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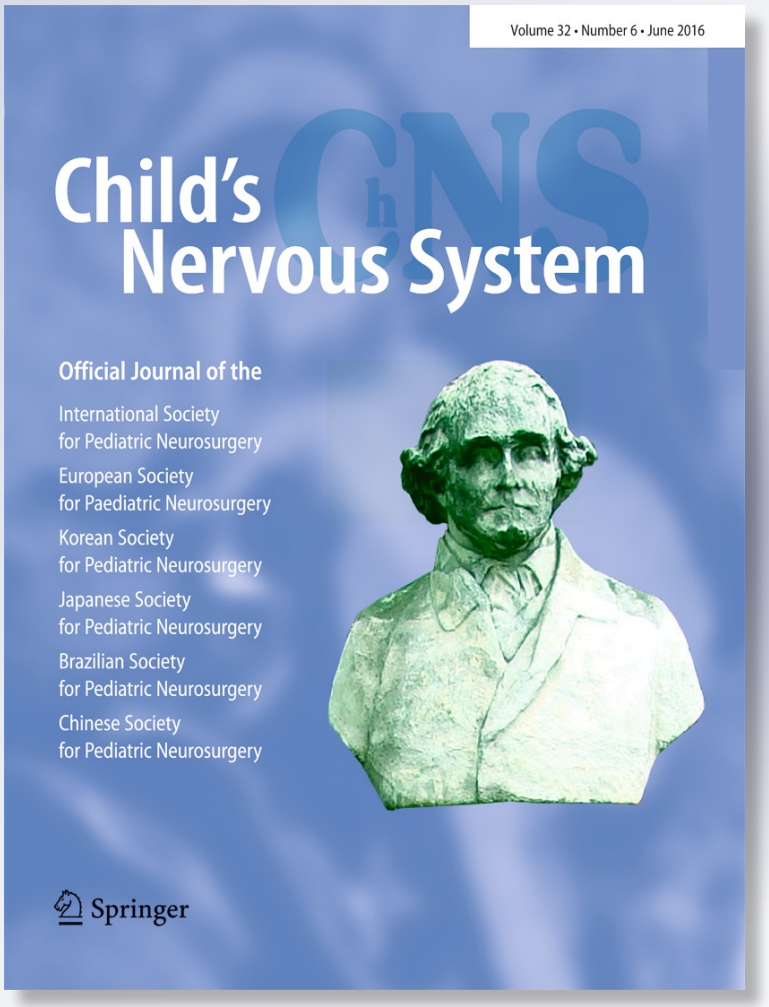

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ORIGINAL PAPER

Aspiration of parafalcine empyemas with flexible scope

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Abstract
Purpose Subdural empyemas are considered neurosurgical emergencies, and the parafalcine location is particularly insidious. We revised the experience of general surgeons who are used to manage chronic pleural purulent collections with video-assisted thoracoscopy.
Methods With a similar technique, we successfully aspirated a parafalcine empyema using a flexible scope avoiding a more invasive craniotomy. A review of the treatment options of empyematous collections is also provided, focusing particularly on the hazardous parafalcine location.
Results The management of subdural empyemas poses different decision-making problems compared to common brain abscesses, urging a more rapid and holistic surgical treatment with minimally invasive approach. Endoscopic aspiration of parafalcine empyema was followed by complete recovery in our patient.
Conclusions Flexible endoscopy is a promising method to obtain complete pus removal even from loculated collections through a bur hole, avoiding large craniotomies and consequent potential complications.

Keywords Empyema · Parafalcine · Neuroendoscopy · Flexible scope · Subdural empyema

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Introduction

Purulent intracranial infections as meningitis and subdural empyemas (SDEs) are uncommon sequelae of paranasal sinusitis in developed countries. In particular, SDEs have a higher incidence in people between 11 and 20 years of age, although the disease can occur throughout the entire life [8, 14, 38]. SDE is a rare disease, representing less than 15 % of all intracranial infections [59]. However, it is not a "benign" pathology [1, 17, 41, 42, 54]. When it is not treated immediately, SDE is associated with high risk of spreading, cortical venous and sinus thrombosis, and brain swelling that can ultimately lead to death. For this reason, SDE is sometimes described as "the most imperative of neurological emergencies" [48]. This malignant behavior accounts for the aggressive neurosurgical procedures as reported in large retrospective series. While most of these perilous collections are located within the convexity, parafalcine empyemas are more insidious and more difficult to be quickly treated. Furthermore, as collections are often multiloculated, single or multiple burr holes are not sufficient to drain the purulent material and large craniotomies are required as suggested by most of the authors.

