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Radiology in Focus

Magnetic resonance imaging after frontal sinus surgery with fat obliteration

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Abstract
The obliteration of the frontal sinus via an osteoplastic approach is performed with the aim of achieving a permanent 'switching off' by final and conclusive clearing out. For this, freshly harvested abdominal fat has shown itself to be the best clinically. It is possible to demonstrate the vitality of fat transplanted into the frontal sinus without an operation i.e. by a macroscopical and histological examination using magnetic resonance imaging (MRI). The magnetic resonance examinations were carried out on a supraconductive 0.5 T Magnet (Gyroscan T.S.II, Philips Medicine Systems, Eindhoven, Netherlands) with a quadrature (square) head spool. We produced T_1-weighted spin echo images (TR: 450–550 ms; TE: 20–25 ms), T_2-weighted fast spin echo images or in double-echo technique in transverse orientation (Turbo SE or TR: 2000–2500 ms; TE: 50–90 ms) and short tau inversion recovery (STIR) sequences for fat suppression (TJ: 140 ms; TR: 1400 ms; TE: 30 ms). The fat implanted into the frontal sinus of 11 patients aged 22–65 years, having undergone an osteoplastic frontal sinus operation with obliteration, was examined post-operatively by MRI. Objectives were the time-dependent distribution of portions of vital fatty or connective tissue, the eventual development of necroses or cysts as well as recurrences, inflammatory complications or re-epithelization of the frontal sinus four to 24 months post-operatively. In only six out of 11 cases was vital fatty tissue found. Fatty necrosis occurred five times, whereas in four cases a transformation into granulation tissue and in one case into connective tissue could be seen. All 11 patients were complaint-free. Long-term observations are needed to see if differences in the recurrence rate of frontal sinus disease are dependent on whether the implanted fat remains vital or necrosed and transformed.

Key words: Frontal sinus, surgery; Magnetic resonance imaging; Fat

Introduction

The obliteration of the frontal sinus is carried out with the aim of achieving final conclusive clearing out by permanent 'switching off'. This takes complete removal of the mucosa for granted. It can be shown that for this drilling of the inner bony layer of the frontal sinus is necessary. This is done with the cutting drill, where necessary. Nearby dura or periorbita can be drilled with the diamond burr. The cutting burr opens vascular canaliculi and thereby improves the chance of fat vascularization, whereas the bony canals are closed with the diamond burr. Just macroscopic removal or curretting out of the mucosa is not sufficient, as this leads, via mucosal remnants, to the formation of cysts, mucoceles and therefore not to a complete clearing out (Schenck, 1975). Similarly the frontonasal duct should be definitely sealed in the frontal sinus so that no re-epithelization of the frontal sinus from caudal ingrowth can follow.

Many techniques have been put forward for the obliteration: spontaneous obliteration which leads to complete scarring with variable extensive ossification (Macbeth, 1954; Fleischer, 1973); packing the cavity with autologous bone which similarly leads to ossification of the frontal sinus (Knauf, 1963; Sasaki *et al.*, 1967; Grahne, 1971; Eason *et al.*, 1976); filling up the lateral part of the frontal sinus with the frontalis or procerus muscle (Alföldy, 1965); proplast (Schenck, 1974; Barton, 1980); hydroxylapatite cement (Friedman *et al.*, 1991); gelfoam (Montgomery and Pierce, 1963), to mention just a few. The experimental procedures and clinical results of Tato *et al.* (1954), Bergara and Itoitz (1955), Goodale and Montgomery (1961); Montgomery and Pierce (1963), Montgomery (1964) and Schenck (1975) have demonstrated that obliteration with freshly harvested abdominal fat presents the most convenient procedure. The fat remains vital in variable large portions (up to over 50 per cent). The remaining portions are transformed into connective tissue. Osteoneogenesis does not occur. Necroses or the formation of oil or pseudocysts were not observed. The large portion of vital fatty tissue prevents the caudal ingrowth of epithelium due to scar tension into the frontal sinus as well as retraction of the anterior sinus wall. In addition, the resistance to infection is unusually high so that acute inflammation does not constitute a contraindication for a single operative clearance and obliteration. In our cases we use cefuroxime, a second generation cephalosporin, which works well against all relevant bacteria.

