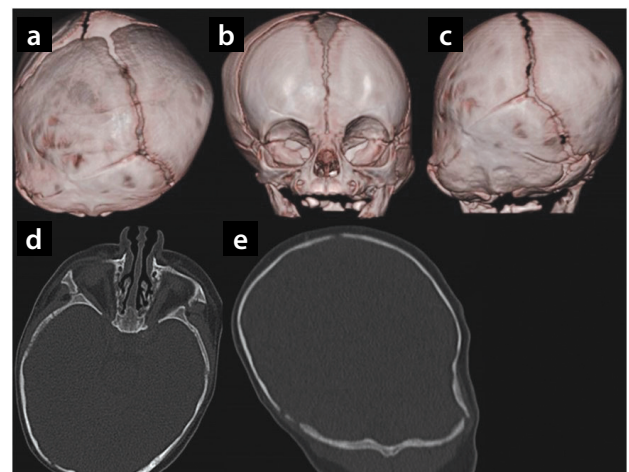

*Fig. 3: Brachycephaly. **a-b.** 3D CT volume rendered images. **c-d.** Axial CT scan of a four month old girl. Complete bicoronal suture fusion, resulting to restriction of the anterior-posterior calvarial growth and pronounced biparietal growth. Consequent prominent frontal bone and an occiput flattening. Courtesy: Andrea Rossi, Genoa.*
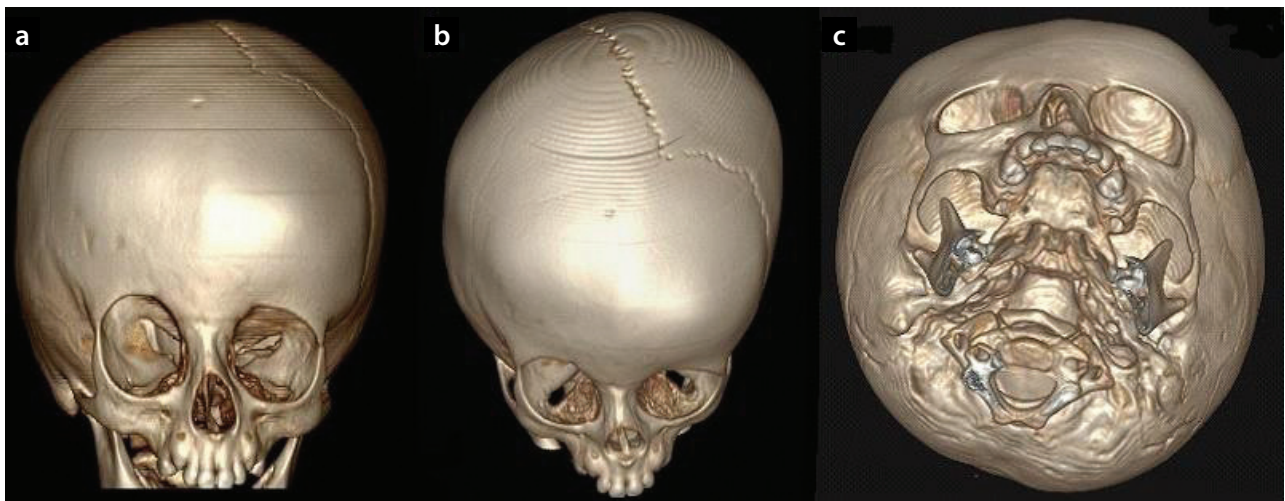
*Fig. 4: Anterior plagiocephaly. **a-c.** 3D CT volume rendered images of a 21 months old boy. Right coronal suture fusion, which results to the flattening of the frontal bone on the affected side, but prominent frontal bossing to the contralateral side. There is also evident orbit asymmetry.*

