Extended supramaximal decompressive craniectomy with temporalis muscle resection in traumatic brain injury

Craneotomía descompresiva supramaximal extendida con resección del músculo temporal en trauma cerebral

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Resumen

Introducción: Se describe una técnica quirúrgica en casos de trauma cerebral donde el músculo temporal causa un efecto de vector sobre las estructuras cerebrales y se presenta una serie de 8 casos característicos. **Material y Métodos:** Se realizó un análisis retrospectivo en 8 pacientes que se sometieron a craniectomía descompresiva, en quienes estudios tomográficos de control revelaron infiltración sanguínea e inflamación del músculo temporal con compresión sobre las estructuras cerebrales. Se realizó una segunda intervención en la que se resecó el músculo temporal, presentando una mejora en el pronóstico funcional. **Resultados:** Tres pacientes murieron a causa del trauma inicial y de la hipertensión intracraneal refractaria al tratamiento médico, cinco sobrevivieron con discapacidad moderada de por vida a los 3 meses después de la cirugía. **Discusión:** La craniectomía descompresiva es un procedimiento estándar que involucra la remoción de un gran colgajo óseo frontotemporoparietal. Sin embargo, la descompresión externa basada en la apertura de la cavidad craneal puede estar limitada por estructuras extradurales, particularmente el músculo temporal y su fascia. La descripción técnica original ha recibido algunas modificaciones, que ciertos grupos han sugerido. Entre estas modificaciones, se puede mencionar la inclusión de la resección del músculo temporal y su fascia. **Conclusiones:** La craniectomía supramaximal con la remoción total o parcial del músculo temporal puede ser útil en casos seleccionados y se requieren un mayor número de estudios para determinar si afecta de manera positiva o negativa el pronóstico en estos pacientes.

Palabras clave: Trauma cerebral severo, craniectomía descompresiva, músculo temporal, hipertensión intracraneal, craniectomía supramaximal.

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Abstract

Introduction: Describe a surgical technique in cases of traumatic brain injury where the temporalis muscle causes a vector effect on brain structures and present a series of 8 characteristic cases. **Material and Methods:** A retrospective analysis was carried out on 8 patients who underwent decompressive craniectomy, in whom control tomographic studies revealed blood infiltration and inflammation of the temporalis muscle with compression on brain structures. A second intervention was performed in which the temporalis muscle was resected, presenting an improvement in the functional prognosis. **Results:** Three died from the initial trauma and intracranial hypertension refractory to medical management, five survived with moderate disability for life 3 months after surgery. **Discussion:** Decompressive craniectomy is a standard procedure involving the remotion of a sizeable frontotemporoparietal bone flap. However, external decompression based on the opening of the cranial vault can be limited by extradural structures, particularly the temporal muscle and its fascia. The original technical description has received some modifications, which some groups have suggested. Among these modifications, we can mention the addition of resection of the temporal muscle and its fascia. **Conclusions:** Supramaximal craniectomy with total or partial removal of the temporalis muscle may be useful in selected cases and a larger number of studies are required to determine whether it positively or negatively affects the prognosis in these patients.

Key words: Severe brain trauma, decompressive craniectomy, temporalis muscle, intracranial hypertension, supramaximal craniectomy.

Introduction

In severe traumatic brain injuries (TBI), quick and adequate treatment is mandatory, which in most cases will consist of medical treatment and, in some cases, will require surgery. Surgical procedures such as decompressive craniectomies are necessary in those cases; this involves the removal of a sizeable frontotemporoparietal bone flap (no less than 12x15 cm or 15 cm in diameter) along with durotomy with or without extensive duroplasty to maximize brain expansion in cases of intracranial hypertension refractory to medical treatment[7].