Flexible endoscopy is a valuable tool in the treatment of extensive parafalcine empyemas, allowing removal also of multiloculated collections through a mini-invasive surgical approach. Similar advantages come from video-assisted thoracoscopic aspiration and decortication for the treatment of chronic pleural empyemas, which is a well-established procedure performed by thoracic surgeons. Along with the removal of the pus, they obtain a sort of "active brushing" of the capsule [32, 34]. In the past, we applied the same principles in the treatment of brain abscesses [31].

We report the case of a patient presenting with frontal parafalcine and convexity multiple SDEs, which have been treated mini-invasively through an endoscopic approach. A

flexible scope has been used with the aim of better managing a collection with complex shape avoiding large craniotomy and dural opening, with minimal injury to the brain structures.

Case report and endoscopic technique

A 13-year-old boy presented to the Emergency Department of a neighborhood hospital with left foot paresis that was preceded by fever (38 °C) and frontal headache for 3 days.

Physical examination revealed signs of nuchal rigidity, photophobia, and Babinski. The GCS score on admission was 13.

A lumbar tap was performed before parenteral administration of 4 mg ceftriaxone twice a day and 7.5 mg dexamethasone. CSF was opalescent, with 700 cells per deciliter (90 % polymorphonucleated), high proteins (150 mg/dL), and 68 mg/dL glucose. However, both direct bacterioscopic exam and viral antigen search were negative. The first MRI scan with gadolinium showed the presence of right frontotemporal and parafalcine subdural collections, associated with an area characterized by restricted diffusivity in the right frontal lobe (Fig. 1). Interestingly there was no sinus thrombosis, but an extensive involvement of the maxillary paranasal sinuses, mainly on the left side, was shown. The patient was radiologically diagnosed with meningoencephalitis and subdural empyema.

The blood investigations revealed an increased white blood cell count (24,770 mm^3) with 95 % neutrophils, thrombocytosis (602 × 103 mm^3), increased CRP (33.4 mg/dL) and ESR.

Immediately after admission to the Pediatric Department, focal seizures were noticed with secondary generalization characterized by myoclonic jerks at the left side of the body with deviation of the left oral rhyme and contraction of orbicularis oculi muscle lasting 1–2 min. A therapy with sodium phenytoin was started. Because of the worsening neurological status, the child was brought to the operating theater in order to immediately evacuate the right frontal subdural collection as first step. A right frontal burr hole was made, and after incision of the dura mater, a copious collection of yellow-grayish pus without any smell was evacuated using saline irrigation through a Nelaton catheter. A grayish and thick appearance of arachnoid was noted. The parafalcine collection was not operated at this point, as we were erroneously confident in the subsequent medical therapy. The pus samples sent for microbiological investigation were positive for *Streptococcus intermedius*, and the antibiotic therapy was then changed to meropenem and ampicillin. The neurological status actually improved, with regression of the paresis.

Although, after surgery, seizures disappeared, the boy was still very weak and febrile (38 °C). A new brain MRI showed the complete resolution of the right convexity subdural empyema complicated, however, by an initial right frontal focal cerebritis (Fig. 2). The previously noted parafalcine collection was increased, and a new contralateral smaller subdural collection of the frontal convexity appeared. On the same day, the patient developed diplopia. A broad ophthalmological examination revealed a complete paralysis of the right rectus lateralis muscle with normal fundoscopy.

As neuroradiological images showed a clear worsening and new clinical signs of intracranial hypertension were manifested, we decided to evacuate also the parafalcine collection even without microbiological data.