the term dolichocephaly (dolikhos=long and cephali=skull) describes the skull's shape after the early synostosis of the sagittal suture (**Figs. 1 and 2**). Scaphocephaly (scaphe=boat) is a subgroup of dolichocephaly, including evident ridging of the sagittal suture, alike to the boat's keel. Similarly, the terms brachycephaly (brachy=short) and turricephaly (turri=tower) correspond to the synostosis of the bicoronal (**Fig. 3**) and the bilambdoid suture, respectively. The term plagiocephaly (plagios=oblique) corresponds to the asymmetry of the neurocranium, due to synostosis of only one of the pair of the coronal (anterior plagiocephaly) (**Fig. 4**) or the lambdoid sutures (posterior plagiochephaly) (**Fig. 5**). Trigonocephaly (trigonos=triangle) corresponds to the resulting deformity from synostosis of either the metopic suture (anterior trigonocephaly) (**Fig. 6**) or the posterior third of the sagittal suture and both the lambdoid sutures (posterior trigonocephaly). Oxycephaly (oxys=sharp) results from bilateral synostosis of the paired coronal and lambdoid sutures [25, 39]. Nevertheless, in cases of combined synostosis of all major sutures, the skull has a cloverleaf appearance, which is the most impressive cranio-facial syndromic deformity, termed pansynostosis (pan=whole) [18]. Pansynostosis can be identified in nonsyndromic cases, but usually appears in syndromic conditions [3].

The most common and clinically significant syndromes are the Apert, Crouzon, Pfeiffer, Vogt, Saethre-Chotzen, Carpenter, Muenke, Antrley-Bixler, Jackson-Weiss, as well as the mixed Apert-Crouzon syn-

*Fig. 5: Uncorrected posterior plagiocephaly. **a-c.** 3D CT volume rendered images. **d.** axial CT scan. **e.** coronal CT scan of a three year old boy. The left lambdoid suture is fused, with consequent bulging of the ipsilateral temporal and the contralateral parietal region. Additionally, the posterior skull base is tilted downward on the affected side.*
Courtesy: Andrea Rossi, Genoa.

dromes. The most significant complication in these cases is the raised intracranial pressure and the coexisting brain malformations, along with marked face and extremities' involvement.

Apert syndrome is characterised by bicoronal synostosis and severe symmetrical syndactyly of fingers and toes, the latter being the critical feature for the differentiation of this from other FRFG2 syndromes. Oth-

er craniofacial malformations include more sutures fusion, up to the cloverleaf deformity, flat forehead and retracted midface, proptosis and hypertelorism, low set ears, hypoplastic maxilla, small and malformed skull base and craniovertebral junction, frequently leading to Chiari I malformation, as well as vertebral fusion anomalies at the level of the cervix (Fig. 7) [9, 25, 39]. Midface retraction and narrow pharynx usually cause airway compromise [9]. At the same time, brain malformations include complete or partial absence or the corpus callosum and significant hydrocephalus, especially after craniectomy [25]. Finally, variable mental deficiency and learning disability are present, even though individuals with normal intelligence have been reported [18, 25]. Apert syndrome is inherited in an autosomal dominant way and is attributed to a FGFR2 gene mutation, located in the linker between the IgII and IgIII domains [40]. However, Goriely et al. [41] reported that, in the vast majority of infants with Apert syndrome, de novo mutations are detected, mainly originating from paternal sperm.

Crouzon syndrome is also inherited in an autosomal dominant way and the mutations are equally located in the FGFR2 gene. Thus it is allelic with Apert syndrome, even if specific mutations in the FGFR3 gene have been indentified in infants whose craniosynostosis is accompanied with acanthosis nigricans on the skin [37]. Similarly to Apert syndrome, Crouzon syndrome is related to advanced paternal age and de novo come up of the entity to the offspring [42]. Cranial features in Crouzon syndrome include multiple suture involvement, which

may result to cloverleaf deformity of the skull (Fig. 8) or acro-brachycephaly, depending on the extent and the order of suture fusion. Accompanying facial features are tall and flat forehead, proptosis, parrot-beak nose, midface and maxillary hypoplasia with prognathism and basilar kyphosis [9, 25, 39]. A nasopharynx deformity is also present in this syndrome, predisposing to life-threatening obstructive sleep apnoea [25, 43]. As regards brain malformations, they are common and include mainly midline anomalies, such as corpus callosum hypoplasia or even aplasia, Chiari I malformation and syringomyelia, as well as hydrocephalus.

