

The ideal timing for revision surgery following an infected cranioplasty

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Summary

It is a challenge to define the ideal timing for revision surgery following an infected cranioplasty. Both healing of infected bone and preparedness of soft tissue must be considered. There is no gold standard regarding the timing of revision surgery and a lot of studies have contradictory findings. Many studies recommend waiting for 6–12 months to reduce reinfection risks. This case report highlights that delay in revision surgery for an infected cranioplasty is a useful and rewarding modality. It allows a longer observational timeframe to monitor for infectious episodes. Furthermore, vascular delay enhances tissue neovascularization and may therefore lead to less invasive reconstructive techniques with minimized donor site morbidities.

Key words

bone flap – cranioplasty – delay – infection – revision surgery

Van Hout G, Vissers G, Thiessen F, et al. The ideal timing for revision surgery following an infected cranioplasty. *Acta Chir Plast* 2022; 64(3–4): 135–138.

Introduction

Infection occurs in 5–33% of cranioplasties in general and in 1–12% of bone flap reconstructions [1,2]. The infection may spread and can cause meningitis, brain damage, epidural abscesses, encephalitis and soft tissue infections. A distinction can be made between early (< 4 weeks after cranioplasty) and late (\geq 4 weeks after cranioplasty) infections. Early infections are likely to be caused by skin flora contamination (especially after trauma or a bifrontal craniectomy). Late infections are more likely to be caused by hematogenous spread of bacteria not initiated by surgery [2].

Several risk factors have been described, including cranial trauma, emergency craniectomy, intraoperative contamination, long surgery (> 200 minutes), revision surgery, insufficient soft tissue coverage, interaction with non-sterile body components (e.g. paranasal sinuses), postoperative cerebrospinal fluid (CSF) leakage, dysfunction of subgaleal drainage, several previous opera-

tions, previous infection in cranioplasty, previous irradiation, diabetic patients, higher patient age in autologous bone flap, longer frozen time in autologous bone flaps, neoplasms as indication for surgery, and longer hospitalizations. The usage of autologous bone flaps following trauma causes more infections because of bone micro-contamination, swelling, and necrosis of soft tissue [1,2]

Infected cranioplasties remain a challenge for both neurosurgeons and the reconstructive surgeons. Not rarely, the surgeon is rushed to treat the defect as urgent as possible. Delay is an aspect of the treatment that is often undervalued, but that may play an important role in infection control and patient outcome. The delay phenomenon is also an important aspect in the survival of tissue. It is known that partially ischemic tissue will develop neovascularization which increases flap survival [3].

This case report shows how delay in reconstruction aids both reconstructing soft tissue defects with less invasive pro-

cedures and obtaining a well-controlled environment to avoid chronic recurrent infectious episodes.

Case description

A 28-year-old male sustained a cranio-cerebral trauma with bifrontal epidural and subdural hematomas because of a left middle meningeal artery bleeding following a high-energetic car accident. An urgent craniotomy was performed. Due to rising intracranial pressures not responding to hypertonic solutions and thiopental, a bifrontal decompressive craniectomy was performed a few weeks later. The dura was opened bilaterally and an intraparenchymatous sensor and a dural replacement patch were inserted. The defect was closed with bilateral musculocutaneous temporal flaps.

Four months later, a bifrontal cranioplasty with a customized 3D printed skull prosthesis (Xilloc) was performed and antibiotic prophylaxis was given for 24 hours. Unfortunately, the skull prosthesis had to be removed after 1 month



Fig. 1. Result after removal of the bifrontal cranioplasty with customized 3D printed skull prosthesis (Xilloc) due to infection.

due to infection. At that time, a tight skin closure was performed over the dura. The infection was treated and no further infectious episodes were observed (Fig. 1).

One year later, a tissue expander was placed at the parietal and temporal regions in preparation of a staged skull reconstruction. Following 8 months of expansion, a bifrontal cranioplasty was performed with a customized 3D printed skull prosthesis (GLACE). The tissue expander was removed and galeal

scoring allowed the expanded skin to be fully advanced over the soft tissue defect with no further need for skin grafting or flap surgery.

