Review Article

Lessons Learned about the Mayfield-Type Cranial Fixation System. How to avoid complications in the pediatric population

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Introduction: Cranial fixation systems are instruments frequently used in cranial and spinal neurosurgical interventions to allow rigid fixation of the patient's head, despite their careful use, they are not free from systemic and intracranial complications.
Method: A literature review was carried out in the PubMed database to extract original articles published between the years 1990 to 2021 with the following terms: "Mayfield skull clamp", "Mayfield head clamp", "Skull clamp" and "Pin-type head fixation device".
Results: 68 articles were selected that met the citation criteria, respective impacts, and content.
Conclusion: The meticulous use of the cranial fixation system has greatly reduced its complications.

Keywords: Mayfield device, complications, immobilization device, Mayfield skull clamp, Mayfield head clamp, skull clamp, pin-type head fixation device, cranial surgery, head holder

INTRODUCTION

Cranial fixation systems or devices employed in neurosurgical interventions for the purpose of immobilizing the skull during the neurosurgical procedure have been widely used [1,2,3].

The Mayfield-type system utilizes fixation pins and is a safe equipment extensively utilized in cranial surgeries [2,4-9] and spinal surgeries [1,10-13] in adults [1,3,7,10,14] and children [1,4,15-17]. However, it is associated with systemic and intracranial complications: intracranial hypertension [18-20], cranial fracture/depression [2,3,6,10,14-17,21-24], epidural hematoma [1,4,7,10,14,15,17-20,22,25-29], venous embolism [5,30-36], and less commonly: cerebrospinal fluid leak (CSF) [37], arteriovenous fistula of the middle meningeal artery [38,39], head slippage [40], superficial temporal artery aneurysm [39,41], alopecia [42], asystole [43], and facial paralysis [11,13].

The authors described the use of the Mayfield-type cranial fixation system, discussed the benefits, the complications produced by its use and its prophylaxis.

METHODS

A literature review was carried out in the PubMed database to extract original articles published between the years 1990 to 2021 with the following terms: "Mayfield skull clamp", "Mayfield head clamp", "Skull clamp" and "Pin-type head fixation device".

RESULTS

Sixty-eight articles were selected that met the citation criteria, respective impacts, and content.

DISCUSSION

Cranial fixation systems allowed effective immobilization of the skull, especially in cases of microneurosurgery, thus avoiding previously encountered cutaneous complications (pressure ulcers) and ocular complications when surgeries were performed for prolonged periods using a horseshoe headrest system [10,29]. Commonly used are the three-pin Mayfield-type systems or the four-pin Sugita-type systems. The Mayfield system has been the most widely used due to its recognized safety in cranial and spinal surgery [2,10].

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Complications arising from the use of cranial fixation devices have been reported in the literature, especially in the pediatric population [2,15,26,35,44], as well as in adults [1,6,7,10,14,19,20,23,27,29,32]. The literature converges to pediatric rates and complications of around 0.65 to 1.1%, which is significantly higher than the rates found in the adult population. [17,49,58] The pin penetrates the outer layer of the cortical bone and provides stabilization of the skull. Complications are more common in children due to the thickness of the cranial vault, especially in children under two years of age, and the use of the fixator in these patients is not recommended. [9,16,44,45] Another factor that facilitates cranial complications is the presence of chronic intracranial pathologies that lead to intracranial hypertension, such as chronic hydrocephalus, which gradually makes the skull cap thinner and more fragile cranial [1,7,16,44]. According to Serramito-Garcia et al. [29], its use is generally indicated for patients above the age of two years, at which point the skull has an acceptable thickness to prevent the penetration of the fixation pin into the intracranial portion.

Wong and Hayes, 1994. When carrying out a tomographic study of 48 children of different ages, it was noticed that despite the tendency towards progressive thickening of the cranial vault, there is no homogeneous growth rate, making it possible to find areas of up to 2 mm thick in children up to 10 years. 44.48.

