Acta Neurochir (2013) 155:373–377
DOI 10.1007/s00701-012-1581-0

TECHNICAL NOTE - NEUROSURGICAL TECHNIQUES

Hollow screws: a diagnostic tool for intracranial empyema

Fanny A. Aldinger · Ehab Shiban · Jens Gempt · Bernhard Meyer · Jürgen Kreutzer · Sandro M. Krieg

Received: 1 July 2012 / Accepted: 30 November 2012 / Published online: 21 December 2012

Abstract
Background Subdural (SDE) and epidural empyema (EDE) are life-threatening intracranial infections. They require immediate diagnosis and treatment. However, in some cases, magnet resonance imaging (MRI) is not able to contribute to diagnosis; therefore, surgical exploration is indicated. Hollow screws used for decompression of chronic subdural haematoma (cSDH) are valuable tools for minimally invasive biopsy in awake patients when SDE and EDE are suspected.
Methods Between 2006 and 2010, eight patients in our department underwent biopsy of a suspected SDE or EDE using hollow screws. In these cases, MRI or computed tomography (CT) were not able to provide sufficient diagnostic security to indicate primary craniotomy. Diagnostic and therapeutic efficacy was evaluated on preoperative and postoperative imaging. The focus was on qualitative parameters, such as contrast enhancement or impaired diffusion on diffusion-weighted images (DWI).
Results The application of the hollow screw under local anaesthesia permitted an exact diagnosis in all cases. In one case, the suspected diagnosis of cSDH could be refuted by diagnostic puncture. In four cases of uncertain diagnosis, the application of the hollow screw revealed a cSDH. Seven of eight patients previously received neurosurgical treatment; three of those cases were SDE or EDE and four were cSDH. Cases of SDE and EDE needed further craniotomy after diagnostic puncture, whereas patients with cSDH were sufficiently treated by hollow screws.
Conclusions Given their comparably wide diameter, hollow screws allow a sufficient sample size and, therefore, lead to precise diagnosis of SDE and EDE without significant operative risks or strains for the patient.

Keywords Subdural empyema · Hollow screws · Biopsy · Diffusion-weighted images

F. A. Aldinger · E. Shiban · J. Gempt · B. Meyer · J. Kreutzer · S. M. Krieg (✉)
Department of Neurosurgery, Klinikum rechts der Isar, Technische Universität München, Ismaninger Str. 22,
81675 Munich, Germany
e-mail: Sandro.Krieg@lrz.tum.de

F. A. Aldinger
e-mail: fanny@aldinger5.de

E. Shiban
e-mail: Ehab.Shiban@lrz.tum.de

J. Gempt
e-mail: Jens.Gempt@lrz.tum.de

B. Meyer
e-mail: Bernhard.Meyer@lrz.tum.de

J. Kreutzer
e-mail: jk@neurochirurgie-dr-kreutzer.de

Introduction

Subdural empyema (SDE) is a focal intracranial collection of purulent material located between the dura mater and the arachnoid mater [2]. Various symptoms can occur from compression of the brain by the infected lesion: headache, seizures, hemiparesis, drowsiness, hemiplegia, unconsciousness and fever [2, 12].

In infants and young children, subdural empyema frequently occurs as a complication of meningitis. In adults, the condition can occur as a complication of paranasal sinusitis, otitis media, mastoiditis or neurosurgical operations. Given cerebral compression and imminent encephalitis, subdural empyema requires immediate diagnosis and therapy. The diagnosis of SDE is made using magnet resonance imaging (MRI) or computed tomography (CT). In addition, blood tests should be requested. Cranial MRI is

