Neurol Med Chir (Tokyo) 53, 590–595, 2013

Autologous Vascularized Dural Wrapping for Temporalis Muscle Preservation and Reconstruction After Decompressive Craniectomy: Report of Twenty-five Cases

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Abstract

Temporalis muscle reconstruction is a necessary step during frontotemporal cranioplasty ensuing decompressive craniectomy (DC). During this procedure, scarring between the temporalis muscle and the dural layer may lead to complicated muscle dissection, which carries an increased risk of dura and muscle damage. At time of DC, temporalis muscle wrapping by an autologous vascularized dural flap can later on facilitate dissection and rebuilding during the subsequent cranioplasty. In a span of 2 years, we performed 57 DCs for different etiologies. In 30 cases, the temporalis muscle was isolated by wrapping its inner surface using the autologous dura. At cranioplasty, the muscle could easily be dissected from the duraplasty. The inner surface was easily freed from the autologous dural envelope, and reconstruction achieved in an almost physiological position. Follow-up examinations were held at regular intervals to disclose signs of temporalis muscle depletion. Twenty-five patients survived to undergo cranioplasty. Muscle dissection could always be performed with no injury to the dural layer. No complications related to temporalis muscle wrapping were recorded. Face asymmetry developed in four cases but it was always with bone resorption. None of the patients with a good neurological recovery reported functional or aesthetic complaints. In our experience, temporalis muscle wrapping by vascularized autologous dura proved to be effective in preserving its bulk and reducing its adhesion to duraplasty, thereby improving muscle dissection and reconstruction during cranioplasty. Functional and aesthetic results were satisfying, except in cases of bone resorption.

Key words: decompressive craniectomy, cranioplasty, temporalis muscle, duraplasty, bone resorption

Introduction

In the past 15 years, the increased number of decompressive craniectomies (DCs) performed all over the world has led to a proportional increase of reconstructive surgeries for cranioplasty,[1,3–5] during which all tissue components need to be reconstructed together in the best anatomical and functional way. Unfortunately, though the removed bone flap may be adequately reinserted using titanium miniplates, realignment of the temporalis muscle poses a separate problem. Considering the emergent situations in which DCs are performed, it is not uncommon to inflict irreparable tissue damage when generating the decompressive flap. The temporalis muscle is one of the structures at higher risk of injury in these cases, whose viability primarily relies both on the preservation of vascularization coming from the middle temporal artery (MTA) and of preservation of the deeper layer of the temporalis fascia, (the lamina profunda), which is immediately adherent to the temporal bone. During decompression it is a frequent habit to use monopolar coagulation to detach the temporalis muscle from its bony insertions and to reflect it over the cutaneous flap. This maneuver has a great impact on muscle structure, causing retraction of fibers and death due to the excessive heat developed locally. Furthermore, it may compromise the vascular supply from both the anterior and the posterior deep temporal arteries (MTA branches). By the use of monopolar coagulation a severe damage is also inflicted to the inner temporalis fascia. Moreover, distant heat transmission through

Received January 25, 2013; Accepted April 8, 2013

muscle bulk might even damage the masseteric and middle temporal nerves, and branches of the anterior division of the mandibular nerve. Finally, at the end of the procedure, a special care for muscle preservation may be lacking and the muscle is simply left lying over the durotomy, facilitating scarring and retraction. Adhesions can lead to difficulties with muscle reconstruction at cranioplasty, both from a functional and aesthetic point of view, creating facial asymmetry at the temple and changing the patient's appearance. Though some technical solutions have been proposed to reduce adhesions and improve muscle rebuilding, temporalis muscle reconstruction remains an underestimated problem and deserves better preservation strategies.[2,6–8] Here, we report our experience with a wrapping technique of the temporalis muscle using a vascularized dural flap prepared during DCs. This technique is aimed at improving temporalis muscle preservation as well as its dissection and at optimizing reconstruction during cranioplasty, to obtain good functional and aesthetic results.