The knowledge gained is the result of experimental

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TABLE I

OPERATIVE TECHNIQUE FOR THE OSTEOPLASTIC FRONTAL SINUS OPERATION WITH FAT OBLITERATION (SEE WEBER *et al.*, 1994; 1995)

1 Incision: coronal or in a forehead fold or wrinkle.
2 Development of the scalp flap up to the supraorbital rim.
3 Opening of the sinus, marked with an X-ray template, with saw and chisel.
4 Turning down the periostium with the attached anterior frontal sinus wall.
5 Removal of the pathological process.
6 Microscopically controlled drilling out of the frontal sinus and complete removal of the mucosa (with cutting burr or diamond drill).
7 Inversion of the infundibular mucosa towards the nose.
8 Sealing of the frontonasal duct with cartilage.
9 Additional sealing towards the frontal sinus with allogen dura (Tutoplast®).
10 Filling up the sinus cavity with freshly harvested abdominal fat.
11 Replacement of the bony cover.
12 Periostial stitching, suction drainage and scalp closure.

procedures and rare revision operations. In order to judge the behaviour of fatty tissue in the obliterated frontal sinus, without operation, we studied the outcome of fat transplantation into the frontal sinus using magnetic resonance imaging (MRI). No sufficiently accurate statement is given in any other way. Whereas computed tomography (CT) is of greater value in the diagnosis of post-operative complications (Catalano *et al.*, 1991), MRI makes precise demonstration of soft tissue parts possible (Lloyd *et al.*, 1987), without radiation. On CT scan fatty tissue appears black in the so-called soft tissue window setting and grey on the bone window (Catalano *et al.*, 1991).

Due to partial volume effects, thickness measurements can give unreliable values. The great variations in thickness at the skull base can lead to line artefacts, which similarly hamper thickness discrimination.

In MRI the demonstration of even small frontal sinuses occurs artefact-free. Partial volume averaging effects can be maximally eliminated by demonstration at multiple levels. The protons bound in fat show a short T_1 relaxation time so that they are demonstrated as very light on the T_1-weighted spin echo image. To limit comparable further processes with short T_1 times (e.g. subacute bleeding) fat suppressant techniques can be put into force which act to selectively suppress signals from lipid-bound protons (Bydder and Young, 1985; Dwyer *et al.*, 1988; Tien, 1992).

Materials and methods

Eleven patients (aged 22–65 years) underwent osteoplastic frontal sinus surgery with fat obliteration (Table I: see also Weber *et al.*, 1994; 1995). There the fat has been obtained in small pieces (maximum size 2 × 1.5 cm) and fixed with some human fibrin glue (Tisseel®; Immuno, Wien, Austria). Table II gives patient data as well as information as to the indication for the intervenion. The fat, always harvested just before transplantation, implanted in the frontal sinus was examined post-operatively by MRI. The objectives were the time-dependent distribution of portions of vital fatty or connective tissue, the eventual development of necroses or cysts, as well as recurrences, inflammatory complications or re-epithelization of the frontal sinus.

The MRI examinations were carried out on a supraconductive 0.5 T Magnet (Gyroscan T.S. II, Philips Medicine Systems, Eindhoven, Netherlands). A quadrature (square) head spool was put into use for every examination. We produced T_1-weighted spin echo images in transverse and coronal or transverse and sagittally oriented cuts (TR: 450–550 ms; TE: 20–25 ms). As a