the imaging of choice and is assumed superior to cranial CT scan [2, 8]. However, even MRI cannot always provide sufficient diagnostic security and explorative craniotomy must be considered [22]. The established therapy for SDE and epidural empyema (EDE) is an immediate neurosurgical treatment accompanied by antibiotic therapy with broad coverage for the suspected organisms [2, 7]. Its neurosurgical treatment is not standardised and varies widely from craniotomy, through stereotactic burr hole with irrigation and drainage, to less invasive hollow screw placement. Craniotomy allows a better exploration and pus evacuation and is therefore considered most effective [13, 15, 18]. In other studies, the evacuation of SDE or EDE with a burr hole and irrigation is seen as a satisfactory and efficient treatment [19, 23]. As SDE and EDE are often found in elderly patients with significant comorbidity, diagnostics and therapy should be precise and as less stressful as possible. Therefore, we evaluated the value of a minimally invasive procedure using hollow screws for the biopsy of intracranial empyema.

Patients and methods

Patients

From 2006 to 2010, eight cases of suspected space-occupying SDE/EDE and questionable chronic subdural haematoma (cSDH) using hollow screws were diagnosed in our department. Six were female and two were male. The median age was 70 years (range, 49–75 years). Indication for treatment was suspected subdural or epidural infection, in which MRI was not able to provide sufficient diagnostic security to indicate immediate craniotomy, even after extensive discussions with our neuroradiological colleagues.

All patients were examined thoroughly. Blood tests were requested, neurological status was assessed and the patient's history was investigated with regard to causative events.

Imaging

MRI or CT was used for initial diagnosis and evaluation of the intracranial lesions. The following characteristics indicated a subdural inflammatory process. On MR images with gadolinium as a contrast agent, a typical sign for SDE is a subdural collection surrounded by a contrast-enhancing rim. Furthermore, high signal areas on T2-weighted MR images and restricted diffusion areas on diffusion-weighted images were suspected. On CT scans, hypodense areas indicated a questionable inflammatory process. MRI and CT scans provided postoperative follow-up (Fig. 1).

Hollow-screw placement

The use of a hollow screw was developed for the decompression of cSDH [10, 14]. The screw has an outer diameter of 5 mm and an inner diameter of 3 mm (Teleflex Medical, Belp, Switzerland), and is placed under local anaesthesia with 5 ml of 2 % Mecain. The Trendelenburg position should be chosen to avoid intracranial air. Initial outflow of purulent material is typical after placement of the screw. The next step is connecting a three-way stopcock to the screw, serving as regulation for subsequent irrigation. To remove the purulent material and rinse the subdural space irrigation with warm Ringer's solution, two syringes are used for alternating injection and suction. Then the hollow screw is removed.

Results

Causative event and symptoms

Seven patients previously underwent neurosurgical procedures. One causative event remained unclear (Table 1). The surgery-related cases were detected by follow-up MRI, CT scans, or clinical deterioration. Patient 4, without previous neurosurgical procedure, presented with aphasia and an increased C-reactive protein (CRP) of 3.3 mg/dl. In some of the other cases, CRP was suspicious and an inflammatory process was consequently suggested (Table 1). CRP was increased up to 16.1 mg/dl. Two patients did not show any clinical symptoms, whereas various clinical symptoms occurred in six cases (Table 1).

MRI

Three patients received preoperative MRI. CT was performed in five cases with doubtful diagnosis. Here, postoperative SDE and cSDH were considered in equal proportions. MRI findings are presented in Table 2 and Fig. 1.

Surgery

All patients received one hollow screw. Four were placed on the right side and four were placed on the left side. For hollow screw placement, the frontal position was chosen in five cases and the parietal position was chosen in three cases.

The mean time interval between previous surgery and hollow screw placement was 75 days (range, 22–130 days). Initial mean width of the lesion was 17.4 mm (range, 11.8–33.4 mm).