Materials and Methods

From December 2008 to December 2010, 57 DCs were performed at our Department. Hemicraniectomy was needed for severe head trauma in 35 cases, subarachnoid hemorrhage in 7, brain ischemia in 4, intracerebral hemorrhage in 7, infection in 3, and hemorrhagic tumor in 1. Balancing the level of urgency/emergency of surgery with the need of muscle preservation for further reconstruction, we were able to perform a meticulous isolation of the temporalis muscle in 30 of those 57 cases. A blunt subperiosteal dissection was performed in every case to preserve muscle viability, avoiding the use of monopolar coagulation to minimize thermal damage and preserve the myoneural unit. Muscle incision was performed by a 21-mm scalpel blade starting from the posterior–superior border of the muscle, 1 cm below the superior temporal line, so as to leave a well-represented muscular cuff of 1–1.5 cm width, to allow later muscle resuspension. It continued anterior-superiorly toward the frontal supraorbital area until the zygomatic process of the frontal bone was exposed and inferiorly along the posterior border of the muscle to expose the zygomatic root (Fig. 1A). At this point a periosteal elevator was used to detach the muscle and its inner fascia as a whole, and then the muscle was retracted by hooks to fully expose the temporal bone. Usually only a single burr hole was placed 2 cm behind the posterior–superior border of the temporalis muscle (Fig. 1B). The inferior contour of the temporal squama and the posterior border of the zygomatic bone were drilled away by a small, 3.4 mm, nondiamond burr, in order to obtain one large bone flap. By this way, a full decompression of the temporal pole (Fig. 1C) was obtained avoiding the use of rongeurs which introduce a sizeable gap at the inferior margin of the bone flap.

The dura was opened by a semilunar incision and reflected over the temporalis muscle (Fig. 2A, Drawing 1A). After osteo-dural decompression was complete, allograft duraplasty was achieved using two sheets (6 × 14 cm wide) of Tutopatch™ (Tutogen Medical, Neunkirchen a. Br., Germany). The outer aspect of the native dura was aligned with the inner surface of the temporalis muscle (Drawing 1B) and sutured to its external fascia on borders and base (Fig. 2B, Drawing 1C). This was then reflected toward the allograft duraplasty (Fig. 2C) and three to four stitches were positioned circumferentially to fix it to the dural layer. When putting such stitches, the enveloped muscle was kept well extended, to better preserve its natural

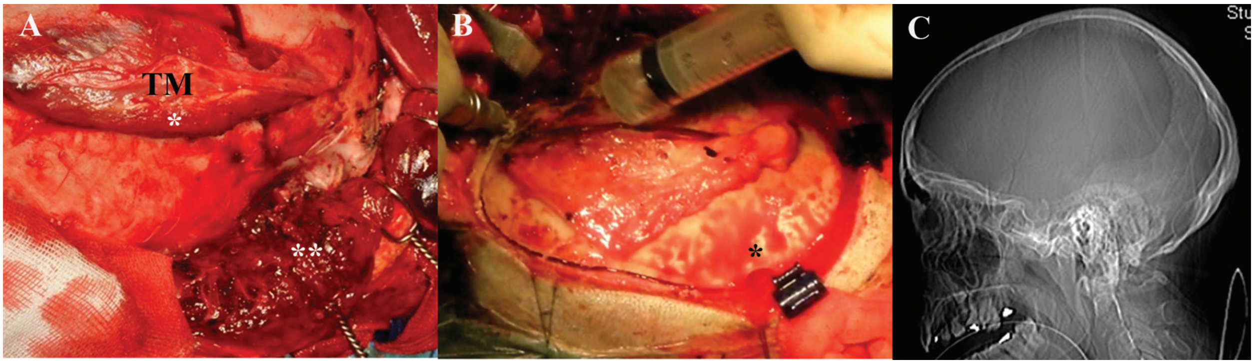


Fig. 1 A: Dissection of the temporalis muscle leaving a muscular cuff over the frontal bone (*white asterisk*) and reflecting the larger part of the muscle over the skin flap (*double white asterisk*). B: Craniotomy performed by a single burr hole made in the parietal region (*black asterisk*). C: Scout view computed tomography scan showing the craniotomy reaching the middle cranial base. TM: temporalis muscle.