Finally, Pfeiffer syndrome is also similar to Apert syndrome and the differential diagnosis is based on the co-existing anomalies to the extremities, including syndactyly, which is restricted to soft tissues, while toes and thumbs are short and broad. Craniosynostosis involves the coronal and sagittal sutures, the latter forming an intracranial bony crest [25]. As Pfeiffer's syndrome clinical phaenotypes are of different severity, it is categorised in three types. Type I has the best prognosis, with normal individuals' intelligence. It is characterised by brachycephaly, midface hypoplasia, hypertelorism and hearing loss accompanied by auditory stenosis or atresia, along with hypoplasia or enlargement of the middle ear cavity. In type II, the main features include cloverleaf skull deformity and severe proptosis. Finally, type III includes the features of both previously mentioned types, along with mental retardation and hydrocephalus [9, 39]. Congenital brain anomalies are rarer than in the previously described
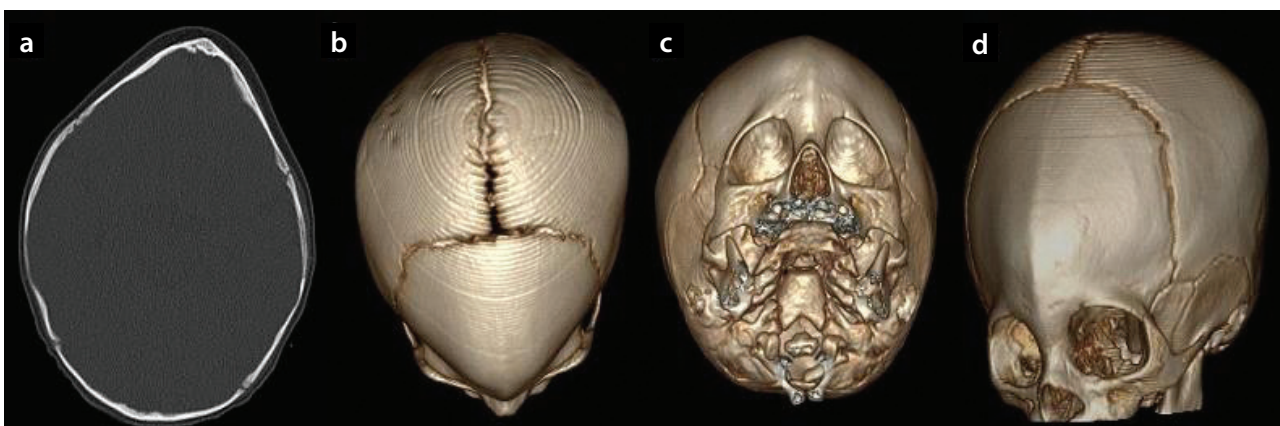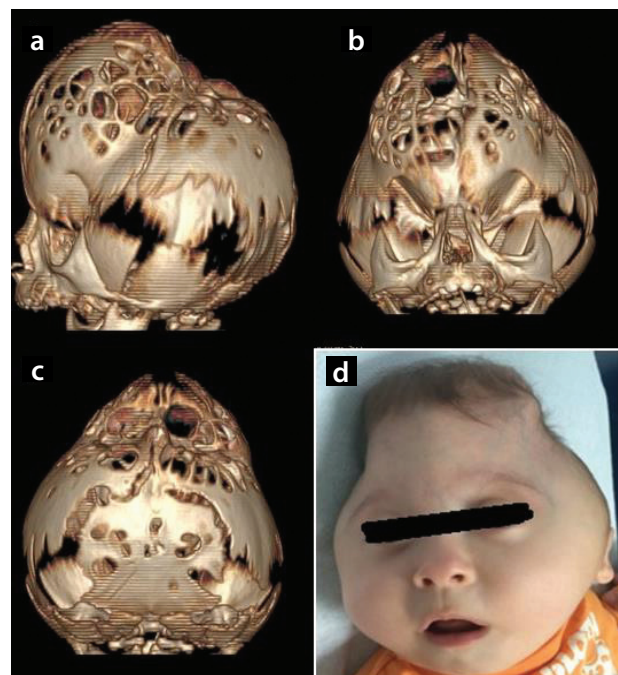