The patient had one year of follow-up with a sound reconstruction and no more infectious episodes (Fig. 2).

Discussion

In the treatment of an infected cranioplasty, removal of the infected bone flap and/or prosthesis and aggressive antibiotic treatment must come first. Antibiotics are given to treat the infection and should be initiated before pathogen identification. Both gram-positive and gram-negative bacteria must be covered. After obtaining antibiogram results, a specified antibiotic should be given for 6–8 weeks [2].

If a soft tissue defect is present, both local and free flaps can be used to cover the defect immediately until the revision cranioplasty with elective soft tissue coverage (Scheme 1). Immediate soft tissue coverage provides a protective layer, additional draining capacities, and may aid containing the infection [1]. Traditionally, muscle flaps have been described to be more resistant to infections than fasciocutaneous flaps, and to reduce reinfection risks, however, this is currently under debate. In this case, we used bilateral musculocutaneous tem-

poral flaps based on the superficial and medial temporal arteries for immediate coverage. Alternative options that have been described include a free latissimus dorsi muscle flap, an anterolateral thigh flap, and a Deep Inferior Epigastric artery Perforator (DIEP) flap.

Most studies say alloplastic materials are needed after a cranioplasty infection. Usage of bone flap or alloplastic materials give the same infection rates; however, bone flap reuse is not possible after bone flap infection mostly because of resorption.

Titanium, hydroxyapatite and polymethyl methacrylate are the most used alloplastic materials. Advantages include an unlimited source of reconstructive material and no additional donor sites. The main disadvantage is the associated infection risk.

On the contrary, autologous bone flaps (e.g. harvested from skull, ribs, or iliac crest) show a better resilience against infection, due to revascularization, growth and ingrowth possibilities; but have a limited amount of donor tissue. An allogeneic bone graft is a bone graft harvested from another person. There are less infection rates after allogeneic bone grafts compared to alloplastic reconstructions, because replacement by autogenous bone over time is possible [1].



Fig. 2. Result 12 months after revision bifrontal cranioplasty with a customized 3D printed skull prosthesis (GLACE). Please note the second lateral incision used for placement of the tissue expander, which was possible due to improved vascularity caused by delay of the reconstruction.

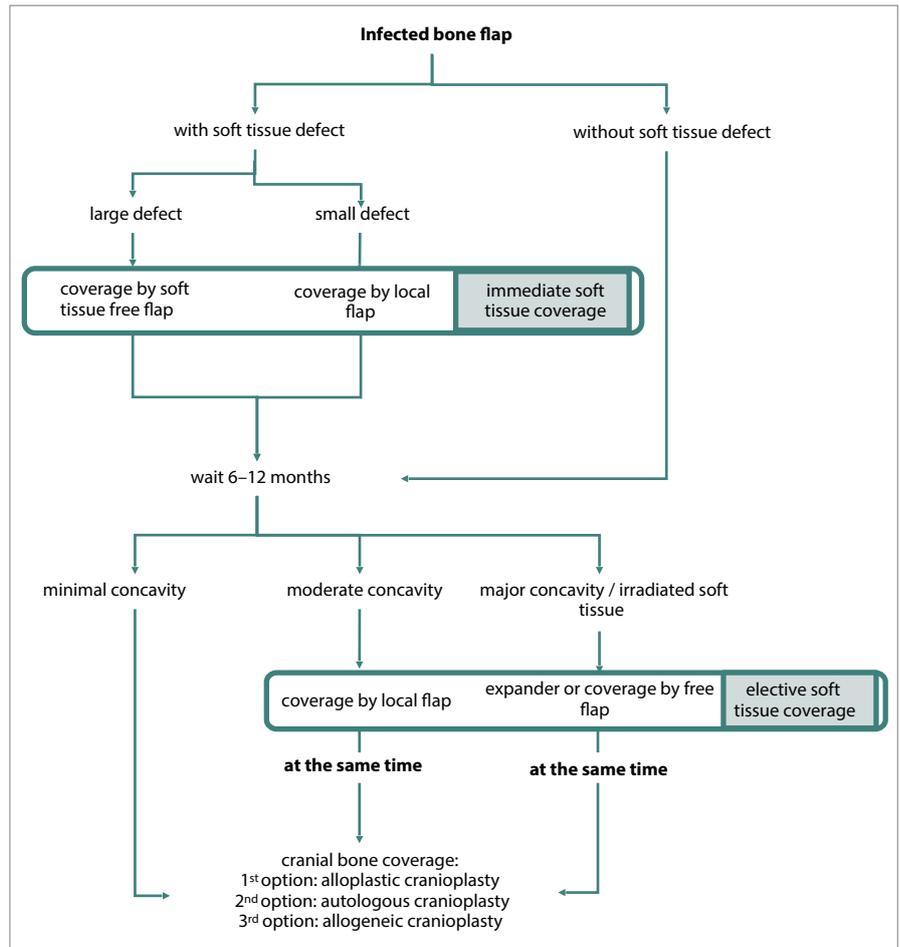
In our patient, a customized 3D printed skull prosthesis was used rather than an autologous reconstruction, because of the extension of the bifrontal cranioplasty. First, a preoperative high-resolution CT was made. Second, a virtual planning adapted the prosthesis via 3D reconstruction software to the cranial structure after removal of the bone flap.