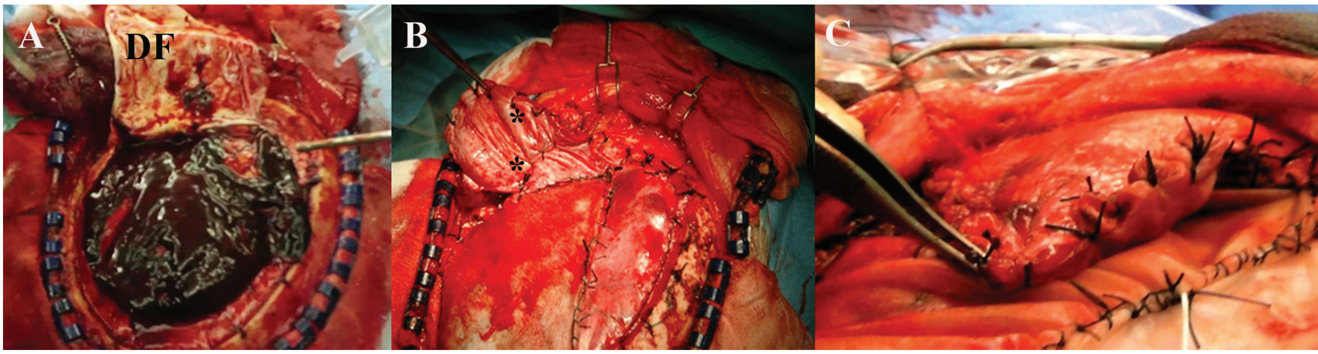
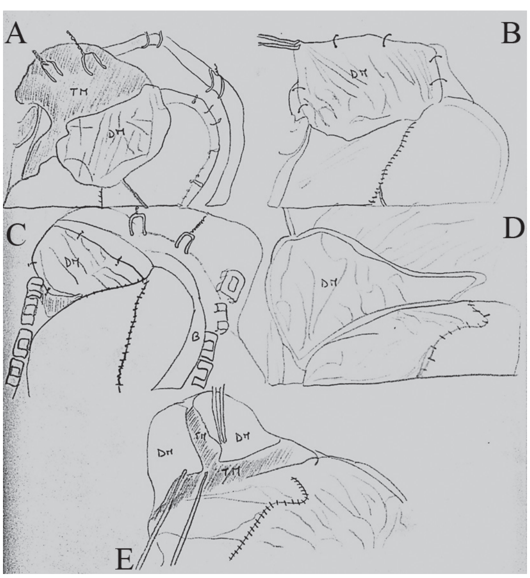


Fig. 2 **A: Frontotemporo–parietal dural flap reflected over the temporalis muscle in a patient undergoing decompressive craniectomy (DC) for a left acute subdural hematoma. B: Dural flap conjoined to the inner surface of the muscle by suturing its base and its external fascia (*black asterisks*). C: Wrapped muscle reflected over the expansive duraplasty. DC: decompressive craniectomy, DF: dural flap.**



Drawing 1 **A: After craniectomy is completed, the dura mater (DM) is opened creating a semilunar flap for covering the temporalis muscle (TM). B: The dural flap is aligned with the muscle and reflected over it. C: The dural flap is sutured to the inner surface (base and borders) of the TM. D: At cranioplasty, the TM is easily identified and isolated from the rebuilt DM. E: The dural envelope is sectioned along the muscle base and on the midline, to allow free movement of the muscle itself needed to put it back in its physiological position.**

shape and to counteract the physiological downward displacement secondary to positional changes of the head and to the progressive loosening of the sutures. At the time of cranioplasty, the inner surface of the temporalis muscle could thus easily be identified and effortlessly detached from the duraplasty (Fig. 3A, Drawing 1D). After reflecting the muscle over the cutaneous flap, the inner surface of the muscle appeared encased by the autologous dural envelope, whose basis continued uninterrupted with the dura covering the middle and anterior cranial base. At craniectomy the dural flap was sutured to the temporalis muscle, so that the basal contour of the temporal bone border remained enclosed between the two layers. At cranioplasty the borders of the dural flap were initially cut to free muscle fibers, so as to allow a satisfying mobilization and to expose the bone margin of the middle cranial fossa (Fig. 3B, Drawing 1E). The external aspect of the muscle, adherent to the flap, was mobilized from the subcutaneous tissue by blunt dissection, thus improving coverage of the frontal area, without any stretching needed to overcome contractions. Once the bone flap was repositioned and secured in place, the temporalis muscle was completely released from the dural envelope and it was sutured back to the cuff over the removed bone (Fig. 3C).