The temporal muscle is fan-shaped and consists of a central portion and three bundles (anteromedial, anterolateral, and mediolateral). It begins from the superior temporal line and goes downward to insert distal in the coronoid process of the mandible; It is covered by a thick temporal fascia that, in turn, divides into superficial and deep layers approximately 2 cm above the zygomatic arch. The superficial temporal fat pad is located between the external and deep fascia. The average width of the deep belly is 14.5 mm on the left side and 14.4 mm on the right side. Its average length is 52.7 mm on the left and 52.4 mm on the right. The deep temporal artery irrigates the muscle by anterior and posterior branches. The anterior division of the mandibular nerve innervates the temporal muscle. This nerve usually gives rise to three components: masseteric nerve (most posterior), deep temporal nerve (middle) and buccal nerve (most anterior). The function of the temporal muscle is to raise and retract the jaw during chewing[14] (Figure 1).

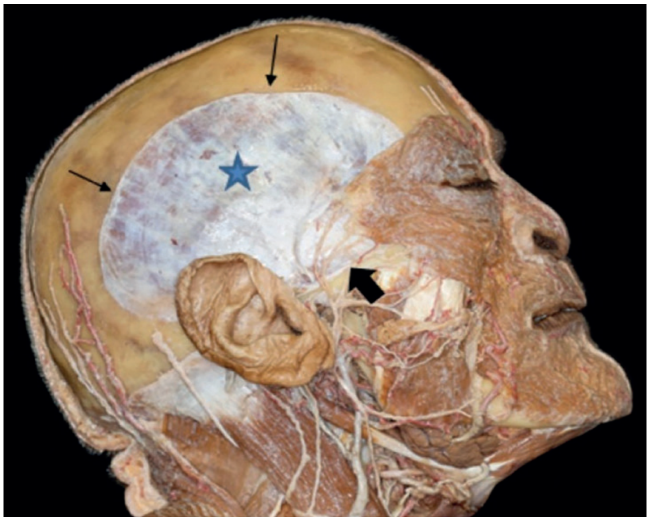

Figure 1. Temporal muscle anatomy. Cadaveric specimen showing the temporal muscle covered by the fascia (blue star), superior temporal insertion (thin arrows), and zygomatic arch (thick arrow).

Materials and Methods

A retrospective analysis of eight patients (seven men and one woman) with TBI was performed over one year from January to December 2019 at Centro Médico "Lic. Adolfo López Mateos"; informed consent and approval of the ethics committee was obtained.

These cases presented with edema and mass effect by the temporal muscle after a decompressive craniectomy. Of the eight patients, seven had blunt TBI, and one had penetrating trauma by a firearm projectile. Age ranged between 19 and 47 years (average 30.3 years). Five patients had mild TBI (Glasgow coma scale [GCS] score ranging between 9 and 11 points), and three had severe TBI (GCS score between 7 and 8 points) (Table 1) without associated comorbidities.

Six presented direct contusion to the temporal muscle, and two cases were attributed to the use of monopolar coagulation at dissection during decompressive craniectomy. The temporal muscle volume was measured after the decom-

Table 1. Cases series of Extended Supramaximal Decompressive Craniectomy with Temporalis Muscle Resection in Traumatic Brain Injury								
Sex/age	**Mechanism**	**Findings at first surgery**	**Cause of temporalmuscle injury**	**Temporal muscle volumen (cc)**	**Midline shift**	**Temporal muscle and neurological repercussion**	**Temporal muscle management**	**Follow up**
M/47 Y	TBI	GCS 10, left uncal herniation	Monopolar use in DC	96 cc	6 mm	GCS 8, left uncal herniation	TMPR	Dead
M/25 Y	TBI	GCS 9, left uncal hemiparesis	Direct contusion	108 cc	8 mm	NA	TMTR	Alive at 1 year follow up
M/19 Y	PGTBI	GCS 8	Direct contusion	110 cc	8 mm	NA	TMTR	Dead
F/20 Y	TBI	GCS 10	Direct contusion	109 cc	8 mm	NA	TMTR	Alive at 10 months follow up
M/37 Y	TBI	GCS 11	Direct contusion	108 cc	7 mm	GCS 9, subfalcine herniation	TMTR	Alive at 10 months follow up
M/35 Y	TBI	GCS 7	Direct contusion	115 cc	9 mm	Uncal Herniation	TMPR	Dead
M/24 Y	TBI	GCS 7	Direct contusion	113 cc	9 mm	Subfalcine herniation	TMTR	Alive at 3 months follow up
M/36 Y	TBI	GCS 11	Monopolar use in DC	106 cc	7 mm	Uncal herniation	TMTR	Alive at 3 months follow up
DC: Decompressive Craniectomy; GCS: Glasgow Coma Score; PGTBI: Penetrating Gunshot Traumatic Brain Injury; TMPR: Temporal Muscle Partial Resection; TMTR: Temporal Muscle Total Resection; TBI: Traumatic Brain Injury.								