Operatively, the patient was positioned in a beach chair position with the head slightly flexed. A precoronal burr hole

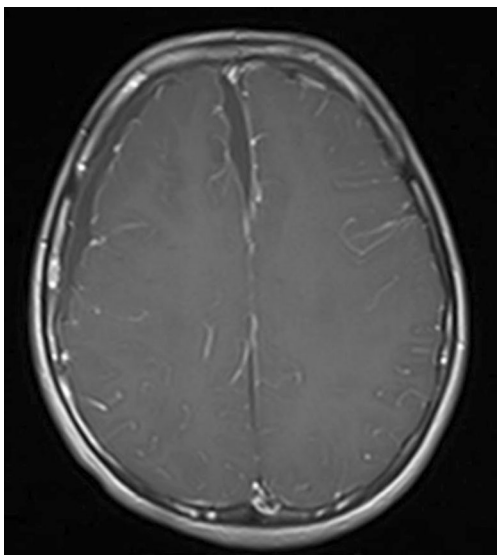

Fig. 1 Axial T1-weighted MR image with gadolinium at admission showing a right frontal subdural and a parafalcine collection

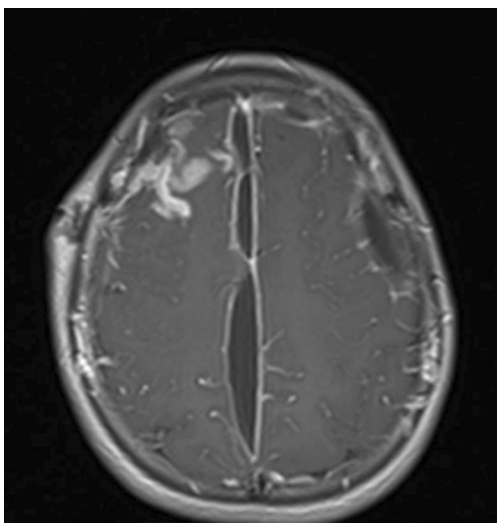

Fig. 2 Axial T1-weighted MR image with gadolinium after the first right frontal burr hole, with disappearance of the right frontal subdural empyema and signs of adjoining cerebritis. Increase of the parafalcine collection is also evident

was centered as close as possible to the parafalcine collection with the aid of frameless neuronavigation (Brainlab, Inc.). After the cruciate incision of the dura and a small piotomy, a peel-away was introduced in the subdural space with immediate release of pus under pressure. A flexible endoscope (KARL STORZ, Tuttlingen, Germany) was then advanced into the parafalcine cavity. The instruments were managed with a freehand technique. The view was initially hazy due to the presence of the pus collection. However, after copious irrigation with lactated Ringer's solution and simultaneous aspirations of the purulent wastewater, the falx was identified, together with the pial surface of the right hemisphere inferiorly and bridge veins posteriorly. The purulent coating entirely covering the falx was scratched away with vigorous endoscopic suctions leaving its surface with a reddish, granulating, inflammatory aspect (Fig. 3). A small septum in the middle part of the empyema was perforated with the endoscope, allowing the aspiration of the isolated collection. After the evacuation, a catheter was left in the interhemispheric fissure.