Fig. 6: *Trigonocephaly.* **a.** *Axial CT scan.* **b–d.** *3D CT volume rendered images of a four months old boy, depicting the fusion of the metopic suture and the consequent triangular morphology of the forehead, as well as the flattening of the two initial frontal bones.*
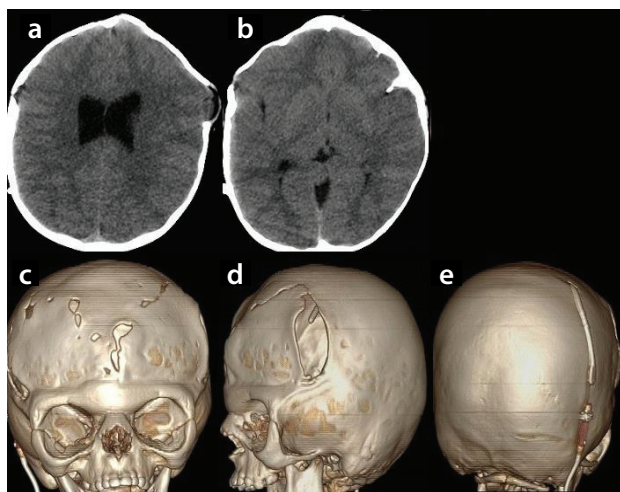
Fig. 7: *Apert syndrome in a three years old girl. **a-b.** Axial CT scan. **c-e.** 3D CT volume rendered images, demonstrating fusion of all sutures, with a small and malformed skull base.*

Fig. 8: *Crouzon syndrome. **a-c.** 3D CT volume rendered images of a ten days old girl. **d.** Photograph of patient at six months of age. There is an evident cloverleaf deformity of the skull, with tall and flat forehead, midface hypoplasia and elliptical orbits, due to undeveloped supraorbital ridges ("harlequin eyes").*

syndromes and the Chiari I anomaly is a result of the altered relationships between the posterior fossa, the foramen magnum and their contents [25].

It is of utmost importance, thus a great diagnostic challenge, to differentiate posterior plagiocephaly from deformational or positional posterior plagiocephaly. Deformational posterior plagiocephaly is the asymmetric flattening of the infant's head as a result of repeated pressure, after constant external forces, even prenatally on the maternal pelvis bones and/or postnatally, for instance lying on one side of the head on a flat surface, still without malformative alterations [44, 45]. Deformational posterior plagiocephaly usually presents some time after birth, progresses until six months of age and remains stable thereafter [46]. The resulting deformity of the skull is only of cosmetic significance, responding to conservative measures, such as changing sleep position or corrective helmets. In contrast, posterior plagiocephaly needs early surgical correction, as it may lead to the complications referred for craniosynostosis, which makes the early diagnosis very important, even though sometimes it is proving challenging. Deformational posterior plagiocephaly has been exponentially increasing since 1992, probably due to the recommendation of the International Paediatric Societies, indicating that infants should sleep in the supine position, in order to prevent sudden infant death syndrome, along with increased awareness of posterior plagiocephaly among

physicians [47-50]. In deformational plagiocephaly the lambdoid suture is patent and is combined with ipsilateral frontal bossing, which is not found in posterior plagiocephaly (**Fig. 9**) [18].