In addition to the relationship between the child's age and the thickness of the skullcap, the presence of certain factors such as fontanelles and sutures must be taken into account. Therefore, the first fontanelle to be closed is the posterior or lambdoid fontanelle, which closes completely 2 to 3 months after birth, followed by the frontolateral and posterolateral fontanelles, which close in 6 months and 6 to 18 months. respectively. Finally, the last fontanelle to be closed is the bregmatic fontanelle, which closes completely from the first to the third year of life. [44,49] Unlike the fontanelles, which begin to close early from birth, the sutures have a gradual closing pattern, with many sutures ossified incompletely until adulthood. Closing of the sutures occurs in the sequence of metopic, coronal, lambdoid sutures and finally the sagittal suture [49-53].

The literature has also reported risk factors for complications associated with the use of these systems in adult patients, such as those with chronic renal insufficiency undergoing hemodialysis and patients on long-term use of anticonvulsant drugs, which can lead to bone fragility and increase the risk of fracture/depression 10,23.

Cranial fracture and depression

Cranial fracture/depression has been reported as one of the main complications of the cranial fixation system [1,2,6,10,14-17,23,24,35,36,39,49,62-64,66,67]. It affects the pediatric population more commonly, likely due to the thickness of the skull bones [35,44,45]. It occurs primarily in cases of children with chronic intracranial hypertension or hydrocephalus. The use of cranial fixators in children under the age of two should be approached with restricted care, as the skull cannot withstand the pressure exerted by the pins, potentially leading to bone or intracranial injury 10. Skull fracture presents a high potential for severity due to the mechanism of sudden drop in intracranial pressure caused by the formation of a cerebrospinal fluid fistula caused by the rupture of the cap by the fixation pins [48.49].

This complication can be detected at the time of pin placement, before the start of surgery, or later in the presence of patient neurological deterioration [10]. Hiwatari et al. 3 studied the risk factors associated with the Sugita fixation system in adults regarding cranial fracture/depression and intracranial hematoma. They found an incidence of 0.29% (5/1749 cases) associated with epidural hematoma, and one case had dura mater laceration, all of which had perforation at the site of pin insertion in the parietal bone near the pterion. None of their patients experienced postoperative neurological deterioration. To prevent this complication, it is advised to avoid placing the pins in less dense areas of the skull, such as the temporal bone scale, frontal sinus, and coronal suture [6,44,45].

Hiwatari et al. 3 recommend that when using this fixation system in surgical procedures, the site of pin application, skull thickness, and fragility should be rigorously observed, along with appropriate control of compressive forces exerted by the head structure. Visentin et al. [46] reached a conclusion in their study regarding the recommendation for head support use, which depends on the patient's history and cranial thickness to reduce complications associated with pin-type head support during clinical application.

Epidural hematoma

Epidural hematoma has been another common complication of cranial fixation system use [6,7,10,12,14,22,28]. The hematoma can be unilateral or bilateral [2,27]. This injury is typically associated with cranial fracture/depression and occurs more frequently in children due to the thickness of the cranial vault, especially in cases of chronic intracranial hypertension and hydrocephalus, while being rarer in adults [7,10]. There are reports of epidural hematoma at the pin application site, which can be attributed to the diagnosis of acute intraoperative cerebral swelling [15,19,26,27], deterioration in the immediate postoperative period, or the development of new focal neurological deficits [14,16,17].

The diagnosis of intracranial complications resulting from the use of cranial fixators in spinal surgery, particularly in posterior cervical spine surgery, has been employed to

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provide rigidity and a stable head position during the procedure. Following surgery, if a patient presents with persistent nausea, vomiting, and headache, attention should be given to this possibility and an immediate cranial computed tomography (CT) scan should be performed 1. Specialists should be alerted to these occurrences, and immediate postoperative CT scan should be indicated.

Gas embolism

Gas embolism is a serious complication that can occur in neurosurgical procedures requiring craniotomy. The majority of events have occurred in a seated position during surgery and are due to the entry of air into the venous structures and medullary spaces of the skull [34, 36, 47]. It is considered rare for an external source to cause this complication. Some authors have reported a possible association of this complication with injury caused by the pin of the cranial fixation system [5, 30, 34, 47]. The likely penetration of the pin into the periosteal sinus or vein provides a direct source and is responsible for this complication.