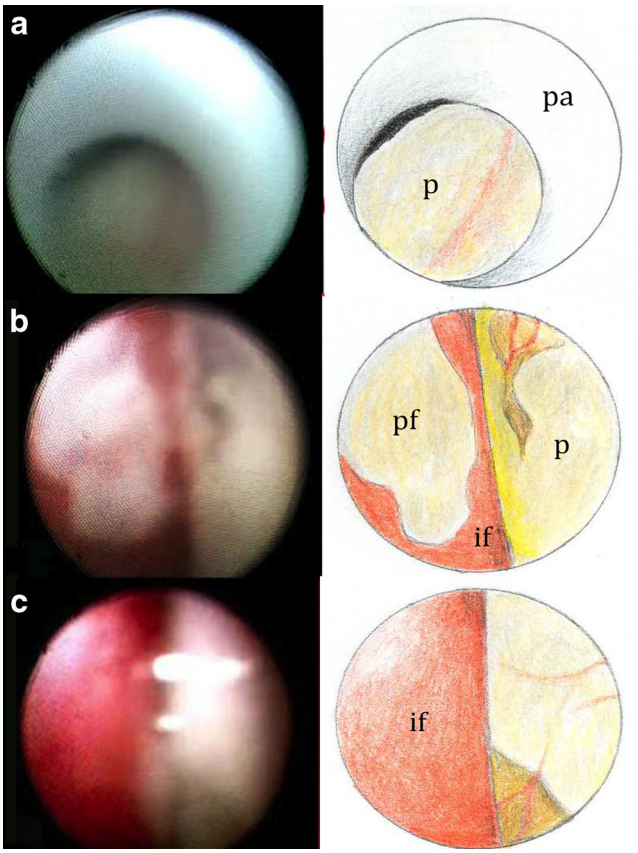

Fig. 3 Endoscopic vision during aspiration of parafalcine empyema and explicative drawings. **a** The endoscope is introduced through a peel-away (*pa*) into the parafalcine space, where abundant pus covers the brain (*p*). **b** The falx covered by pus (*pf*) is identified. **c** Aspiration of pus progressively unveils the inflamed falx (*if*). **d** After scratching, the pus is completely removed from the inflamed, red falx; conversely, the pus covering the brain is not removed completely in order to avoid damages to the pia and the underlying cortical vessels

A second neuronavigated burr hole was then made to evacuate the left frontal collection. The pus samples resulted negative as expected after the initiation of antibiotic therapy. Gradually, diplopia improved in the following days.

On day 16 after admission, a new MRI showed complete resolution of both the parafalcine and the convexity collections (Fig. 4). Conversely edema at the level of the right frontal intraparechimal lesion was more evident. The postoperative course was uneventful, with complete resolution of fever 15 days after admission. The patient was able to walk and was independent in his daily activities. Anticonvulsant therapy was gradually tapered after discharge till complete suspension on day 50 after admission. The 1-month follow up MRI showed complete resolution of the leptomeningeal enhancement (Fig. 4).

Discussion

Empyema is defined as a collection of pus between the cranial dura mater and the arachnoid. It represents about 20 % of all intracranial pyogenic infections, and it is associated with extradural collections or subperiosteal abscess and osteomyelitis (Pott's puffy tumor) in 10 % of cases. The first known case of subdural empyema is reported in the Novi Commentarii Societatis Regiae Scientiarum Gottingensis, tomus III: the author was initially asked to examine a 55-year-old man with left palpebral edema and purulent discharge from a cutaneous ulceration. The patient unfortunately showed a rapid neurological worsening with right hemiparesis, coma, and death 24 h later [43].

More than one century later, Ceci and Onetti from the Surgical Clinic of Geneva published the first operated cases of subdural empyema [11]. A man was treated with explorative craniotomy and trephination of the left infero-anterior parietal angle, but the postoperative course was unfavorable. In the following years, many authors reported cases of surgically treated empyemas, invariably with an unfavorable outcome [12, 16, 19, 25, 26]. This was considered a hopeless disease due to its frequently fatal outcome until the middle of the last century. Keith published the first report of a successfully treated case of subdural empyema in 1946 [23]. Notably, an interhemispheric collection was successfully treated with three parasagittal burr holes along with subdural and systemic administration of penicillin.

Paranasal sinusitis and otomastoiditis are more frequently involved in the pathogenesis of subdural empyemas [18, 27, 46, 57]. The spread of infection to the diploic veins of the sinuses or the cavernous sinuses may cause intracranial contamination through septic emboli or thrombophlebitis. Other causes of subdural empyemas may include head trauma, complications of intracranial surgery, osteomyelitis of the skull, or it can simply develop after meningitis especially in infants