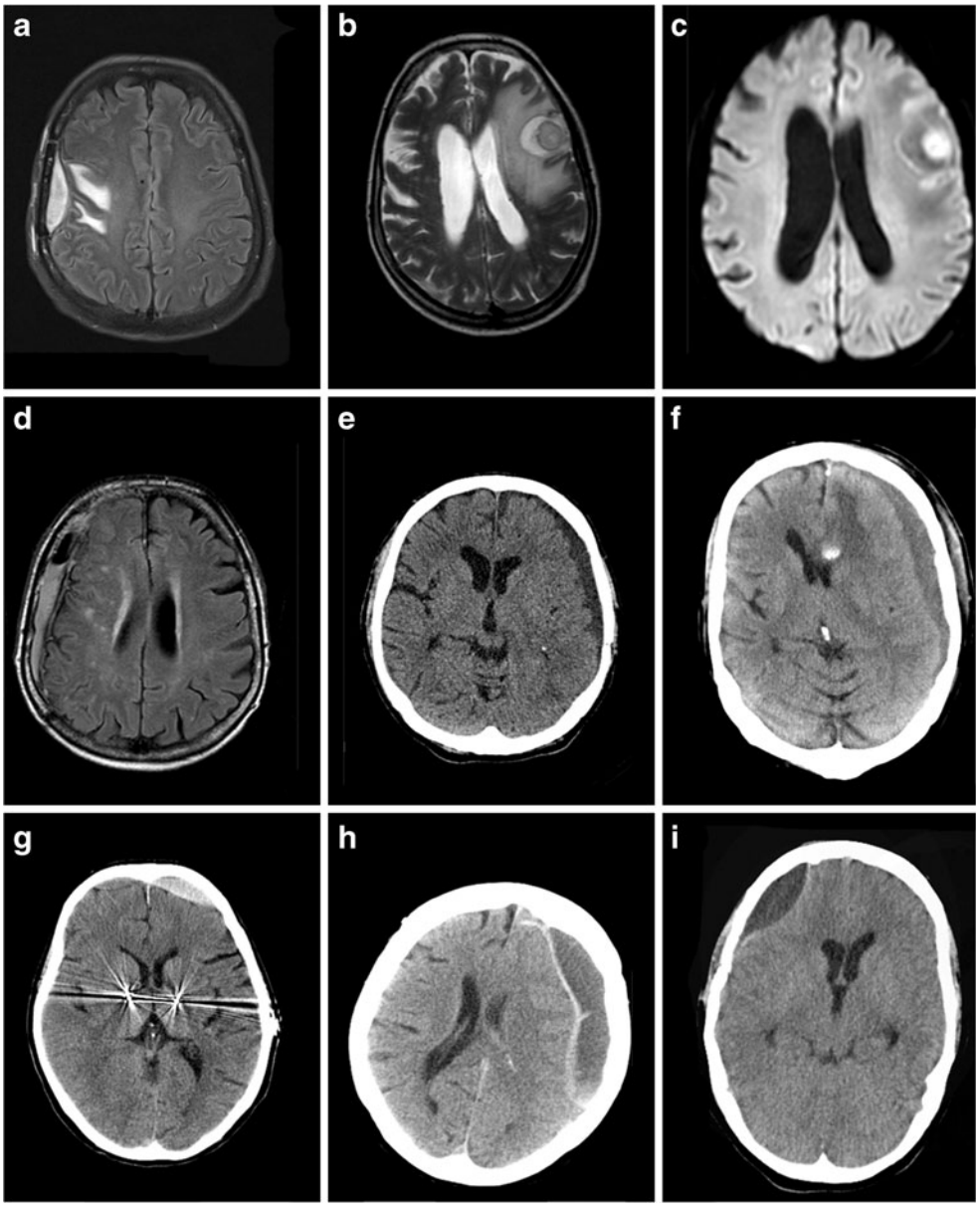

Fig. 1 Preoperative MR images and CT scans. Images **a** (patient 1) and **d** (patient 6) show the subdural lesion on T2-weighted MR images. MRI of patient 4 is shown on image **b** (spin-echo T2 image) and on image **c** (diffusion-weighted image). CT scans on image **e** (patient 5), **f** (patient 8), **h** (patient 6) and **i** (patient 2) present the subdural lesion as a hypodense area. Image **g** (patient 7) presents the subdural lesion as a hyperdense area

Final diagnosis and further treatment

In three of four cases, the suspected diagnosis of SDE or EDE was confirmed. Given preoperative MRI, one patient was suspected to suffer from cSDH rather than empyema (patient 2). The diagnostic puncture refuted this diagnosis because, apparently, the correct diagnosis was epidural empyema. In four cases, the diagnosis from the imaging was doubtful. SDE and cSDH were considered in equal proportions. After diagnostic puncture, a diagnosis of cSDH was concluded (Table 1).