pressive craniectomy in the postoperative simple CT scan with the ellipsoid formula (A + B + C/2). The temporal muscle volume ranges were between 96 and 115 cc, and the midline shift ranged from 6 to 9 mm, with neurological repercussions through uncal herniation in three patients and subfalcine herniation in two patients.

According to the tomographic findings (temporal muscle volume and midline deviation) and neurological compromise, a second surgical intervention was performed that included partial resection of the temporal muscle in two cases and total resection in six patients. The two patients who underwent partial resection of the temporal muscle died, and of the complete resection cases, only one died. However, in the latter case, death was attributed to the shock wave of the firearm projectile, which damaged the brain structures. The remaining five cases of total resection of the temporal muscle showed an improved neurological state and survival during a six-month follow-up. We consider that the presence of the temporal muscle mass effect is due to traumatic brain injury per se, transsurgical management of the muscle, or even a combination of both.

In this paper, we report two representative cases, showing the clinical and tomographic improvement represented by the performance of a supramaximal decompressive craniectomy that involves total resection of the temporal muscle in patients with malignant cerebral edema.

Results

Case 1

A 37-year-old male presented with a direct contusion on the left temporal region due to a fall from a vehicle in motion, causing TBI. At admission, the GCS score was 11 points (E4 V2 M5), and motor aphasia. A simple head CT scan showed an acute left frontotemporoparietal subdural hematoma, 27 cc left frontal contusion, traumatic subarachnoid hemorrhage, cerebral edema, and a 7 mm midline shift. A left frontotemporoparietal decompressive craniectomy with preservation of the temporal muscle was done. During the postoperative period, the patient showed no neurological improvement, with 9 points on the GCS (E3 V1 M5), and the postoperative CT scan showed an image suggestive of acute postsurgical epidural hematoma, which conditioned mass effect, midline shift of 6 mm and compressive effect of the brain with subfalcine and uncal herniation (Figure 2).