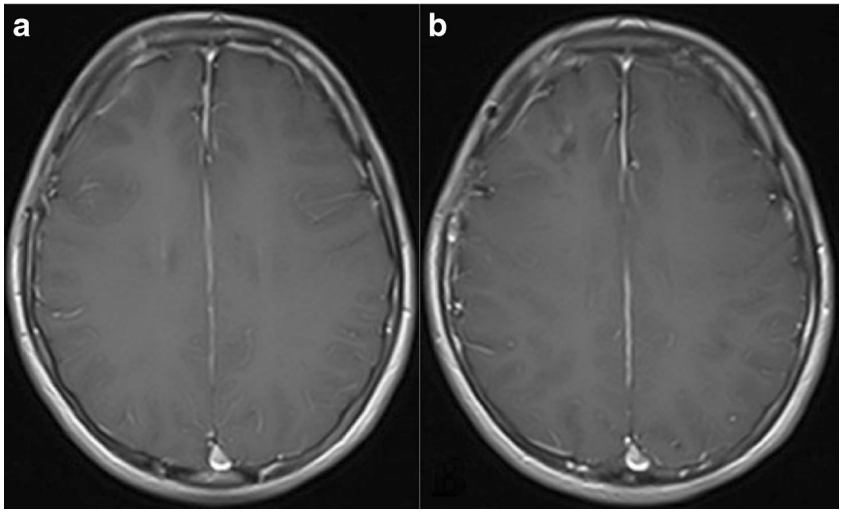

Fig. 4 **a** Axial T1-weighted MRI with gadolinium showing complete resolution of both the parafalcine and the convexity collections on day 16 after admission. **b** One-month follow-up axial T1-weighted MRI with gadolinium confirming complete resolution of the leptomeningeal enhancement

[15, 38]. Frontal and sphenoid sinuses are the most common source of complicated sinusitis in the pediatric population. A possible explanation can be related to the growing of the posterior wall of the frontal sinus during childhood [47, 53].

Diagnosis of SDE was a challenge for physicians before the 1960s. Lumbar tap was not always diagnostic as reported in many series, and it could conversely be a hazardous procedure.

Diagnosis was based on clinical signs (as local clues of infections at the level of periorbital or frontal region, cranial nerves palsy), and radiological signs (as warnings of intracranial suppuration) [2, 22]. The advent of angiography and CT scan a few years later made a non-invasive diagnosis of SDE finally possible [20, 50]. SDE is usually seen on CT scan as a hypodense crescent-shaped area with displacement of the midline structures. After contrast administration, an enhanced rim is usually evident along the cortex. Hypodense changes in the white matter are common at this stage and are related to edema and ischemia due to cortical venous infarction.

Nowadays, MRI is available for an easier and more precise diagnosis. Furthermore, the use of magnetic resonance angiography and venography can eventually detect intracranial phlebitis and cavernous sinus thrombosis with a sensitivity and specificity that are comparable to CT angiography [52, 56].

The clinical presentation of SDE can be described as a bimodal peak. Initially, undefined signs of infection like fever and sickness often seem to be successfully treated by oral antibiotic therapy. Later, usually after 5–7 days, acute neurological signs ranging from cranial nerves deficits through hemiparesis and coma can come into picture [13].

As SDEs usually have a quick progression, prompt recognition and treatment are mandatory to avoid clinical worsening [3, 6]. Patients operated within 72 h have a 10 % risk of disability compared to 70 % risk for patients operated at a later stage.

The neurological status at admission, the volume of the collection, and the parafalcine location of the empyema are the most important factors affecting outcome [5, 30, 35, 51]. The presentation of parafalcine-located subdural empyema can vary from the classic "falx syndrome," consisting of convulsions starting in the contralateral lower extremity with secondary generalization or weakness of this extremity, to a more subtle picture starting with fever until symptoms of high intracranial pressure are seen [55].

Usually, small pus collections without any neurological deficit can be treated with hospitalization and antibiotics for several weeks [15, 29, 36, 39, 44, 45]. However, when there is a concomitant failure of initial medical therapy surgical evacuation should be carried out early [33, 58].

Surgery has the evident advantage of rapidly reducing the mass effect and of removing the toxic effect of products of bacterial metabolism on the underlying brain parenchyma. Among the available surgical options, data from large series have confirmed a lower mortality rate of craniotomy-based evacuation of subdural empyema compared to multiple burr holes and saline irrigation [9, 28, 37, 40, 49]. The main reasons for this are represented by the frequently concomitant brain swelling in these patients, as well as by the presence of multiloculated collections and by the intrinsic characteristic of subdural pus, which is always thick. In addition, parafalcine collections represent a challenge for surgeons due to the deep location of the collection into a narrow space.