All the same, the metopic ridge is a normal variant of the metopic suture closure, which has to be differentiated for the same reasons from metopic synostosis. It occurs in 4% of asymptomatic children, aged 1-18 months, without any other characteristic feature of the corresponding synostosis, such as trigonocephaly, hypotelorism or medially upward slanted orbital roof [18]. Birgfeld et al. [51] reported that infants with metopic craniosynostosis are usually younger than those with metopic ridge.

Diagnostic approach

Although the diagnosis of craniosynostosis can be clinical, all imaging techniques contribute to the accurate diagnosis of the entity, by demonstrating the exact extent of the suture fusion, the resulting craniofacial deformities, as well as the coexisting anomalies or complications. Therefore, the main goals of imaging are to
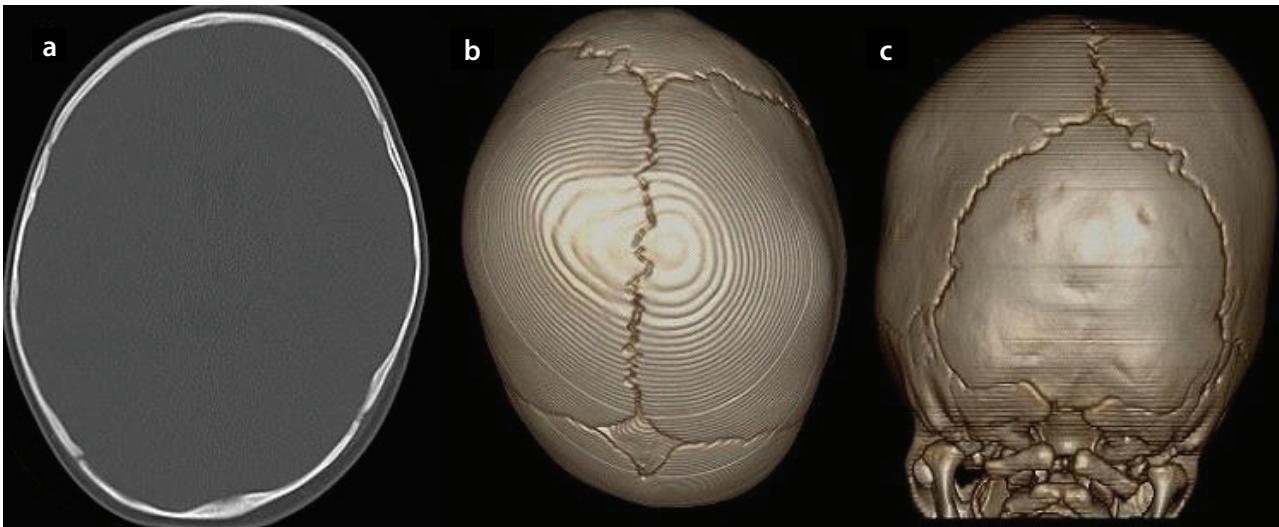
Fig. 9: *Deformational posterior plagiocephaly.* ***a.*** *Axial CT scan.* ***b-c.*** *3D CT volume rendered images of an eight months old boy, imaging the patent coronal, sagittal and lambdoid sutures, without tilting of any part of the skull, despite its parallelogram shape.*

confirm the clinical diagnosis, as well as to guide surgical planning and post treatment evaluation.

Three-Dimensional Computed Tomography (3D CT) is considered the gold standard for the diagnosis of craniosynostosis in the assessment of infants with abnormal skull shape, as it can provide highly detailed 3D images of the skull, along with information about the possible coexisting anomalies of the brain. As a rule, 3D CT is the imaging modality of choice for syndromic cases, provided that the number and extent of suture fusion are depicted in detail, as well as possible coexisting brain anomalies. On the other hand, for non syndromic disease, the suggested diagnostic algorithm includes plain radiographs for the initial assessment, followed by 3D CT only in the case of positive or equivocal results [52].