TABLE II

PATIENT DATA

Patient no.	Indication for frontal sinus surgery	Interval between operation and MRI
1 (Male aged 32 years)	FS mucocele after Lynch operation performed twice due to a posterior wall fracture	8 Days 6 months
2 (Female aged 39 years)	Multiple FS fractures	13 months
3 (Female aged 48 years)	FS osteoma	6 months
4 (Female aged 56 years)	FS mucocele after Lynch operation for chronic polypoid sinusitis (4 years previously) and Lynch revision operation for FS pyocele on the opposite side (1 year previously)	8 Days 4 Months
5 (Male aged 43 years)	FS mucocele after fracture (16 years previously) and Lynch operation performed twice (1978 and 1982) because of FS mucocele	6 Months
6 (Male aged 53 years)	FS mucocele after Lynch operation (6 years previously)	4 Months
7 (Male aged 22 years)	FS pyocele 2 years after Lynch operation because of FS fracture	6 Months
8 (Male aged 65 years)	Acute frontal sinusitis with destruction of anterior wall and frontal abscess (intraoperative bony obliteration of nasofrontal duct; in addition ethmoidal osteoma removed endonasally)	8 Days 6 Months
9 (Female aged 25 years)	Recurrent FS pyocele after Lynch operation performed twice because of polypoid sinusitis	6 Months 12 Months
10 (Female aged 65 years)	FS pyocele after Lynch operation (4 years previously)	12 Months
11 (Female aged 44 years)	Infected haematoma (origin ?) beneath the orbital roof with FS pyocele after endonasal median drainage (2 years previously) because of polypoid sinusitis	8 Days 6 Months

FS = frontal sinus; MRI = magnetic resonance imaging.

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TABLE III
RESULTS

Patient no.	Clinical result	Type of tissue in the obliterated frontal sinus as per MRI
1	Complaint-free	Vital fat; little connective tissue
2	Complaint-free	Vital fat; little connective tissue
3	Complaint-free	Vital fat 60%; 40% connective tissue
4	Complaint-free	Vital fat; little connective tissue
5	Complaint-free	Vital fat; little connective tissue
6	Complaint-free	Vital fat; little connective tissue
7	Complaint-free	Granulations; little fat
8	Complaint-free	Granulations; little fat
9	Complaint-free	Granulations; little fat
10	Complaint-free	Granulations; little fat
11	Complaint-free	Connective tissue; little fat

supplement, T_2 weighted fast spin echo images or the double-echo technique in transverse orientation were also carried out (Turbo SE or TR: 2000-2500 ms; TE: 50–90 ms). For fat suppression, STIR-sequences succeeded in usage (TJ: 140ms: TR: 1400 ms; TE: 30 ms). In case contrast application becomes necessary, gadolinium DTPA solution (Magnevist®, Schering, Berlin) can be administered intravenously as 0.1 mmol/kg body weight.

Results (see Table III)

Eight days following osteoplastic frontal sinus surgery with fat obliteration, the sinuses in all four patients examined in this period, were filled totally with vital fat and a small quantity of quickly resorbing haematoma (Figure 1a and b). Neither necroses, inflammatory changes nor air inclusions were found. The fatty tissue remained (from four to 24 months) almost completely vital with a small amount of connective tissue (six out of 11 patients: patients 1–6) (Figure 2a and b) or was almost completely replaced by granulations (four out of 11 patients: patients 7–10) or conective tissue (1 out of 11 patients: patient 11). Clinically, all 11 patients were complaint-free. In no patient did any cystic change (pseudocyst or oil cyst) or bony transformation take place.

Discussion

With MRI it is possible to demonstrate the vitality of fat implanted into the frontal sinus *in vivo* without surgery and without microscopical and histological examination. Besides operative risks, radiation doses which occur during computed tomography can be avoided.

The observations of Smahel (1986; 1989), that, after abdominal fat transplantation subcutaneously on the back of rats, oil cysts, necroses and definite resorption occur, do not apply to the frontal sinus; necroses are however possible. On the basis of his investigations Smahel (1986; 1989) saw the coherence of smaller pieces to larger lumps, which cannot be nourished. As a consquence only partial revascularization takes place as the fact acts as a foreign body, which is taken up by macrophages and not simply resorbed.

