Historical Review and Current Progress of the Cranioplasty

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Abstract. Cranialplasty is one of the typical neurosurgical procedures.As a result of their aesthetics and biocompatibility, autologous grafts are chosen. Numerous patients with skull defects experience local scalp depression as a result of atmospheric pressure, which can cause an imbalance in intracranial pressure, displacement of brain tissue, reduction in cerebral hemispheric blood flow, and problems with cerebrospinal fluid circulation, all of which can result in a variety of clinical manifestations. Then cranioplasty can effectively restore normal cerebrospinal fluid dynamics and cerebral cortical blood perfusion, which is conducive to reducing intracranial complications and assisting in the restoration of neurological function. It can also repair skull defects, restore the patient's skull appearance and protective function. This paper's goal is to investigate a foundation for the viability and timeliness of cranioplasty, This paper discussed the history of cranioplasty, the pathophysiological effects of recovery, complications, and rehabilitation issues from both qualitative and quantitative viewpoints. According to the average cranioplasty score, having a procedure done within three months following a traumatic DC may help with neurological function recovery. In addition, effective communication between the surgical team and the rehabilitation staff is crucial for maximizing recovery and enhancing results.

Keywords: cranioplasty; complication; skull defect; indication; rehabilitation.

1. Introduction

Skull fracture refers to the partial or complete fracture of one or more bones in the head, mostly caused by blunt impact. It is not life-threatening in itself, but common clinical complications caused by skull fractures such as intracranial hematoma, intracranial hemorrhage, increased intracranial pressure, etc. If not treated in time, it may lead to poor prognosis and even death in severe cases. Therefore, some trauma patients remove bone flaps in order to remove intracranial hematoma, or some patients ' tumors invade the skull, or perform decompressive craniectomy (DC) for brain decompression, resulting in skull defects [1].

Skull defect is a common sequelae after craniocerebral injury and decompressive craniectomy. It not only has a great impact on the external image of human beings, but also makes brain tissue vulnerable to secondary injury due to the loss of normal skull barrier protection. Therefore, patients with skull defects usually need to use their own bones or artificial prostheses to reconstruct bones. This method is called cranioplasty, which can improve neurological function while restoring skull integrity. However, the current repair methods have certain limitations. The incidence of complications, nerve recovery, and results, the effect of timing on these factors, material choice, overall cost-effectiveness, and the potential for escalating cerebrospinal fluid contamination or intracranial infection, for instance, are all areas where systematic understanding is lacking. As a result, patients will be able to create more focused rehabilitation plans to maximize the advantages of skull repair with a greater understanding of the pathophysiological effects of cranioplasty and the relationship between timing and problems. This may maximize rehabilitation potential, improve function and cognitive ability, improve quality of life, and may reduce long-term care needs. Therefore, this article summarizes the progress of the current multidisciplinary team from the perspective of the history of skull repair, the pathophysiological consequences of recovery, complications, and rehabilitation considerations, in order to provide a basis for the feasibility and timeliness of skull repair.

2. Historical Aspects

Early humans likely executed the first craniotomies for magical or religious purposes, either as a type of imprinting practice or as a part of an exorcism ritual to provide a means of escaping demons and evil spirits. They thought that the man had been troubled by these demons and demonic spirits. Trepanning was the first procedure in neurosurgery that was known to have been performed, and evidence of this procedure was found in the skull that was discovered at the Inca cultural cemetery in Peru more than 3000 years ago. Later, craniotomy was used for therapeutic purposes: Due to brain decompression, this surgery can improve some pre-existing neurological symptoms, such as headache, paralysis, and spasticity, which may lead to the use of this surgery when these symptoms occur, especially in traumatic injuries. They quickly took over as the primary therapeutic indication for drilling, which allowed for the removal of embedded shards, bone fragments, and clots and produced outcomes that were astounding for prehistoric society. Despite the extremely high risk of complications due to bleeding or infection, nearly 50% of the patients survived the operation, some of them for several years. This is demonstrated by the presence of remnants of regenerated bone in several of the skulls. Hence, despite having only simple instruments like pointed or sharp cutting tools made of silica or obsidian, the neolithic doctors had attained an exceptional level of technical proficiency in performing this type of surgical treatment, cranioplasty was then performed [2]. It was initially reported by Flemish physician and anatomist Fallopius. The first successful instance of xenogeneic bone transplant cranioplasty was documented in 1668 by the Dutch physician Janszoon van Meekeren. Further improvements were made by the French surgeon Augustin Belloste (1732), who described covering the dura mater with two wings on either side of the osteoplasty. Later, in 1820, the very first autogenous bone transfer for a cranioplasty was performed by a German surgeon Van Walter. It is now a frequent neurosurgical treatment due to advancements in surgical techniques and biomaterials [2,3].