Patients with SDE and previous neurosurgical procedures underwent consecutive craniotomy to evacuate the empyema as well as the bone flap. One patient without previous neurosurgery was sufficiently treated by hollow screw placement and consecutive antibiotic therapy. Patients with cSDH and previous neurosurgical procedures were treated sufficiently by hollow screw placement.

Discussion

This technical note shows that hollow screws have a diagnostic value in cases of suspected intracranial empyema when MRI or CT is unclear. However, MRI is actually capable of providing reliable diagnosis in most cases of subdural and epidural empyema [8]. Contrast medium also improves the sensitivity of MRI [2, 7, 8], which showed the exact size and cerebral involvement. Thus, MRI is highly superior to CT, which often leaves doubts on the nature of such lesions [2].

Table 1 Overview of diagnosis, previous surgery and further procedures

Patient	Presumed diagnosis	Final diagnosis	Causative event/ neurosurgery	Symptoms	CRP	Antibiotic therapy	Further procedure
1	EDE	EDE	metastasis resection	none	0.1	Cefuroxim axetil	boneflap removal
2	cSDH	EDE	aneurysm clipping	none	1.1	Cefuroxim axetil	2nd hollow screw placement
3	SDE	SDE	acute subdural haematoma	confusion	0.1	Cefuroxim axetil	bone flap removal and consecutive titanium cranioplasty
4	SDE	SDE	unknown	aphasia	3.3	Ceftriaxon, Vancomycin, Metronidazol	none
5	SDE	cSDH	astrocytoma resection	headache	0.1	no antibiotic therapy	none
6	SDE	cSDH	meningeoma resection	aphasia confusion	0.3	no antibiotic therapy	none
7	SDE	cSDH	implantation thalamic stimulator	hemiparesis	0.6	no antibiotic therapy	none
8	SDE	cSDH	glioblastoma resection	aphasia nausea	16.1	no antibiotic therapy	none

Additionally, diffusion-weighted imaging (DWI) improves the diagnostic accuracy of MRI [4, 9, 11, 16] and is able to monitor the therapeutic response in SDE [17]. DWI has been established as a considerably reliable instrument to detect intracranial infections because pus usually shows restricted diffusion and appears as an area of high signal on T2-weighted images [4, 24]. This result can be explained by the increased protein content in the purulent material [1]. Nevertheless, DWI still does not visualise all infectious lesions and, in particular, cannot reliably detect cases related to neurosurgical procedures. In the context of neurosurgery-related subdural lesions, inflammatory processes must be considered as a post-operative complication and was taken into account in seven cases. Moreover, the absence of diffusion restriction does not prove the lack of an inflammatory process [5]. Consequently, the diagnosis remains uncertain and an invasive diagnostic procedure is required in many cases.

Morbidity and mortality after SDE or EDE are severely associated with the delay of diagnosis and therapy [2]. The diagnostic puncture by hollow screws allows a precise and immediate diagnosis and a sufficient sample size was gained in all cases. In addition, potentially unnecessary general anaesthesia can be avoided.

In particular, elderly patients with high comorbidity face a significantly higher risk of surgery-related sequels attributable to general anaesthesia [21]. Therefore, a less invasive but effective method under local anaesthesia offers a highly valuable option. The use of hollow screws is an easy, fast, safe and sufficient method [14]. Because the inner diameter of 3 mm is larger than needle trephination, hollow screws are applicable for diagnostic samplings, even in cases of highly viscous pus [20].