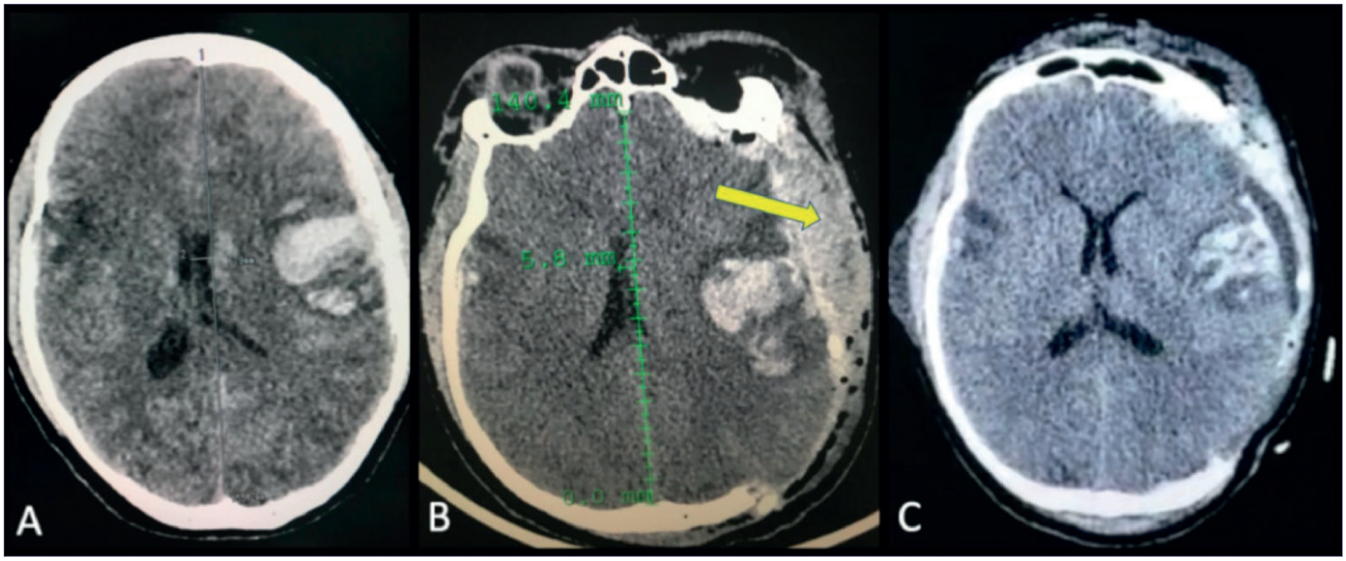

Figure 2. Representative CT scan. **A)** Sequential computed tomography (CT) scans CT scan upon admission; **B)** CT scan after performing a decompressive craniectomy showing the temporal muscle (yellow arrow), conditioning mass effect, which was confused with acute epidural hematoma, displacing midline structures; **C)** CT scan after performing total resection of the temporal muscle showing the regression of the midline structures and resolution of brain herniation.