According to Grinberg et al. [36] in their report, air could have been carried through the venous circulation from any location where atmospheric pressure exceeds local venous pressure. The risk of air entry increases in areas where anatomical structures such as stents keep the veins open, preventing their collapse, namely the venous sinuses, epidural veins, and medullary spaces. Early detection and appropriate treatment of this complication have been crucial for its management and outcomes.

How to avoid cranial complications

Furthermore, despite the risks presented by the Mayfield cranial fixation system, it still proves to be a very useful tool in the process of stabilizing the skull. Therefore, adaptations are necessary so that complication rates are exponentially reduced. 9.44

Due to variations in the thickness of the cranial vault, especially in younger children, the use of imaging tests such as cranial tomography to estimate cranial thickness can help in the decision process regarding the positioning of the pins. [48,49,54-57] Careful insertion of the pins becomes an essential part of using the method, therefore, checking the sounds emitted during insertion, the depth of entry of the pins, intraoperative cerebral edema, etc. Furthermore, it is extremely important that certain locations are avoided at all costs, such as fontanelles, sutures, squamous region of the temporal bone, frontal sinus, mastoid air cells [16,49]. Another valid technique in challenging cases is the use of Phantom with a reliable impression of the images obtained in preoperative head computed tomography [49,59].

Currently, with technological advancements, there have been modifications in cranial fixation systems. There are now fixation systems available with small, specific pins for the pediatric population, and some technical aids have minimized their effects on children's skulls [9,45]. It is necessary to exercise caution and have knowledge about risk factors when using these systems. Careful technique is required for their utilization, as well as the management of complications, which can prevent more disastrous complications for the patient.

Complications are more common in children due to the thickness of the cranial vault, which requires extra caution in their use. When using them, it is necessary to be mindful and knowledgeable about the risk factors, employ a meticulous technique for their application, and be prepared to address any complications in order to prevent more disastrous outcomes for the patients [1, 7, 10].

Preventing these complications involves several strategies. In cases of thin cranial bones or suspected bone fragility when using the Mayfield-type device, careful placement and gentle tightening of the pins are recommended. The application of tightening force should be done slowly and manually, without applying axial pressure. A rubber cup can be used as a barrier for the pin to prevent deep penetration. Another option is to decrease the pressure force on the screws to below 60 lbs in adult patients (table 1). For patients suspected of having bone fragility or a thin skull, cranial fixation devices such as a mask or ring or horseshoe-shaped halo can be used to create rigid immobilization of the skull, particularly in cases of cervical spine surgery [10].

Table 1- Recommendations for pressures to be applied and pins to be used to stabilize the pediatric skull. Source: Berry et al. 2008

Recommendations of pins pressions in pediatric skull fixation	
< 2 years	Do not recommended use of pins
2 - 3 years	10 - 20 lbs using pediatric pins
3 - 4 years	21 - 30 lbs using pediatric pins
4 - 5 years	21 - 40 lbs using pediatric pins
5 - 10 years	31- 50 lbs using adult pins
> 10 years	60 lbs using adult pins

CONCLUSION

Careful considerations of various nuances are recommended to avoid inadvertently causing complications to patients. Attention should be given to the anatomy of the region and the surgical steps, including the placement of the cranial fixation system. Cranial fixation systems need to be used with great caution and knowledge of risk factors, employing meticulous technique in their application, and

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addressing any complications that may arise in order to prevent harm to patients

DISCLOSURES

Ethical approval

This study was executed in adherence to the principles outlined in the Declaration of Helsinki. Notably, no formal approval was necessitated, given the nature of the study as a literature review article

Conflict of interest

The authors declare no conflicts of interest with respect to the content, authorship, and/or publication of this article.

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CONTRIBUTIONS

-Carlos Umberto Pereira: Conceptualization, Data curation, Formal Analysis, Methodology, Writing – review & editing
- Lauro Roberto de Azevedo Setton: Data curation, Formal Analysis, Investigation, Writing – original draft
- Débora Moura da Paixão Oliveira: Data curation, Formal Analysis, Writing – original draft

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