

Pediatric Issue

Current and Future Perspectives in Craniosynostosis

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Craniosynostosis has a varied clinical spectrum, ranging from isolated single suture involvement to multi-sutural fusions. Greater understanding of the pathogenesis of craniosynostosis has led to the development of practical treatment protocols. Three stages of growth have determined the approach to managing craniosynostosis : the early period, up to 12 months; the intermediate period, from 1 to 10 years; and the late period, beginning at 10 years. This review discusses current surgical management and future perspectives in craniosynostosis.

Key Words : Craniosynostosis · Neurosurgery · Pediatric.

INTRODUCTION

Craniosynostosis is a wonderfully descriptive term, meaning “the skull has fused bone”. However, it is also a fairly nonspecific clinical designation, encompassing multiple presentations ranging from isolated single suture involvement to multi-sutural fusions⁵. Multi-sutural fusion can occur as isolated fusions or with associated anomalies that occur outside the skull. Epidemiologic studies have suggested that the incidence of craniosynostosis may be as high as 1 in 1700 live births^{6,12}. Several causes of craniosynostosis have been proposed⁹. For example, early theories regarding the pathogenesis of this condition, based on clinical observations and an experimental animal model, included intrauterine constraint^{8,11}.

Over the last quarter century, there have been many advances in the understanding of craniosynostosis, resulting in more rational management of the problems associated with this condition, both in its simple form and its syndromic manifestations^{3,15}. These advances have included reduced emphasis on the technical aspects of this disease and greater emphasis on its pathology and natural history, along with more accurate analysis of the morphology of the craniofacial skeleton^{1,3,10}. More recently, genetic studies have identified the genetic loci of many craniosynostosis syndromes, as well as determining the downstream pathways associated with disease development. Recent clinical and genetic studies have identified multiple forms of

human craniosynostosis, each associated with mutations within various growth factor signaling pathways. Knowledge gathered from these investigations may result in the future development of alternative strategies to enhance or perhaps even replace current approaches for the treatment of craniosynostosis.

CURRENT SURGICAL TREATMENT

Craniosynostosis was first treated surgically in the late 1800s, using techniques such as fragmentation of the cranial vault and linear craniectomies. These early procedures were associated with high rates of reossification and poor esthetic outcomes, mandating many subsequent procedures⁷. At present, however, simple craniectomy is used only in patients with transient cranial decompression. These early procedures have been supplanted by surgical remodeling of the affected area of the cranial vault and orbits. Surgery is generally performed at age 6–9 months to take full advantage of the regenerative capacity of the skull at this age. Three stages of growth have determined the approach to the management of craniosynostosis³.

The early period, up to 12 months

During this time, cerebral growth is the greatest, and craniosynostosis may have detrimental effects on the developing brain. The original surgical approach consisted of excision of the premature suture or sutures by linear craniectomy, allowing the

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growing brain to expand. If urgent decompression was required, fronto-orbital advancement and multiple suture excisions were performed, resulting in lateral and posterior expansion.

The intermediate period, from 1 to 10 years

After the second year, cerebral growth slows; nevertheless, severe craniostenosis may still lead to papilledema and potential visual failure. The cranial capacity must therefore be expanded by large bilateral decompressive craniotomies, generous fronto-orbital advancement, or a combination of these procedures.

Late period, beginning at age 10 years

Definitive facial surgery can be performed, beginning at age 10 years, although waiting until maturity may achieve better esthetic outcomes. Patients with Crouzon syndrome who have proptosis and/or maxillary hypoplasia are especially likely to need surgical treatment^{12,14}.

Early surgical correction has been limited by a late diagnosis and the risks associated with intraoperative blood loss, which was less effectively managed in the past than currently¹³. Since the beginning of the 21st century, many centers have tended to determine whether a less invasive procedure could be performed at an earlier stage with acceptable risk. Endoscopic linear craniectomy, with postoperative application of helmets and cranial remodeling through small skin incisions, has led to cosmetic results comparable to those of more invasive procedures if performed during the first 4–6 months of life, with acceptable blood loss and operative risks¹³. Surgical management of complex craniostenosis has also changed significantly. For many years, the early treatment of this condition consisted of bi-frontal advancement. More recently, the combination of frontal advancement and posterior cranial enlargement during the first months of life has been found to protect both the ocular and posterior cranial structures. Currently, a free bone flap (floating technique) or springs are used to allow for cerebral growth until a rigid fronto-orbito-maxillary advancement can be performed¹³. The advent of osteodistraction has lowered the age for facio-maxillary advancement (3–5 years), and may avoid the necessity of repeating fronto-orbital procedures. This has reduced the risks of dural tears and postoperative cerebrospinal fluid fistulas in a significant proportion of patients.

As the procedures used to remodel the calvarial vault are extensive, complications can occur following surgery for craniostenosis. Although the mortality rate has been reported to be as high as 2.3%, most international studies had mortality rates of 1.5% to 2%⁷. Most deaths were attributed to hemorrhagic complications, but various other causes have been reported, including air emboli, cerebral edema, and respiratory infections⁴. Attention to intraoperative hemodynamics and careful postoperative intensive care unit monitoring are critical in minimizing overall morbidity and mortality rates.

FUTURE PERSPECTIVES IN CRANIOSYNOSTOSIS

The combination of early technical success with recent advances in treatment¹⁴ has indicated the necessity of multidisciplinary management. The overall approach can be distilled into six principles⁹: 1) Care should be provided by multi-disciplinary teams; 2) Care should be a protocol-driven process, with all forms of care defined and delivered optimally; 3) Care should be longitudinal, as age, healing and growth processes; 4) Secure financial support is needed to implement such longitudinal care¹¹; 5) Competent professionals should be involved in ongoing education and training in teaching and research; and 6) Research should explore causes, treatment strategies, and treatment outcomes.

CONCLUSION

Centers with the appropriate vision and infrastructure are necessary to optimize the care of patients with craniostenosis, as well as to enhance scientific knowledge and education about this disease. Several investigations have evaluated the roles of various growth factors and cytokines in determining the fate of sutures. Fibroblast growth factors (FGFs) are particularly important, as mutations in their receptors have been implicated in many craniostenosis syndromes. Mutations in three of the four known FGF receptors have been associated with premature pathologic suture fusions^{16,17}. Recent advances in developmental biology and genetics have identified some of the events governing suture fate, highlighting multiple axes of cellular signaling with the potential for clinical manipulation. Such knowledge and comprehension may facilitate therapeutic translations, ultimately enhancing or perhaps even replacing contemporary modalities for treating craniostenosis.

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