In patients without previous neurosurgical treatment, the hollow screw can even serve as diagnostic puncture and minimally invasive treatment in one step. Because the literature on hollow screws is sparse, their use must be increasingly advocated among the neurosurgical community [3, 14].

Patients with previous neurosurgical intervention, i.e. reimplantation of a bone flap, usually require further treatment. The infected bone flap must be removed to discard the bacterial colonisation. In this case, the hollow screw confirms the diagnosis of a purulent infection but is inappropriate for treatment.

Various controversial opinions exist concerning the best surgical treatment for SDE. Given clinical improvement and complete eradication of the subdural material after an invasive surgical treatment such as craniotomy, Nayan et al. [15]

Table 2 MR images, CT scans and empyema-related characteristics

Patient	Diagnostic modality	T2 FLAIR signal/CT density	DWI	Meninges	Osteolysis on CT	Diagnosis
1	follow-up MRI	hyperintense	d-restriction	enhancement	0	EDE
2	CT	hypodense	-	-	0	EDE
3	MRI	hyperintense	d-restriction	enhancement	0	SDE
4	MRI	hyperintense	d-restriction	enhancement	0	SDE
5	CT	hypodense	-	-	0	cSDH
6	CT	hypodense	-	-	0	cSDH
7	CT	hyperdense	-	-	0	cSDH
8	CT	hypodense	-	-	0	cSDH

suggested a cranial bone opening procedure as first-line treatment. The reoperation rate was lower among patients who received craniotomy. By performing burr hole treatment or other minimal invasive methods, purulent material may remain in the subdural cavity and cause an unsatisfying outcome and recurrence [15]. Feuerman et al. [6] report a recurrence rate of 40 % of SDE after burr hole treatment. The reason for that is seen in the partitioned subdural collections, which cannot be reached with burr holes.

In contrast, Tewari et al. [23] emphasised that burr holes with irrigation lead to a satisfactory result in SDE. Immediate diagnosis, treatment, and management is assumed to reduce significantly morbidity and mortality [1]. A large study on the application of hollow screws in cSDH reported a good outcome in 79.5 % of cases that were sufficiently treated by hollow screws [14]. Similarly satisfying results could be expected in cases of subdural infections.

Consequently, the hollow screw can even be used for treatment of subdural and epidural empyema, provided that the patient had not received previous neurosurgical treatment, which would require bone flap removal in most cases.

Acknowledgements The study was completely financed by the Department of Neurosurgery, Klinikum rechts der Isar, Technical University Munich.

Conflicts of interest None.