A prosthesis was the primary choice because a bone flap reuse has a high risk for resorption. An alloplastic prosthesis can be manufactured very precisely via a 3D printer for biomaterials to aim for lower complication rates with a shorter operation time and a pleasing aesthetic outcome. The disadvantages include high cost and an impossibility to be used in case of emergency due to the period of 4–6 weeks needed to prepare the prosthesis [4].

There is no gold standard regarding the timing of revision surgery and a lot of studies have contradictory findings. Many studies recommend waiting for 6–12 months to reduce reinfection risks [2,5,6].

Some surgeons wait < 3 months after finishing antibiotic treatment, which is inadvisable because this timeframe after infection resolution is needed to rule out a new or persistent infection [2,5]. The possible advantages include faster protection of the brain and an attempt to restore normal physiology (e.g. CSF dynamics) as quickly as possible. An early cranioplasty after normalization of brain oedema may lead to better neurological outcome, and the dissection plane during revision surgery might be easier. Only in selected patients (e.g. a severe sunken flap syndrome) an immediate revision cranioplasty can be done without increased risks [2].

An immediate revision cranioplasty after a couple of weeks of performing antibiotics followed by aggressive debridement with removal of the thick layer over the dura (which might cause bacteria remain and insufficient antibi-



Scheme 1. Flowchart for the reconstruction of an infected cranial bone defect. Adapted from Baumeister et al [1]. A distinction between immediate and elective soft tissue coverage must be made, with a recommended time interval of 6–12 months in between [1].

otic penetration) might be a successful option for some patients (e.g. neuro-oncological patients). This revision cranioplasty also showed less recurrent infections, probably due to the extra preoperative regimen of broad-spectrum antibiotics and the removal of the thick layer over the dura. However, special caution is needed because the removal of this layer results in a higher risk for cerebrospinal fluid leak, brain damage and transfer of infection to other brain areas [7].

Reducing the time till revision cranioplasty from 6 to 3 months does not increase infection and other complication risks (e.g. epidural collection needing evacuation, stroke, cerebrospinal fluid leak). The advantages (ear-

lier brain protection, easier dissection plane, improved neurological outcome) are possibly higher, compared to waiting for 6 months. Furthermore, there is less temporalis foreshortening and temporal fat pad atrophy [2,6]. Also waiting > 6 months gives more social (social isolation) and work problems (fear to return to work) due to a changed physical appearance [6,7]. Some studies are not convinced of reducing the time from 6 to 3 months because they conclude that each month of delay reduces the reinfection rate by 10% [5].

Waiting for 12 months until revision surgery imposes some advantages, including a longer timeframe to monitor for recurrent infections, and improved

neovascularization of soft tissues. Vascular delay affects the soft tissue in two phases. In an early phase, sympathetic nerves will be transected, which will lead to a hyperadrenergic state due to norepinephrine. When there is little norepinephrine left, there will be a reactive vasodilation and an increased blood flow. Furthermore, recruited by ischemia, choke vessels will improve blood supply to dynamic and potential angiosomes of the flap, improving flap perfusion. Vascular delay has anti-oxidative and anti-apoptotic effects which promote rapid regeneration of affected tissues. Anti-inflammatory effects can be seen too [3].