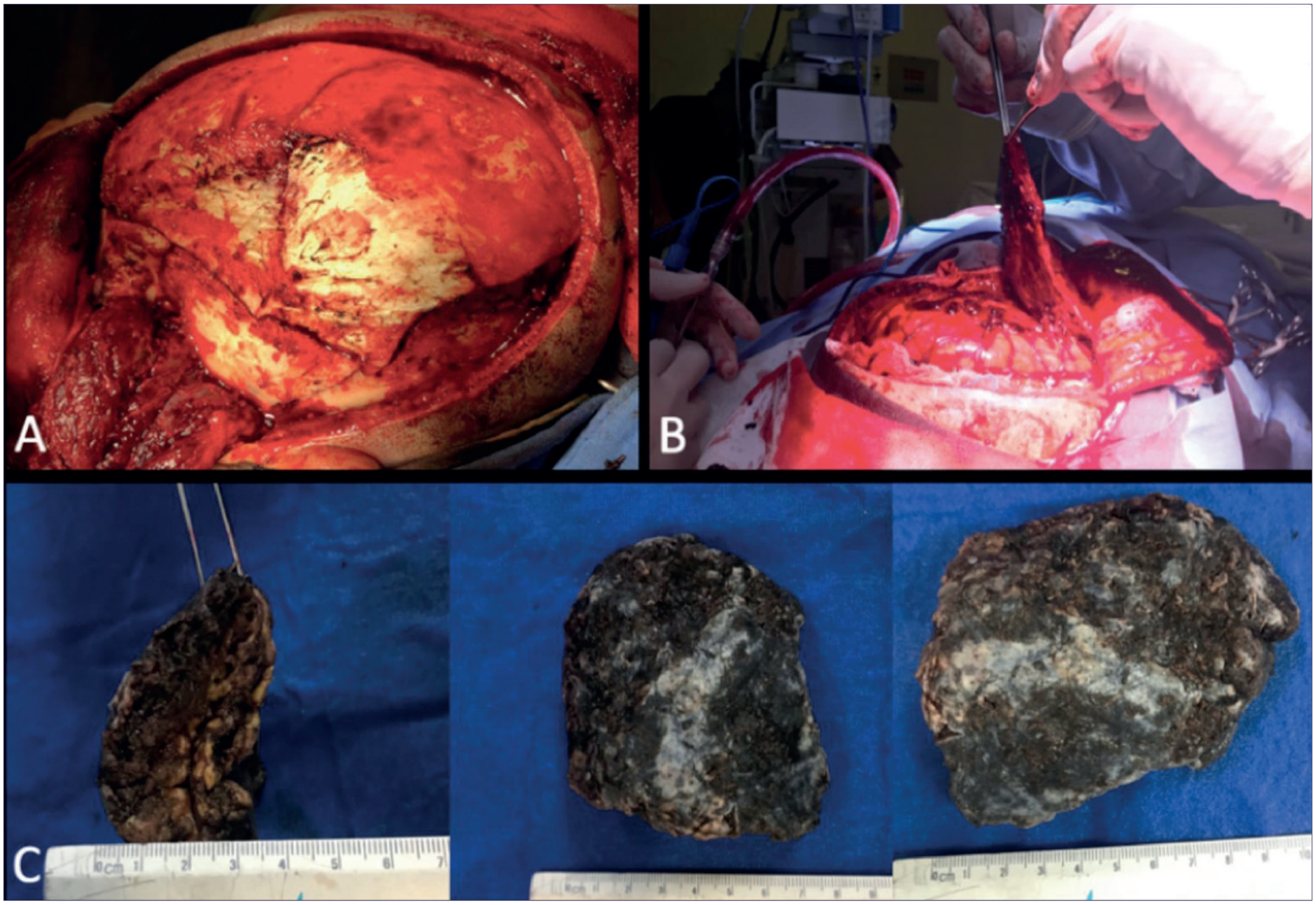

Figure 3. Intraoperative photographs. **A)** Photograph of the first surgery showing a cranial fracture (thin dark arrows) and blunt temporal muscle (thick arrow); **B)** Photograph of the second surgery showing external brain herniation (stars) and thickened temporal muscle (thick arrow); **C)** Images of resected temporal muscle with respective measurements of its thickness, width, and length 30 × 80 × 90 mm.

A second surgery was performed; however, as a trans-surgical finding, the epidural hematoma was ruled out, finding hematic infiltration and an increase in the volume of the temporal muscle, which was the cause of the mass effect (Figure 3).

Given these findings, total resection of the temporal muscle and its fascia was decided. The patient had a favorable postsurgical course; the postoperative simple CT scan showed midline restitution without the vector effect, open basal cisterns, and maximization of external cerebral herniation. The patient was discharged due to improvement to a GCS score of 14 (E4 V4 M6) points, without motor aphasia.

Case 2

A 20-year-old woman suffering a motorcycle accident with a frontal impact without wearing a helmet, presented at admission with 10 points in the GCS (E3 V2 M5) and posteriorly with neurological deterioration to 7 points (E1 V1 M5); advanced airway management was performed, and a simple head CT scan showed right frontotemporoparietal subdural hematoma, cerebral edema, and posttraumatic subarachnoid hemorrhage. Decompressive frontotemporoparietal craniectomy and hematoma drainage were performed. Expansive hematoma of the temporal muscle and edema and hematic infiltration were observed in the postsurgical control tomography, which caused compression of brain structures, subfalcine herniation, and more significant deviation of midline structures (Figure 4).

A second surgery was needed by performing a total resection of the temporal muscle and its fascia (Figure 5), recovering midline structures by reducing the volume, and maximizing external herniation. The patient's postsurgical evolution was satisfactory. Postoperative CT scan showed midline restitution with no vector effect and adequate brain decompression. The patient was hospitalized for seven days and discharged due to clinical improvement with 13 points in the GCS (E4 V3 M6) without motor and sensitivity compromise.