However, concerns about the exposure of infants to radiation and the risks of sedation have led to a consensus, in order to avoid or at least to postpone 3D CT for the end of the first year of life or as late as possible in infants with suspected or diagnosed craniosynostosis [18, 34, 53, 54]. Plain radiographs have been indicated as an alternative choice to 3D CT, estimating their effective dose between 0.01-0.04 mSv, when the reported effective dose of 3D CT is estimated to be between 0.2-2 mSv [18, 23, 55, 56]. They give answers to the majority of clinical questions related to surgical planning and postoperative follow up in cases of monosutural craniosynostosis [18]. In addition, plain radiographs are a widely available, low cost examination, with a satisfac-

tory diagnostic accuracy, when they are of good quality and when they are interpreted by experienced readers. Nevertheless, even the utility of plain radiographs is in question, because there are cases where the quality is poor and crucial information is not provided.

Therefore, the most recent trend includes clinical examination as the first step in the assessment of infants with abnormal skull shape, which is considered to be enough to diagnose almost all monosutural forms of craniosynostosis [18]. Secondly, cranial ultrasound can provide additional information in cases where the diagnosis is in question. Cranial ultrasound is radiation free and is currently increasingly recommended as the modality of choice for the investigation of neonates and infants younger than one year of age, as it seems to be a highly specific and sensitive technique [8, 57]. It can differentiate fused from patent sutures and, thus, positional skull deformities from real craniosynostosis [18, 58], which is the most common and the most critical question in daily clinical practice. However, cranial ultrasound has its own limitations, as it cannot depict cranial base sutures and is highly operator depended [45]. Furthermore, large studies evaluating its accuracy are not yet available.

On the other hand, 3D CT is unavoidable in syndromic or even multisutural cases, as well as in complicated types of the disease, in order to plan the surgical treatment [18]. Furthermore, Magge et al. [59] have emphasised the ability of CT to demonstrate inciden-

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tal findings in the brain, some of which required additional follow-up or management, for instance prominent extra-axial cerebrospinal fluid, ventriculomegaly and Chiari malformation. However, as these children may undergo 3D CT more than once, not only for diagnoses, but also for the different stages of surgical corrections, an effort to minimise the radiation dose has been made. Certain low-dose dedicated cranial protocols have been proposed, reducing the effective dose to 0.08 mSv or even to 0.02 mSv, an amount compatible to that of plain radiographs, archiving at the same time images of good quality for the diagnosis of craniosynostosis [60-62]. Additionally, even in syndromic cases, brain ultrasound can play an important role, as it can depict the brain, without any anaesthesia needed, provided that the fontanels are open. Moreover, Soboleski et al. [63] suggested that increased sutures' width on serial cranial ultrasounds may indicate increase of intracranial pressure, which is a complication of craniosynostosis, important to be diagnosed in time.

Magnetic Resonance Imaging (MRI) plays a limited role in the investigation of the skull in craniosynostosis, as it cannot reliably identify the cranial sutures. On the contrary, it is a method of great interest and of good prospective, as it involves no radiation, a parameter of utmost importance for the ages studied for craniosynostosis. Bearing this in mind, Eley et al. [64, 65] suggested a new promising 3D MRI technique, called "Black Bone" MRI, aiming to ameliorate the method's accuracy in the diagnosis of craniosynostosis, by stressing the bone-soft tissue boundary and minimising soft tissue contrast. The effectiveness and the value of this technique remain to be proven. However, being the method of choice for brain imaging, MRI is for the moment an ideal diagnostic tool, supplementary to brain ultrasound, in the investigation of intracranial anomalies or complications associated with craniosynostosis [18].