All patients were clinically evaluated every 6 months after cranioplasty. The shortest follow-up time was 18 months, the longest being 42 months. Anterior-posterior (AP) and lateral digital pictures were obtained at every examination to reveal eventual changes and side differences of the patient's profile.

Results

In 30 out of the 57 patients treated by DC, muscle wrapping by autologous dura was made possible by nonemergent preoperative conditions. Mean age in this group was 39 years (the youngest patient was a 16-year-old male, the oldest a 67-year-old female). At admission, 9 patients were in GCS Class 3–5, 15 in GCS Class 6–8, and 6 in GCS Class 9–11. Three of these patients died within 72 hours from DC because of massive brain swelling. Two more patients died, respectively, within the first month and after

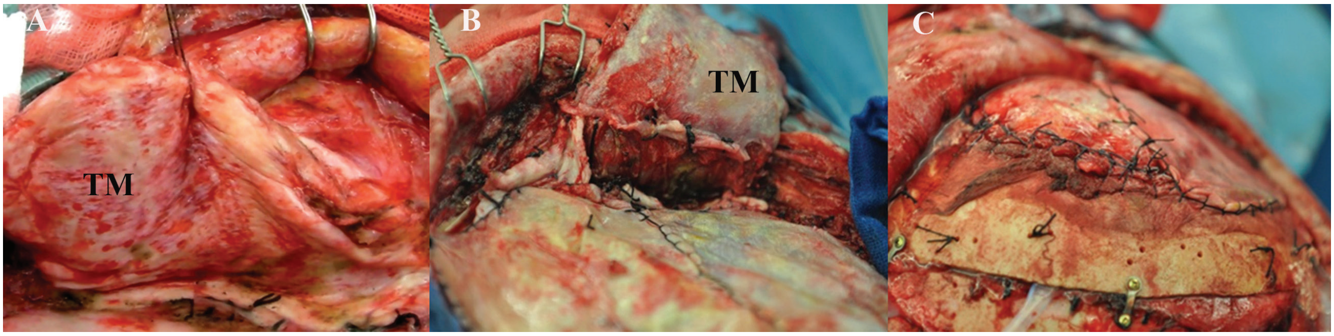


Fig. 3 A: Wrapped temporalis muscle is immediately identified and easily detached from duraplasty. B: Muscle base is freed by its dural envelope gaining access to the outer border of middle cranial base for an optimal bone resynthesis. C: After complete removal of the dural envelope, temporalis muscle is sutured back in place. TM: temporalis muscle.

49 days because of sepsis from multidrug-resistant bacteria (*Acinetobacter Baumannii* one case, *Klebsiella pneumoniae* one case). In the remaining 25 patients, admission neurological evaluation before cranioplasty showed: 3 patients in persistent vegetative status (GOS 2), 2 severely disabled (GOS 3), 10 with moderate disability (GOS 4), and 10 with full neurological recovery (GOS 5). Mean time from DC to cranioplasty was 53 days (from a minimum of 35 days to a maximum of 121 days). In patients undergoing hemicranietomy without muscle coverage, only one patient developed a bone flap infection, requiring resurgery. In three cases, bone resorption was observed within 18 months from the reconstructive procedure. Temporalis muscle isolation from the surrounding tissues was always uncomfortable and muscle was either underpreserved or retracted. The anterior profile of the muscle was sutured back to the subcutaneous tissue of the frontal region and, every time it was possible, to the cuff left over the removed bone. However, a gap always remained between the muscle bulk and the cuff. In 10 patients, cosmetic results were considered unsatisfying. In a time from 5 to 15 months, muscle atrophy creating a significant facial asymmetry was observed in five cases. In five more patients muscle retracted over the zygoma, with two patients expressing a requirement for a new surgical procedure for muscle mobilization and forward displacement, to fill the gap.