3. Clinical Indications

Decompressive craniectomy has various indications, such as intracerebral hemorrhage, neoplasm, and infections, and is related to traumatic brain injury (TBI) or stroke in about 65% of cases. Most surviving patients will need skull reconstruction through cranioplasty, which is usually a planned and selective procedure [3]. By enhancing vestibular system balance and cricoid syndrome recovery, it protects the brain and lowers the risk of falls. Even while enhancing face appearance is typically not the primary goal of reconstruction, it should nevertheless be considered. The likelihood of neurological and cognitive recovery may be increased by early cranioplasty, according to mounting data. When treating and minimizing post-craniectomy pulsation or pain abnormalities, or in clinical cases of trephination syndrome, rapid cranioplasty may be an option. Any potential infection of the brain or bones as well as untreated hydrocephalus are contraindications to having a cranioplasty.

3.1. Section Headings Syndrome of Trephined

In 1939, Grant and Norcross first described a syndrome, including severe headache, pain and dizziness at the craniotomy site, and changes in mental cognition. There are now three main elements to the existing definition:

Neurological dysfunction occurs between weeks and months after craniotomy.

The onset of neurologic defects make it possible to distinguish the defects related to the original pathology.

Clinical solutions after cranioplastic surgery.

As defined, the term " cricoid syndrome " is not used until the neurological symptoms have been resolved by cranioplasty, so the term " depressed valve syndrome " is used before cranioplasty; nevertheless, in clinical practice, both terms are interchangeable. This is an under-estimated consequence of decompressive craniectomy, likely due to the complexity and heterogeneity of patient outcomes following a serious brain injury, which usually progresses slowly over a period of days to

weeks, in the worst cases resulting in a significant decline in neurological status and a coma. Nerve damage from the bone flap subsiding is thought to be caused by the negative pressure difference between the skull and the air. The clinical signs might take many different forms. The most frequent symptom is physical weakness (61%), which is followed by cognitive impairment (44%), linguistic impairment (30%), altered mental state (28%) and headache (20%), according to a recent comprehensive study by Ashayeri et al. At the time of the craniotomy till symptoms, it usually takes 5 months. The systematic study covered 54 patients in total, of whom 34.6% reported complete resolution of neurological problems following cranioplasty [3].

It is essential to recognize and comprehend this frequently subtle and challenging clinical scenario because of the timing of onset, which frequently places those most at risk in rehabilitation facilities. Comprehensive clinical evaluations are part of the treatment to see if there are any new or worsening neurological symptoms or damage to the brain. In the meantime, the patient's position is crucial because lying horizontally typically speeds up skull reconstruction and improves neurology [4].

3.2. Methodology and Considerations

The Guidelines for the Treatment of Severe Traumatic Brain Injury in Adults (4th edition) recommends that the minimum size of DC in the frontotemporal parietal lobe is 12 cm × 15 cm to improve neurological prognosis and mortality. The size and location of the DC, the necessity and method of scalp closure, and the identification of temporal muscles are all factors that should be taken into consideration early in the surgical planning of cranioplasty. These factors will all have an impact on the success of cranioplasty.

