

Modified Shoelace Dural Closure With Collagen Matrix in Extended Transsphenoidal Surgery

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Abstract

Extended endonasal transsphenoidal surgery (eTSS) offers a wide surgical field for various parasellar lesions; however, intraoperative high-flow cerebrospinal fluid (CSF) leakage is inevitable. Therefore, secure sellar reconstruction methods are essential to prevent postoperative CSF leakage. Although collagen matrix has been applied for dural reconstruction in neurosurgery, its suitability for application in extended eTSS remains unclear.

Fifteen patients underwent modified shoelace dural closure using collagen matrix after lesionectomy via extended eTSS. In this technique, a collagen matrix, which was placed subdurally (inlay graft), was continuously sutured with both open dural edges like a shoelace. Then, another collagen matrix was placed epidurally (onlay graft), and rigid reconstruction was performed using the septal bone and a resorbable fixation mesh. Postoperative CSF leakage did not occur in fourteen patients, but did in one patient with tuberculum sellae meningioma. In this case, the CSF leakage point was detected just around the area between the coagulated dura and the adjacent collagen matrix. The collagen matrix harvested from this area was pathologically examined; neovascularization and fibroblastic infiltration into the collagen matrix were not detected. On the other hand, neovascularization and fibroblast infiltration into the collagen matrix were apparent on the surface of the collagen matrix harvested from the non-CSF leakage area.

Our novel dural closure technique using collagen matrix could be an effective option for sellar reconstruction in extended eTSS; however, it should be applied in patients in whom normal dural edges are preserved.

Clinical trial registration

Not applicable

Introduction

Endoscopic endonasal transsphenoidal surgery (eTSS) has become the first-line treatment for pituitary adenomas [10, 12, 13, 17, 24]. With the popularization of extended eTSS, various parasellar lesions, including craniopharyngiomas, meningiomas, and chordomas, have been safely and effectively resected via extended eTSS [11, 14, 19, 23, 25]. However, there is a dilemma in that the risk of postoperative cerebrospinal fluid (CSF) leakage increases as the dural opening widens. To overcome this drawback of extended eTSS, several sellar reconstruction methods have been reported in the literature [1, 2, 4–6, 20]. We also have reported on the usefulness of dural suturing using autologous tissue grafts [7, 22]. In particular, shoelace dural closure with autologous fat grafts is one of the most effective and versatile sellar reconstruction methods in extended eTSS; it can minimize the gap between the open edges of the dura mater and achieve watertight dural closure [22]. Although autologous tissue grafts, including those of fat, fascia lata, and pedicled nasoseptal flaps, have been employed as the most reliable materials for sellar reconstruction, harvesting autologous grafts requires additional operations.

In this article, we present a novel sellar reconstruction method using collagen matrix (modified shoelace dural closure) in extended eTSS, which can eliminate the additional harvest of autologous tissue grafts. In Japan, collagen matrix (DuraGen®, Integra Life Sciences) became available in 2019, and it has become an optional material for dural reconstruction in neurosurgery. However, the suitability of collagen matrix for dural closure in extended eTSS with intraoperative high-flow CSF leakage remains unclear because no studies have shown sufficient data on clinical and pathological outcomes after sellar reconstruction using collagen matrix in extended eTSS. Herein, we also assessed the application of collagen matrix as a material for sellar reconstruction in extended eTSS from a pathological viewpoint.

Materials And Methods

Patients

During the study period between August 2019 and August 2021, patients who underwent sellar reconstruction using the modified shoelace dural closure technique with collagen matrix (DuraGen®, Integra Life Sciences) after lesionectomy via extended eTSS were enrolled in this study. The intraoperative findings, operative movies, and postoperative outcomes of these patients were retrospectively reviewed. Patients with postoperative CSF leakage underwent repeated sellar reconstruction surgery using autologous tissue grafts. At the time of reoperation, samples of the collagen matrix that had been implanted in the first surgery were harvested. These samples were evaluated by routine pathological examination. Postoperative magnetic resonance imaging (MRI) was performed one week and 6 months after the surgery. Informed consent for the publication of this article and to undergo surgery was obtained from patients. This study was performed upon approval by the institutional review board at Nagoya University (approval no.: 2020–0590).