These collections are usually restricted to the falcine surface without communication with the subdural space over the convexity, due to the presence of densely adhered arachnoid at the edge of convexity and falx dural junction.

Craniotomy allows also for a better exploration of the subdural space and for the treatment of the underlying osteomyelitis of the bone when present. Moreover, in some cases when intracranial hypertension already developed, decompressive craniectomy may be required [15]. Specific antibiotic therapy is nonetheless required during and after surgery.

However, some studies showed no significant difference between craniotomy and burr holes in terms of outcome and mortality [35, 36], contributing to increase the controversy about the best method for surgical evacuation of SDEs. Moreover, osteomyelitis of the bone flap has been reported to occur in up to 9 % of patients treated with craniotomy [15].

An interesting paradigm for optimal treatment of empyemas is represented by thoracic empyemas. Similarly to parafalcine collections, thoracic empyemas develop in narrow spaces that cannot be easily and completely reached. Despite the introduction of broad spectrum antibiotics, thoracic empyema still remains a serious problem [10]. During the fibrinopurulent stage, closed-chest drainage is no longer effective, and the progression through the so-called organizing phase leads to the restriction of the movements of pleura and diaphragm. At this point, video-assisted thoracoscopy has been used instead of thoracotomy for the management of patients developing pleural empyema [34]. Compared to open surgery, patients have shorter general anesthesia, and also, the postoperative stay is shorter, with earlier mobilization and a lower use of analgesics.

Similarly to the approach to chronic pleural empyemas, the idea of treating SDE through a mini-invasive approach overcoming the intrinsic limitations of the "closed" irrigation of the subdural space, mainly the lack of direct visual control with potential injury to bridge veins or parenchyma, is intriguing.

In our previous report on the endoscopic management of brain abscess, we reported on the advantages of the use of flexible endoscopy over "close" stereotactic draining [31]. The association of extensive evacuation of purulent material with the complete aspiration of the thicker component of the collection that is adherent to the capsular wall adds obvious advantages and is better achieved under direct visual control. With these evidences, we applied the same principles in the treatment of SDE. We are strongly convinced of the importance of direct visualization of the subdural space with a flexible endoscope during the irrigation and aspiration maneuvers. Direct inspection allows neurosurgeons to extensively explore the cavity in all directions, also in presence of thick and dense pus material (Fig. 5). Furthermore, direct visualization allows surgeons to delicately perforate septa that are common in chronic inflammatory changes through the working cannula of the endoscope, also with microforceps if needed. In this case, we have reported a pyogenic layer covered the dura and we attempted the same "scratching maneuver" described by thoracic surgeons. After scratching away the pyogenic layer covering the falx, an unexpectedly thick reddish and inflammatory falx was evident. However, a similar aspiration must be avoided on the brain surface because any damage to the arachnoid membrane would carry the risk of bleeding and infection spread through CSF.

Fig. 5 Schematic image showing the possibility to reach every part of a parafalcine subdural collection using a flexible scope through a single burr hole approach

A previous case report from a postoperative subdural empyema of the convexity [24] treated with flexible endoscopic evacuation in a 71-year-old man has shown good efficacy of the procedure with no complications. To the best of our knowledge, although endoscopy has already been performed for convexity subdural collections and for other intracranial locations, our case is the first parafalcine empyema successfully treated using a flexible endoscope [7, 21]. In our opinion, the flexible endoscope allows a wider exploration of the subdural space and of empyema locations compared to the rigid endoscope. Neuronavigated flexible scope could be of great interest and should be available in the next future thanks to the recent advancements in electromagnetic frameless neuronavigation [4].

Conclusions

Besides the technical details, the experience of our case confirms that the management of subdural empyemas poses different decision-making problems compared to common brain abscesses, urging a more rapid and holistic surgical treatment with minimally invasive approach.

Flexible endoscopy is a promising method to obtain complete pus removal even from loculated collections through a bur hole, avoiding large craniotomies and consequent

potential complications. This technique is particularly valuable for deep-seated collections, as parafalcine empyemas.

Compliance with ethical standards

Conflict of interest The authors declare no industry affiliation.

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