In the late phase, neovascularization will occur in the form of both angiogenesis and vasculogenesis.

The rich vascularity allows a safer access when flaps need to be raised to re-enter the skull. There is less fat necrosis and partial flap loss. Another advantage is that the increased time interval can be used for tissue expansion. This might waive the need for more complex (e.g. free flap) reconstructions and their associated morbidities. Especially in frail patients this might improve patient outcome.

In this case, a 12-month delay was respected before inserting a tissue expander, and a 20-month delay before performing the final reconstruction. The long infection-free interval almost guarantees no further infectious episodes. A sound reconstruction with bilateral musculocutaneous temporal flaps protected the brain in the meantime. The delay in combination with the tissue expansion allowed an increase in soft tissue volume that could be used for final reconstruction. Of course, the patient must be counselled appropriately because of the change in physical appearance during the expansion period.

The increased reliability of the dermal blood supply enabled galeal scoring to advance the soft tissues even further, making other reconstructive techniques redundant. Although other authors have advocated a shorter time interval to reconstruction because of easier dissection planes, we did not experience difficulties during dissection, as the dura has become rigid following the long-standing process of scar formation and calcification.

Conclusion

Delay in revision surgery for an infected cranioplasty is a useful and rewarding modality. It allows a longer observational timeframe to monitor for infectious episodes. Although the delay phenomenon is used less nowadays with the arrival of new techniques (e.g. microsurgical free tissue transfers), vascular delay remains a recommended technique when a reconstruction with local tissue and no additional donor sites is preferred. It enables the surgeon to apply less invasive reconstructive techniques with fewer donor site comorbidities and excellent patient outcomes.

Conflict of interest: The authors declare no conflict of interest.

Funding: No funding was received from any source with regards to the writing of this article.

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Gino Vissers, MD – literature search, drafting the manuscript
Filip Thiessen, MD, PhD – revision of the manuscript, study supervision
Thierry Tondu, MD, PhD – revision of the manuscript, study supervision

Ethics approval: Not applicable

Consent for publication: Patient's consent was given.

References

1. Baumeister S., Peek A., Friedman A., et al. Management of postneurosurgical bone flap loss caused by infection. *Plast Reconstr Surg.* 2008, 122(6): 195e–208e.
2. Frassanito P., Frascchetti F., Bianchi F., et al. Management and prevention of cranioplasty infections. *Childs Nerv Syst.* 2019, 35(9): 1499–1506.
3. Hamilton K., Wolfswinkel EM., Weathers WM., et al. The delay phenomenon: a compilation of knowledge across specialties. *Craniomaxillofac Trauma Reconstr.* 2014, 7(2): 112–118.
4. da Silva Junior EB., de Aragao AH., de Paula Loureiro M., et al. Cranioplasty with three-dimensional customised mould for polymethylmethacrylate implant: a series of 16 consecutive patients with cost-effectiveness consideration. *3D Print Med.* 2021, 7(1): 4.
5. Kwiecien GJ., Aliotta R., Bassiri Gharb B., et al. The timing of alloplastic cranioplasty in the setting of previous osteomyelitis. *Plast Reconstr Surg.* 2019, 143(3): 853–861.
6. Lopez J., Zhong SS., Sankey EW., et al. Time interval reduction for delayed implant-based cranioplasty reconstruction in the setting of previous bone flap osteomyelitis. *Plast Reconstr Surg.* 2016, 137(2): 394e–404e.
7. Di Rienzo A., Colasanti R., Gladi M., et al. Timing of cranial reconstruction after cranioplasty infections: are we ready for a re-thinking? A comparative analysis of delayed versus immediate cranioplasty after debridement in a series of 48 patients. *Neurosurg Rev.* 2021, 44(3): 1523–1532.

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Submitted: 19. 3. 2022

Accepted: 7. 11. 2022