Moreover, as foetal MRI is a well established method of prenatal diagnosis, it can be applied for the earlier detection of craniosynostosis. Even though large prospective studies have not been published as yet, certain interesting retrospective studies support this potential application of foetal MRI in combination with foetal ultrasound. The goals of antenatal diagnosis in craniosynostosis is to avoid untreated cases and to differentiate syndromic from isolated non-syndromic craniosynostosis, thus to indicate cases where early interventions

should be made, such as (a) proper delivery planning and elective Caesarean section (b) early postnatal investigation and early surgery or even (c) foetal surgery [66]. Even though prenatal diagnosis of syndromic cases of craniosynostosis is difficult to be made before the third trimester, where possible, foetal MRI can play a complementary role to the previously operated foetal ultrasound, giving important information about craniofacial relationships and coexisting brain and body anomalies [67, 68]. At any rate, it is clear that cranial sutures cannot be depicted directly on foetal ultrasound or foetal MRI, but skull deformities and other indirect signs can indicate the disorder. Until now, a small percentage of cases of isolated craniosynostosis are prenatally diagnosed [69]. However, Helfer et al. [70] suggested that a foetal 3D ultrasound technique may improve the efficiency of conventional foetal ultrasound in the diagnosis of craniosynostosis in the near future.

Treatment

A conservative management of craniosynostosis may include molding helmets and is typically applied in cases of secondary craniosynostosis with normal intracranial pressure, as well as in deformational posterior plagiocephaly [39]. The remaining types of this entity, accompanied by restriction of brain growth and raised intracranial pressure, always require early surgical management.

There are two main indications for surgical treatment of isolated craniosynostosis, the first being the correction of the calvarium shape for aesthetic and psychosocial reasons, improving the patient's quality of life during early childhood or puberty (Fig. 10). The second is to ensure that there is enough space for brain growth after the reconstruction of the skull [71].

In cases of non-syndromic craniosynostosis, no definitive or strict guidelines exist about the optimal time or the type of surgical intervention. Treatment of these children may vary, based on the patient's age at presentation, location and number of craniosynostoses, severity of deformity and the final decision is up to the neurosurgeon. Surgery is suggested as soon as the infant is able to tolerate it. In our institution we tend to treat children at the age of 6-12 months, because of sufficient available circulating blood resources compared to younger infants and improved and more permanent aesthetic outcome. In addition, during this life period of rapidly growing cranial vault, the bones are malle-

*Fig. 10: **a.** Flattening of the occiput on the side of the fused lambdoid suture, with compensatory bulging on the contralateral perieto-occiput. **b.** Postoperative image, depicting the correction of the lambdoid synostosis and the skull asymmetry.*
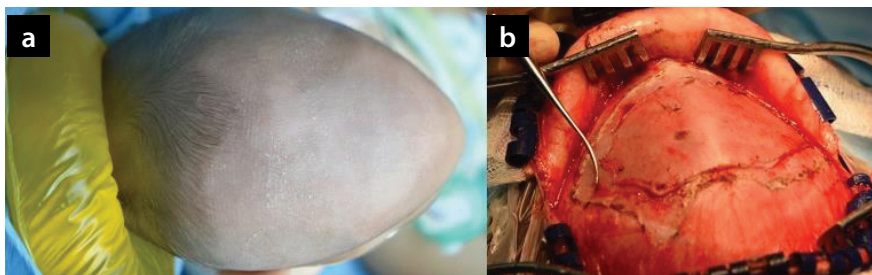
*Fig. 11: **a.** Triangular shape of the head, just before surgery. **b.** Coronal incision and elevation of the skin flap. The surgical reconstruction is based on the remodeling of the fused suture in the midline of the forehead and fronto-orbital reconstruction.*
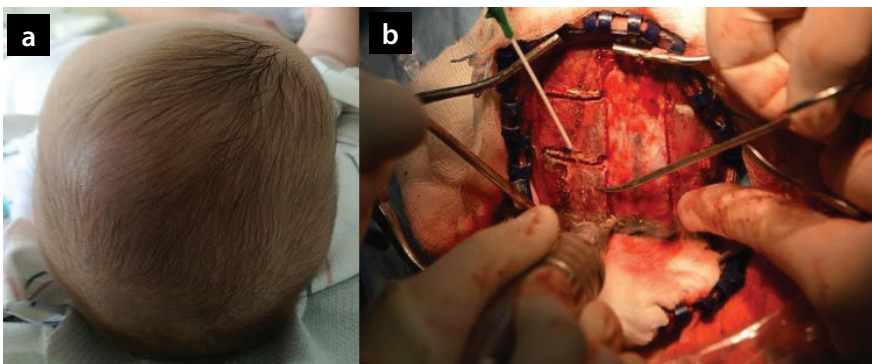
*Fig. 12: **a.** Head deformity (dolichocephaly) before surgery. **b.** Strip craniectomy, with perpendicular osteotomies.*