The resected temporal muscle was sent for neuropathological analysis in both cases, corroborating an inflammatory and hematic infiltrate (Figure 6).

Discussion

Decompressive craniectomy is a standard procedure involving the remotion of a sizeable frontotemporoparietal bone flap[1-3]. However, external decompression based on the opening of the cranial vault can be limited by extradural structures, particularly the temporal muscle and its fascia. The original technical description has received some modifications, which some groups have suggested. Among these modifications, we can mention the addition of resection of the temporal muscle and its fascia. Some other groups go further and recommend zygomatic arch resection. After a craniectomy, the temporal muscle can become significantly swollen and have a mass effect on underlying structures, specifically on the temporal lobe putting lives at risk. Bleeding from the temporal muscle has also been reported to lead to inadequate decompression and cause persistent damage from brain herniation[4]. In other cases, it is common to use monopolar coagulation during decompression to separate the temporal muscle from its bony attachments and reflect it on the skin flap. This maneuver significantly impacts the muscular structure, causing retraction of the fibers and their death due to the excessive heat applied, compromising the vascular supply of both the anterior and posterior deep temporal arteries, conditioning the risk to present edema, and expanding hematoma of the temporal muscle[9]. Temporal muscle damage is caused due to either direct traumatic brain injury or the decompressive craniectomy approach itself[12,15,16]. Craniectomy with temporal

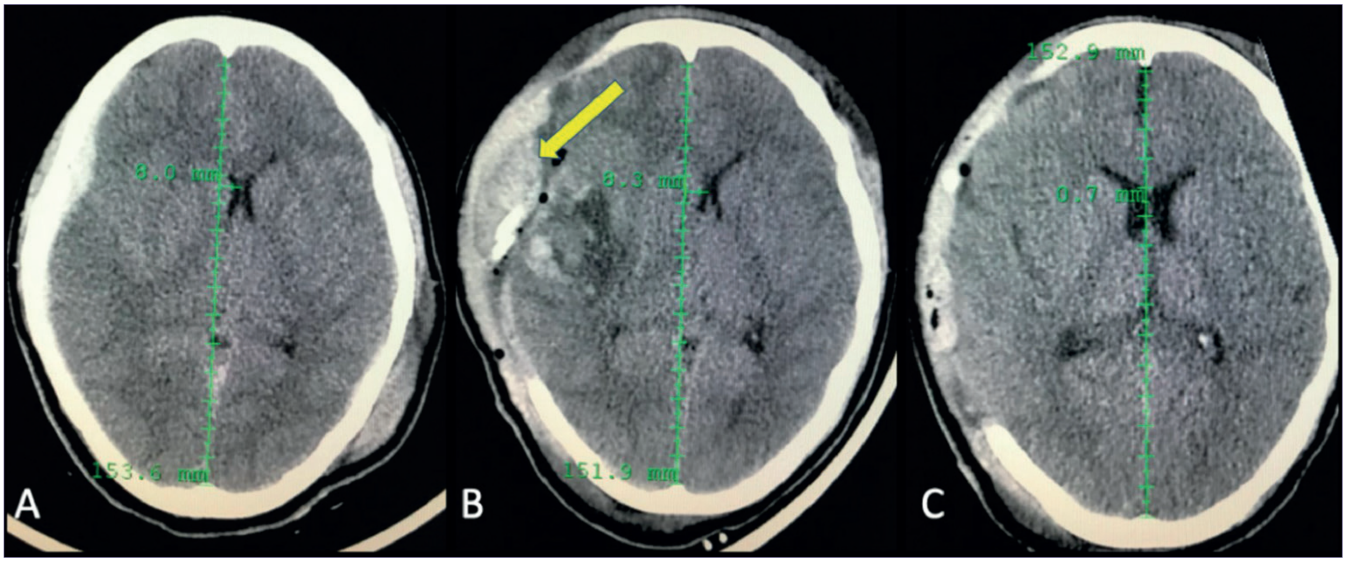

Figure 4. Representative CT scans. **A)** CT scan upon admission; **B)** CT scan after decompressive craniectomy, where the temporal muscle is observed, conditioning mass effect, simulating the presence of an expanding epidural hematoma (yellow arrow); **C)** CT scan after resection of the temporal muscle showing regression of the midline structures.