Ideally, during a craniotomy, a plane between the brain and the scalp flap should be considered. Elevation of the scalp flap, dissection of the dural soft tissue, and flap vascular reconstruction are additional surgical considerations. It has been demonstrated that bifrontal cranioplasty has a 2.5-fold higher infection rate than hemispheric cranioplasty. Additionally, double frontal cranioplasty patients are said to have a higher rate of reoperation. Disability will be affected by the location of DC, but primarily by the severity and type of potential brain injury. During induction and surgery, antibiotics are frequently used, but it is unclear how often and how much antibiotics are used for surgical site infections after surgery [5].

4. Complications

Patients generally benefit from cranioplasty, but there are significant risks. Overall, the incidence of complications is generally between 15 % and 30 %. An orderly survey of 2016 (18 investigations of 3126 patients) showed that the general inconvenience rate was 19.5 %, and there was no distinction between the time periods. In a similar vein, there was no statistically significant difference in the prevalence of complications between artificial bone and autogenous bone. [6,7].

Ubiquitous complications include infection, intracranial bleeding, extraaxial effusion, seizures and bone flap resorption (BFR).

4.1. Infection

The high infection rate of early cranioplasty has historically caused concern, but recent studies and systematic reviews have refuted this. In 2016, a multicenter prospective cohort study found that early cranioplasty and late cranioplasty had the same infection rate. It is now generally believed that the infection rate is relatively independent of the time frame. The infection rate was between 1.4 % and 24.4 % (the pooled ratio was 7.7 %), which was due to the difference in infection rates due to the different definitions of infection by different symptoms.

Scalp tenderness, pain, redness, and swelling are clinical signs of an infection, and they may be accompanied by the reopening of surgical scars. The most concerning infection and has the greatest impact on patients is severe infection caused by cranioplasty. It is typically reinserted at least one

year after being removed. The patient's recovery, function, and quality of life may all be significantly impacted by multiple antibiotic courses, acute rehospitalization, and subsequent surgeries.

4.2. Seizures

Epilepsy incidence following cranioplasty is estimated to be 6.1 % (36 cases), but it is difficult to describe the secondary risk after cranioplasty compared to the potential risk of brain injury. Craniocerebral injury, stroke, postoperative infection and bleeding, male gender, and neurological dysfunction prior to cranioplasty are all risk factors. The number of common pathogenic factors accurately reflects the effect of antiepileptic drug (AED) prophylaxis on the incidence of epilepsy following cranioplasty. However, studies have demonstrated that the incidence of epilepsy following cranioplasty is significantly reduced when AED is administered for at least seven days. Due to the possibility of brain injury, patients typically already receive AED during cranioplasty [6].

4.3. Bone Flap Resorption (BFR)

BFR is a known complication of autologous cranioplasty that can significantly affect patients, particularly in terms of the need for additional surgical resection and/or revision and cosmetic outcomes.

The pathophysiological mechanism of BFR is not fully understood, but it may be due to changes in the blood supply to the scalp and dermis, as well as the lack of binding to the bones around it. Infection may be one of the reasons. Multiple fractures, bone fragmentation, larger cranioplasty, younger age, ventriculoperitoneal shunt, and early cranioplasty were additional risk factors. Bone flap resorption can result in more serious defects, which can cause additional complications and necessitate surgery. It can also make patients' appearance worse.

5. Rehabilitation Considerations

The surgical incision healing of cranioplasty is generally about 8 days, and the suture can be completely removed. After 2-3 days of rest, the patient will basically recover. After 1-2 weeks of hospitalization observation, if the patient 's postoperative condition is good, the wound recovers well, and the doctor can be discharged after the evaluation of the relevant examination. However, there are still many aspects in daily life that need attention to prevent complications.

5.1. Positioning and Mobility

Traumatic brain injury or stroke patients frequently have intricate physiological, cognitive, psychological, and psychosocial needs. Skull defects add an additional layer of complexity to the rehabilitation picture, despite the fact that these conditions can vary greatly and no case is the same. Positioning, mobilization, and general personal care difficulties are common. Sunken flap patients typically experience elevated muscle tension and require a 24-hour postural management plan. The head, pelvis, trunk, and limbs are thought to be in the best possible position with orthotics and splints, and both global and local antispasmodic medications are used in drug therapy [3].