In patients undergoing autologous dural wrapping at the time of cranioplasty, identification of the inner surface of the temporalis muscle and its separation from the duraplasty layer was never complicated, regardless of the time interval since DC. Temporalis muscle turned out to be well preserved and reapproximation to the cuff over the removed bone could be successfully achieved in 19 patients. In the remaining six cases a partial gap (< 1 cm) remained among the two portions, but it did not affect patient physiognomy. The first clinical examination at 6 months after cranioplasty was considered as the most reliable standpoint to assess the final neurological outcome, with none of the patients having significant improvement after this time window in our series. Cranioplasty had no impact on the GOS of the three patients in persistent vegetative status. One of the three subjects affected by severe disability recovered to a moderate disability, five patients changed from moderate disability (total number: 6) to full neurological recovery (total number: 15). During follow-up examinations, one patient complained of pain over the temporal area, (treated by nonsteroidal anti-inflammatory drugs), four patients developed a delayed face asymmetry due to bone resorption, and two patients had a wound infection immediately after cranioplasty, successfully treated by cutaneous flap revision and antibiotics. No functional and aesthetic complication related to temporalis muscle depletion or inadequate reconstruction was noticed.

Discussion

The importance of saving temporalis muscle in patients undergoing DC has not been adequately addressed in the literature and most authors consider it only a minor aesthetic problem. This notion probably comes from the emergency situations in which DC is commonly performed with the need to achieve and focus on rapid brain decompression rather than temporalis muscle preservation. Nonetheless, a considerable percentage, ranging from 30% to 40%, of surviving DC patients will have a satisfying neurological outcome (from full neurological recovery to moderate disability, GOS 4–5), especially younger individuals (30–50 years).[1,5] In these patients, temporalis muscle wasting or inadequate reconstruction during cranioplasty can lead to profound functional and aesthetic problems. In our experience, muscle tissue health at the time of cranioplasty seems to be related to subjects' neurological conditions. Patients in persistent vegetative status or with severe disability are frequently affected by comorbidities that lengthen the time interval between DC and cranioplasty, thus increasing scarring and retraction of the temporalis muscle. Moreover, many of these patients are frequently fed via percutaneous endoscopic gastrostomy (PEG), which leads to hypotrophy of masticatory muscles. On the other side, in patients with good neurological status, time from decompression to cranioplasty is usually short and temporalis muscle is well preserved with moderate scarring only.

Taking into account the difficulties of predicting which patients will have a good neurological result, we decided to perform temporalis muscle wrapping in all cases of DC, and introduced this procedure after completing brain decompression, thus not compromising on neurological outcome. The minimal gap between the bone flap and the borders of craniectomy, facilitating reossification, was a strategic companion to muscle rebuilding, with it preventing the formation of a nonphysiological bone window into which the muscle could sink deforming the face contour (Fig. 4A, B). The decision to generate a muscle cull at the superior

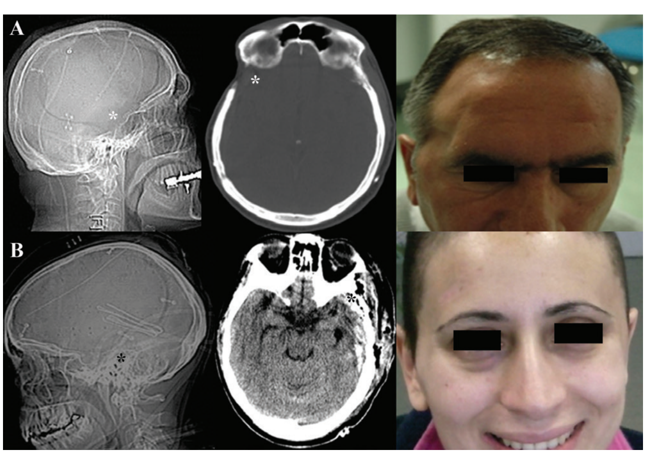


Fig. 4 A: Decompressive craniectomy (DC) performed by the use of rongeurs to remove the basal temporal bone. At cranioplasty, the bone loss of substance in the basal temporal area caused a large gap between the bone flap and the craniectomy's borders (*white asterisk*) inducing a delayed temporalis muscle deepening with face asymmetry. B: One-piece DC performed with the use of a small nondiamond burr to drill the inferior contour of the temporal squama. At cranioplasty, there was no gap between the removed bone and the skull (*black asterisk*). No face asymmetry developed.

temporal line always allowed a better reapproximation of muscle stumps.