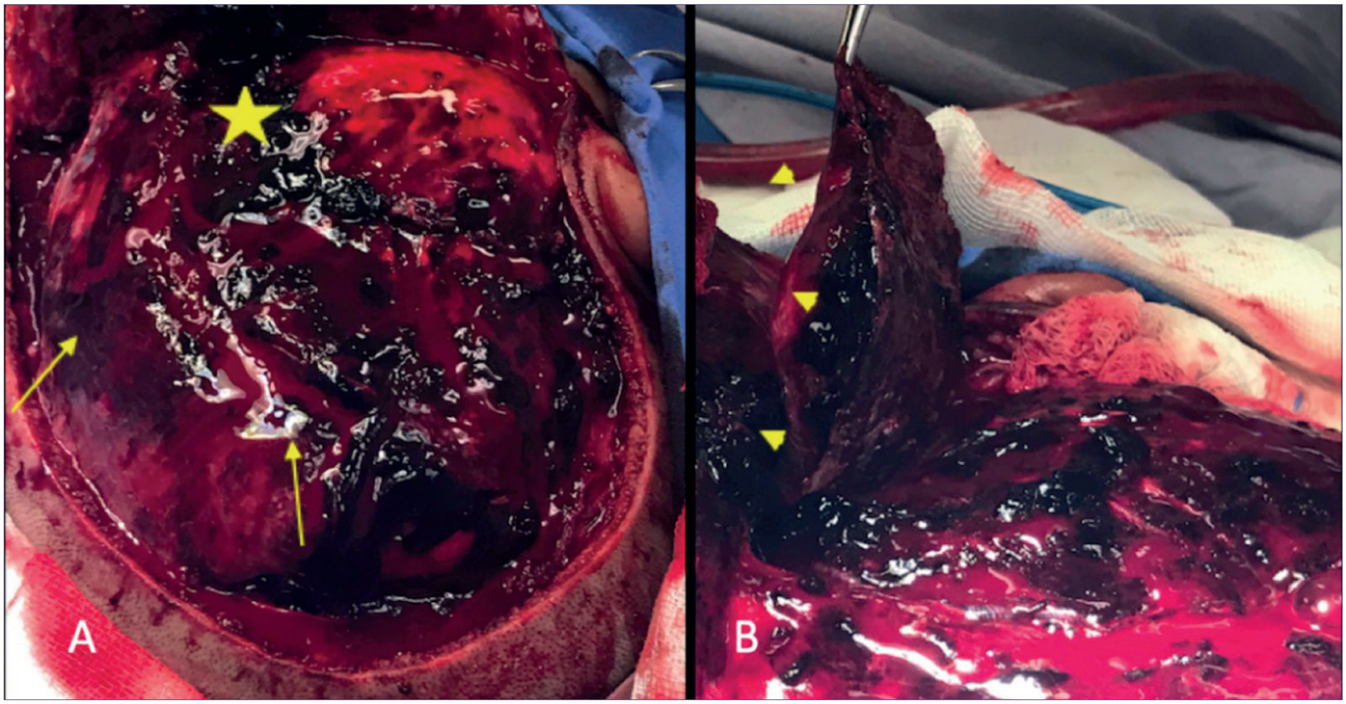

Figure 5. Intraoperative temporal muscle. **A)** Photograph of the temporal muscle (star and arrows) bruised and edematous after performing decompressive craniectomy; **B)** Lifting the temporal muscle (arrowhead) shows a marked increase in thickness.