able and heal effectively. However, in infants bearing severe deformities, surgical treatment may take place earlier than the age of six months or even after the first year of life.

As regards syndromic craniosynostosis, general practice in craniofacial repair indicates early cranial vault repair, between six and nine months of life, in order to achieve normal brain growth. Repair of facial structures, including the orbit, the maxilla and the mandible, may be delayed, between five and eight years of life, so as to deal with aesthetic problems, as well as the position of the orbits, dental occlusion and pharyngeal function [72]. However, it should be clearly stated that the continuous impact of genetic mutations on the developing skull tends

to turn it back to the preoperative state, thus multiple consecutive operations may be needed [71, 72].

In non-syndromic craniosynostosis, the surgical technique includes a bicoronal zigzag or straight skin incision behind the hair line, which usually allows for good handling of the whole skull, from the supraorbital rim to the occiput (**Fig. 11**). The incision is extended anteriorly or posteriorly, depending on the treated pathology. Subsequently, the surgical procedure is tailored by the synostotic suture and the degree of secondary cranial vault defect (**Fig. 12**). In general, the affected suture has to be removed, placing burr holes around it, while the bone flap containing the suture has to be reconstructed and reassigned in the same location, facing the same

or a different direction. In certain types of craniosynostosis, the supraorbital margin needs to be reconstructed as well. Moreover, the skull around the craniotomy is reconstructed by creating "barrel-stave" osteotomies and bending or fracturing the bony segments outwards, in an effort to increase intracranial volume. The decision for the bony fragments fixation with absorbable plating system and the possible use of subgaleal drains depends on the medical institution and the surgeon's preference. Recently, an increasing preference for endoscopic surgical treatment of non-syndromic craniosynostosis has been noted. The endoscopic technique is based on the old open suturectomy, according to which only the fused suture is released, without reconstruction of a greater portion of the skull [71, 72].

Moreover, in surgical operations for syndromic craniosynostosis, the skin incision follows the same principles. However, the procedure following bone revelation is quite complex and involves many surgical specialties. The most frequently used techniques are fronto-orbital advancement, cranial vault expansion with or without the use of springs or distraction technology, monobloc frontofacial advancement and facial bipartition. All these different approaches increase intracranial volume, protect the orbits, free the upper airway and improve aesthetic results [73].

Conclusion

Even though craniosynostosis is a well-known entity, there are still several topics for investigation, as new information is coming up with advancing imaging modalities. At the same time, craniosynostosis is quite a demanding disorder, as it affects infancy, an age with a lot of particularities. The challenges for the diagnosis and treatment of this entity are significant, and their consequences will follow the patient throughout his or her entire life. Thus, every diagnostic or treating intervention has to be cautious and evidence based, in order to have optimal outcomes for the infant. On the domain of diagnosis, there are still questions to be answered, specifically on the possibility to effectively replace diagnostic methods with ionising radiation (plain radiographs and 3D CT), with other, more infant-friendly methods, such as cranial ultrasound and MRI. Large, prospective and multicentre studies may be needed, in order to reliably establish such diagnostic protocols. **R**

Conflict of interest

The authors declared no conflicts of interest.

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