Only few papers have thus far dealt with the problem of temporalis muscle preservation in DC. In 2003, Kawaguchi and coworkers[6] reported their experience on the use of expanded polytetrafluoroethylene (ePTFE) membranes placed but not sutured between the temporalis muscle and the duraplasty leaving a portion directly below the skin incision to allow easy visualization. Cranioplasty took place 38–126 days after decompression and no adhesions were observed between ePTFE membranes and the surrounding tissues, including the temporalis muscle. No complications were reported and the author concluded that the use of these membranes improved the ease and safety of cranioplasty, decreased the operating times and blood loss, and avoided injury to the muscle, dura, and the underlying brain. These encouraging results were partially disavowed by the subsequent study of Nakagawa et al.[9] in which a 14.3% rate of infection was reported. Good results in terms of reduced operating times, improved tissue dissection, and reduced blood loss were also reported by Lee et al. in 2007.[7] The following year, Missori et al.[8] reported on the use of the so-called double dural patch. In these cases the first patch was used for the expansile duraplasty, whereas the second was put between the duraplasty and the inner aspect of the temporalis muscle. The dural substitute in this series was Tutopatch™ and described results were encouraging but were based on a relatively small number of cases (11 patients). In 2010, Bulters and Belli[2] described the use of silicone sheets to prevent adhesions. In all of these techniques employed, the materials used for duraplasty and muscle preservation were avascular. This might lead to the creation of an avascular area, more prone to infections.

Our technique employs the use of a vascularized flap of autologous dura. The time needed for preparing the flap does not significantly prolong the surgical procedure adding only a really short time (from 10 to 15 minutes) needed to affix the dural layer to the muscle. In our series, temporalis muscle wrapping by autologous dural flap always allowed the surgeon to promptly recognize the difference between the artificial dura used for duraplasty (Tutoplast™) and the patient's dura covering the muscle, making its dissection easier. Furthermore, in all of the cases in our series, separating the muscle from the dural envelope always required no more than 2–3 minutes, either when a short or a long time had passed between craniectomy and cranioplasty. We believe that flap vascularization minimizes the risks of infection and increases the potential for muscle preservation due to dural vessels in direct contact with the inner surface of the muscle. However, we did not obtain histological samples for microscopic analysis to support this last supposition. Another advantage derived from suturing the patient's dura to the muscle was immediate hemostasis at the inner surface of the muscle, eliminating the need for time spent coagulating, which might cause thermal damage and result in loss of fibers.

Oikawa et al.[10] was the first to include inappropriate muscle tension between the factors contributing to muscle atrophy after pterional craniotomy. We too preferred not to leave the muscle lying freely above the duraplasty, because in our experience it led to severe fiber retraction and muscle compaction. With the aim to preserve muscle anatomy as much as possible we chose to suture the autologous dural envelope to the duraplasty at 3–4 points, so as to keep the muscle stretched. Considering that most of the patients will not be chewing for at least 2–3 weeks after DC (usually because of prolonged orotracheal intubation and sedation for neuroprotection), such sutures help to keep the muscle in the correct position. At the time of cranioplasty, this will make the muscle itself more manageable and easier to reaffix in the physiological position.

The autologous dural flap for muscle wrapping provides another, indirect advantage. The lower the inferior margin of the craniectomy is on the temporal bone, the more frequently it leads to a oozing from the detached dura surrounding the middle meningeal artery. Dural reflection and its sewing to the base of the temporalis muscle solved this problem simply in all of our patients.

In the vast majority of our cases, temporalis muscle reapproximation was achieved completely leading to good restoration, with no significant functional or aesthetic complaints. We feel that this is an important point, because patients with temporalis muscle deformity may experience a reduced sense of self-esteem, difficulties in entertaining social relationships, problems in getting back to work, and foster a tendency of isolation and, occasionally, obsessive thinking. This may lead to the pursuit of further surgical solutions, which at best creates further frustration, but may well expose the patients to further unnecessary procedures with risk of infections of the cranioplasty site and potentially devastating consequences.

Conflicts of Interest Disclosure

None of the authors has any financial or personal relationship with people or organizations that could inappropriately influence their work. No actual or potential conflicts of interest exist with regard to the above submitted manuscript on behalf of anyone of the authors.

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