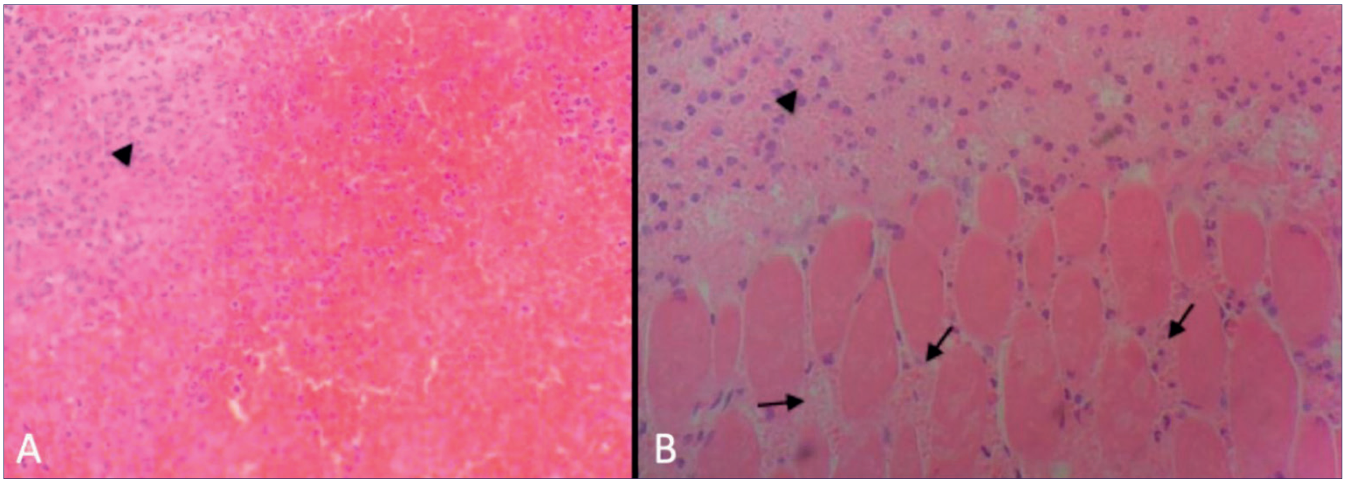

Figure 6. Histological findings. **A** and **B.** Histological section with hematoxylin and eosin staining shows an acute inflammatory infiltrate characterized by the presence of polymorphonuclear neutrophils (arrowheads) and muscle necrosis (arrows) characterized by the absence of nuclei with extensive cytoplasm and hemorrhage between muscle fibers.

muscle resection is a life-saving measure, and in surviving cases, the functional and aesthetic consequences are usually mild and not disabling[17].

No pain was identified in our patients who preserved life, and they presented with good mouth opening and adequate chewing force[11]. In this series, resecting the temporal muscle with its fascia was crucial and essential[5]. This is necessary to resolve the mass effect and intracranial hypertension, keeping patients alive[10].

Decompressive craniectomy has many complications, the rates range up to 53.9% and the increased volume of the temporal muscle should be considered an early complication[13]. Under certain circumstances, muscle resection after decompressive craniectomy can effectively control intracranial pressure[6]. However, it is essential to note that this is only the initial experience with a small series of cases. Thus, more extensive studies are needed to provide a better perspective on the need, or not, to resect the temporalis muscle when performing a decompressive craniectomy. Specifically, it is imperative to individualize the cases, pay due attention to the volume of the temporal muscle during the surgical event, and of course, remember to be subtle during the surgical management of the temporal muscle to avoid excessive damage to the structure[8].

Conclusions

Supramaximal craniectomy with total or partial resection of the temporal muscle may be helpful in cases that require decompressive craniectomy and present with a temporal muscle swelling with a significant mass effect.

Traumatic injuries in the temporal region may lead to subsequent temporal muscle swelling and increased volume. Properly managing the temporal muscle during the surgical approach is essential to avoid more volume increases. Finally, more studies in this matter are needed with a more significant number of patients and with control groups to increase the evidence level.

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