The nourishment of fat in the frontal sinus occurs through the vessels of the drilled open frontal bone. Vascularization of fat, from the surrounding bone, can be demonstrated after one week (Montgomery, 1964; Donald and Ettin, 1986). During the three-layered closure of the frontonasal duct to the frontal sinus (Weber *et al.*, 1995), it should be noted that the selected covering dural piece is not too large otherwise the danger of hindering vascular proliferation arises. If major parts of the sinus walls are absent because of extended fractures, necessary resections within the framework of tumour surgery, or as a result of pressure atrophy in mucoceles, then a high risk operative failure of the obliteration exists, since there are disturbances in the nutrition of the fatty tissue (Donald and Ettin, 1986). In such cases the cranialization of the frontal sinus is possibly more promising (Donald and Bernstein, 1978). We could not confirm the experimental and intraoperative findings, that large parts of the fat remain vital, to the extent expected. Only about half the cases showed a frontal sinus almost completely filled with vital

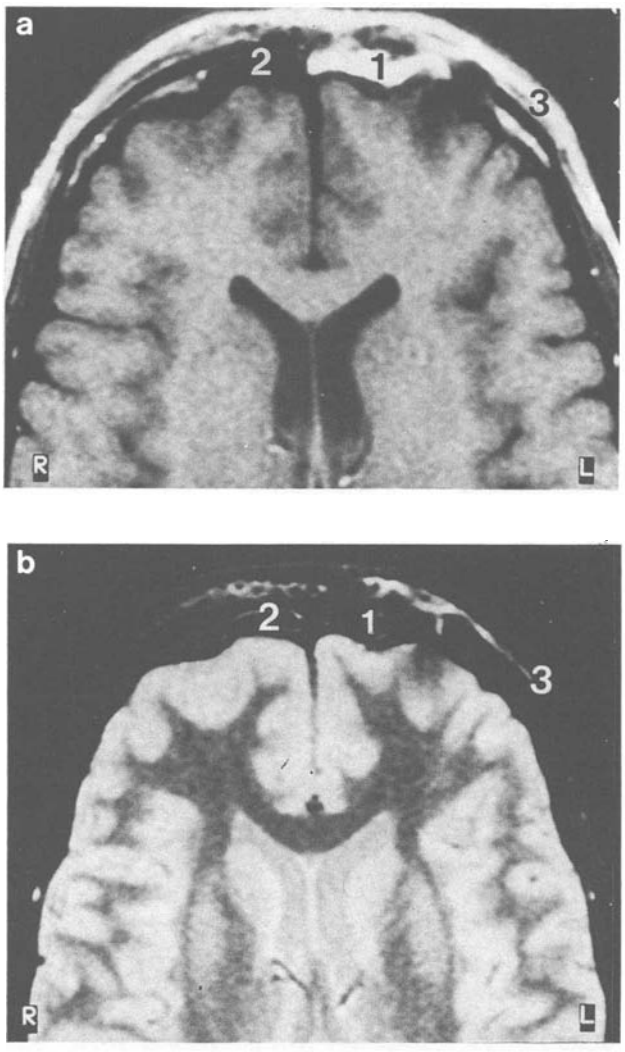

FIG. 1

(a) and (b) MRI eight days after osteoplastic frontal sinus surgery with fat obliteration on the left side: (a) T_1-weighting, axial; (b) STIR – fat suppression, axial. 1 = Vital fatty tissue in the obliterated frontal sinus; 2 = right frontal sinus with bland mucosa; 3 = subcutaneous fat.