5.2. Drugs

Post-operative physicians will use antibiotics, hormones and inhaling aerosols for 3 to 7 days, if necessary, to prevent infection. If the post-operative pain is unbearable, it is also possible to take oral analgesics, which must be practiced in accordance with the doctor's advice. At the same time, different degrees of swelling of the face may occur after surgery, and the dehydrating agent may be used depending on the doctor's advice. In addition, patients with epilepsy should continue to take antiepileptic drugs according to the doctor 's advice after discharge, and should not be discontinued without authorization.

5.3. Recurrence

After cranioplasty, the first review time generally requires three months after surgery. Generally, CT can be reviewed and magnetic resonance can also be performed. The purpose is to observe whether the local cerebral cortex adapts to the new skull after repair, whether there are some changes, and whether there are secondary hematomas on the surface of the fire cortex below the skull. If there is no special case after the review, it can be reviewed once in the next 1-2 years. Some patients have complex diseases, such as brain trauma, cerebral hemorrhage, etc., may also do some other corresponding review.

5.4. Cosmesis

Due to the fact that it is so subjective for a single patient, head and face cosmesis is typically difficult to measure objectively. However, because of their appearance and self-confidence, patients may be reluctant to enter the hospital or outpatient setting prior to skull reconstruction. Their recovery path, self-esteem, and mental health may be impacted by this. After cranioplasty, some cosmetic scales for cranioplasty can be used. However, they have not yet been utilized extensively in clinical practice. Cosmetic acceptance is often measured with visual analogue scales, but there is little evidence that this helps patients recover [3,8].

5.5. Exercise

Some long-term bedridden patients should be regularly turned over, the pressure site should be replaced regularly, bedding and massage, to avoid skin damage infection and pressure sores. Postoperative patients need to avoid premature exercise, generally after three months can do some intensity exercise. Even if you want to exercise, you must strictly control the exercise time. Excessive exercise time may increase intracranial pressure and lead to aggravation of the patient 's condition.

5.6. Driving

The risk of seizures is the primary constraint on recovery after cranioplasty. It is reported that the risk of seizures after cranioplasty is about 6 % (36 cases). There may be other reasons that may not properly link driving to potential brain injury, but cranioplasty itself should not restrict driving in the future. It's not an absolute taboo to drive, but the potential impact of cranioplasty needs to be considered when getting a driver 's license [3,9].

5.7. Flying

The Civil Aviation Authority (CAA) recommended that it take at least seven days from the end of the neurosurgical intervention to the end of the flight because of the risk of an expansion of the air-brain at high altitude. However, it did not provide specifics about more complicated interventions, so each case should be examined by the appropriate experts. Nevertheless, once the patient has fully recovered from cranioplasty, there is no specific restriction on flight; similarly, potential brain injury should be taken into consideration [10].

6. Discussion

As a routine neurosurgical procedure, cranoplasty carries a number of risks for complications. In particular, early cranioplasty within 3 months of traumatic DC may promote the recovery of neurological function. The neurological status of patients prior to cranioplasty and the prognosis of traumatic DC following operation have a positive impact. Complications, timeliness, quality of life, and attractiveness are all variables that need to be taken into consideration. To maximize healing and enhance outcomes, a solid communication channel between the surgeon and the rehabilitation staff is crucial. Cranioplasty can be used as an important part of the rehabilitation program for patients with brain injuries because these decisions and plans are incorporated into a framework like the

International Classification of Functional Disability and Health. However, better clinical evidence and future research are needed to support the rehabilitation of patients.

7. Conclusion

For the purposes of cranioplasty's indications, scheduling, contraindications, repair materials, skull preservation, and restoration techniques, there is currently no absolute consistent standard. The advancement of science and technology, the expansion of clinical application research, and particularly the clinical promotion of synthetic materials (like polyetheretherketone skulls) with improved histocompatibility, robust anti-pressure, and more precise shaping will make it possible to perform skull defectplasty with improved materials and techniques. The clinical outcome will be improved, and surgical complications will be reduced even further.

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