References

1. Bannister G, Williams B, Smith S (1981) Treatment of subdural empyema. J Neurosurg 55:82–88
2. De Bonis P, Anile C, Pompucci A, Labonia M, Lucantoni C, Mangiola A (2009) Cranial and spinal subdural empyema. Br J Neurosurg 23:335–340
3. Emonds N, Hassler WE (1999) New device to treat chronic subdural hematoma—hollow screw. Neurol Res 21:77–78
4. Fanning NF, Laffan EE, Shroff MM (2006) Serial diffusion-weighted MRI correlates with clinical course and treatment response in children with intracranial pus collections. Pediatr Radiol 36:26–37
5. Farrell CJ, Hoh BL, Pisculli ML, Henson JW, Barker FG 2nd, Curry WT Jr (2008) Limitations of diffusion-weighted imaging in the diagnosis of postoperative infections. Neurosurgery 62:577–583, discussion 577–583
6. Feuerman T, Wackym PA, Gade GF, Dubrow T (1989) Craniotomy improves outcome in subdural empyema. Surg Neurol 32:105–110
7. Greenlee JE (2003) Subdural empyema. Curr Treat Options Neurol 5:13–22
8. Grossman RI (2000) Brain imaging. AJNR Am J Neuroradiol 21:9–18
9. Hughes DC, Raghavan A, Mordekar SR, Griffiths PD, Connolly DJ (2010) Role of imaging in the diagnosis of acute bacterial meningitis and its complications. Postgrad Med J 86:478–485
10. Illian CHP (2004) Das chronisch subdurale Hämatom: operative technik mit einer speziellen Hohlschraube. Aus dem Klinikum Duisburg Wedau Kliniken Klinik für Neurochirurgie. Medizinische Fakultät der Universität Duisburg-Essen, Duisburg-Essen
11. Kawano H, Yonemura K, Misumi Y, Hashimoto Y, Hirano T, Uchino M (2005) A case of interhemispheric subdural empyema with sinusitis diagnosed by diffusion-weighted MRI. Rinsho Shinkeigaku 45:449–452
12. Khan M, Griebel R (1984) Subdural empyema: a retrospective study of 15 patients. Can J Surg 27(283–285):288
13. Klein O, Freppel S, Schuhmacher H, Pinelli C, Auque J, Marchal JC (2006) Subdural empyema in children: therapeutic strategy. Five cases. Neurochirurgie 52:111–118
14. Krieg SM, Aldinger F, Stoffel M, Meyer B, Kreutzer J (2012) Minimally invasive decompression of chronic subdural haematomas using hollow screws: efficacy and safety in a consecutive series of 320 cases. Acta Neurochir (Wien) 154:699–705
15. Mat Nayan SA, Mohd Haspani MS, Abd Latiff AZ, Abdullah JM, Abdullah S (2009) Two surgical methods used in 90 patients with intracranial subdural empyema. J Clin Neurosci 16:1567–1571
16. Mishra AM, Gupta RK, Jaggi RS, Reddy JS, Jha DK, Husain N, Prasad KN, Behari S, Husain M (2004) Role of diffusion-weighted imaging and in vivo proton magnetic resonance spectroscopy in the differential diagnosis of ring-enhancing intracranial cystic mass lesions. J Comput Assist Tomogr 28:540–547
17. Narita E, Maruya J, Nishimaki K, Heianna J, Miyauchi T, Nakahata J, Kitahara H, Minakawa T (2009) Case of infected subdural hematoma diagnosed by diffusion-weighted imaging. Brain Nerve 61:319–323
18. Nathoo N, Nadvi SS, Gouws E, van Dellen JR (2001) Craniotomy improves outcomes for cranial subdural empyemas: computed tomography-era experience with 699 patients. Neurosurgery 49:872–877, discussion 877–878
19. Ouahes O, Kalamarides M, Redondo A, Berthelot JL, Bouali I, Rey A (1995) Subdural empyema. Apropos of 17 cases. Neurochirurgie 41:319–323
20. Reinges MH, Hasselberg I, Rohde V, Kuker W, Gilsbach JM (2000) Prospective analysis of bedside percutaneous subdural tapping for the treatment of chronic subdural haematoma in adults. J Neurol Neurosurg Psychiatry 69:40–47
21. Rohde V, Graf G, Hassler W (2002) Complications of burr-hole craniostomy and closed-system drainage for chronic subdural hematomas: a retrospective analysis of 376 patients. Neurosurg Rev 25:89–94
22. Silvera S, Oppenheim C, Touze E, Ducreux D, Page P, Domigo V, Mas JL, Roux FX, Fredy D, Meder JF (2005) Spontaneous intracerebral hematoma on diffusion-weighted images: influence of T2-shine-through and T2-blackout effects. AJNR Am J Neuroradiol 26:236–241
23. Tewari MK, Sharma RR, Shiv VK, Lad SD (2004) Spectrum of intracranial subdural empyemas in a series of 45 patients: current surgical options and outcome. Neurol India 52:346–349
24. Tsuchiya K, Osawa A, Katase S, Fujikawa A, Hachiya J, Aoki S (2003) Diffusion-weighted MRI of subdural and epidural empyemas. Neuroradiology 45:220–223