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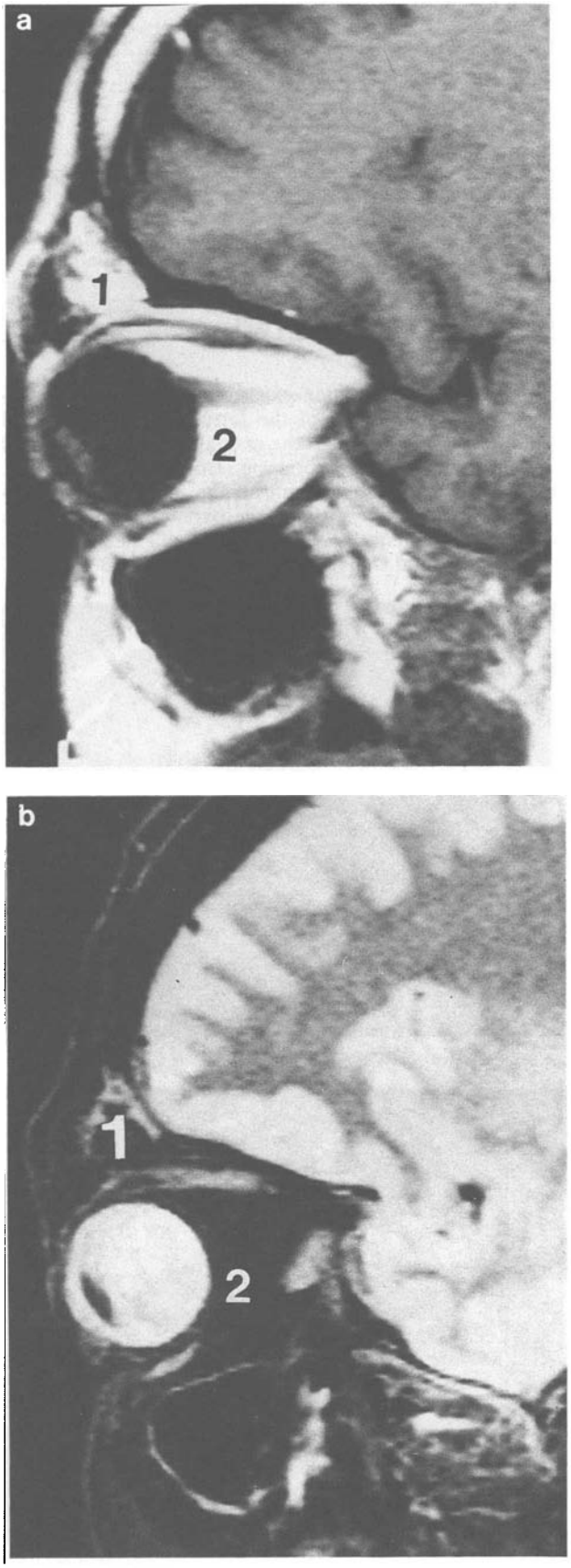

FIG. 2

(a) and (b) MRI six months after osteoplastic frontal sinus surgery with fat obliteration on both sides: (a) T_1-weighting, sagittal; (b) STIR – fat suppression, sagittal. 1 = Vital fatty tissue in the obliterated frontal sinus; 2 = orbital fat.

fat four to 24 months later. In five cases we observed few portions of vital fatty tissue mostly it was necrosed and replaced by granulations (four out of five cases) or connective tissue at six to 12 months post-operatively. The reasons why the fatty tissue remained vital in six cases and became necrotic in five cases remains unclear. Probably part of the reason may lie in an individually variable 'sensitivity' of the fatty tissue with reference to its nourishment, which cannot be compensated for operatively. Independently of whether the fat remained vital or was replaced by necroses or granulations, all patients were complaint-free. When the individually variable transformation of fat into granulation or connective tissue takes place, cannot yet be stated. We are investigating this further. Similarly, long-term observations can then explain if variations in the recurrence rate of frontal sinus disease depend on whether the implanted fatty tissue remains vital or becomes necrotic and transformed.

Which consequences arise from the technique of operative obliteration, particularly the choice of material, remains to be seen. The concept of using freshly harvested fat (to remain vital, prevent scar tension and therefore avoid the pulling in of the walls of the frontal sinus, and to prevent re-epithelization from caudal ingrowth has to be taken into consideration when studying our results.

Although MRI allows good differentiation of soft tissue in the obliterated frontal sinus, a histological diagnosis is not possible. There have been no studies which compare magnetic resonance imaging, computerized tomography, and histology after frontal sinus surgery with fat obliteration previously. There is a new role for MRI in patients with persistent post-operative cephalgias, recently arising headaches after a complaint-free interval, or swelling in the forehead and periorbital regions. In acute complications however computerized tomography is still indispensable.

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