Surgical technique

Under general anesthesia with endotracheal intubation, the patient was placed in a supine position with the upper body raised 15 degrees, and the head was fixed in a Sugita four-point head holder® (Mizuho Medical Innovation, Tokyo, Japan). The sellar and suprasellar lesions were accessed via the right transseptal approach using an Endo Arm® (Olympus, Tokyo, Japan). Septal bone was resected and stored as autologous graft material for rigid sellar reconstruction. Sufficient sellar and parasellar bone was removed based on the size and shape of the lesion. Then, the dura mater was incised in an inverted "T" shape (Fig. 1a). After the lesionectomy, the dural opening was repaired using the modified shoelace dural closure technique. The details of the original shoelace dural closure have been previously reported [22].

First, a collagen matrix of sufficient size to cover the dural opening was placed subdurally as an inlay graft. Then, the frontal edge of the dural opening in the planum sphenoidale and upper part of the inlay graft were sutured with 6–0 Prolene double-armed sutures, and a knot was tied and tightly cinched. Subsequently, running suturing of the dura was performed by each needle in a zigzag manner: stitches

were made alternately on both sides of the dura, minimizing the gap between the open edges of the dura. It was important to also suture the inlay graft to the dura with each suture to prevent unexpected migration of the inlay graft. After dural suturing to the bottom edge of the dural opening, a knot was tied and tightly cinched with a curette. However, watertight dural closure is never achieved at this point because of a small gap between the open edges of the dura and the porous nature of the collagen matrix (Fig. 1b). Thus, another collagen matrix was placed epidurally as an onlay graft and was fixed by laying its edges under the surrounding bone (Fig. 1c). After the septal bone was placed onto the onlay graft (Fig. 1d), a resorbable fixation mesh (LactoSorb®, Medical U&A, Inc., Osaka, Japan) of an adequate size was fixed under the edge of the bony window (Fig. 1e). After confirming the absence of CSF leakage by performing a Valsalva maneuver, the bony window was covered with a pedicled sphenoid sinus mucosal flap, if available (Fig. 1f). Finally, fibrin glue was spread on the sellar floor. The practical method of this technique is shown in Video 1. Vascularized nasoseptal flaps and lumbar drainage were not used in any patients.

Results

A total of fifteen patients underwent modified shoelace dural closure after lesionectomy via extended eTSS. The patients included seven males and eight females, with a mean age of 50.3 years (range, 9–74 years) at the time of surgery. The clinical diagnosis was craniopharyngioma in seven patients, pituitary adenoma, meningioma, and Rathke's cleft cyst in two patients, and sellar arachnoid cyst and xanthogranuloma in one patient. Two cases of craniopharyngioma and one of pituitary adenoma were recurrent cases. Intraoperative CSF leakage was classified as grade 3 based on Esposito's CSF leak grading system [3] in all patients.

Postoperative CSF leakage was detected in one patient with tuberculum sella meningioma. In this case, the dura of the tuberculum sella, which was the tumor origin, was sharply resected; the surrounding dura was coagulated with bipolar forceps in the first surgery (Fig. 2a). The area between the coagulated dura and the adjacent collagen matrix was detected as the CSF leakage point in the repeated surgery 3 weeks after the first surgery (Fig. 2b). Previously implanted collagen matrix was thoroughly removed, and sellar reconstruction was performed using autologous fat and fascia lata grafts. Pathological examination revealed inflammatory cells on the surface of the collagen matrix harvested from the CSF leakage area; neovascularization and fibroblast infiltration into the collagen matrix were not detected (Fig. 2c and d). On the other hand, neovascularization and fibroblast infiltration into the collagen matrix were apparent on the surface of the collagen matrix harvested from the non-CSF leakage area (Fig. 2e and f).

Postoperative MRI in patients without postoperative CSF leakage showed clear enhancement of the neoplastic dura mater after gadolinium injection (Fig. 3).

Discussion

Extended eTSS can provide a wide surgical field from the sella turcica to the parasellar region. Several parasellar lesions can be safely and effectively resected using this method [11, 14, 19, 23, 25]; however, intraoperative high-flow CSF leakage is inevitable. Thus, secure sellar reconstruction methods are essential to prevent postoperative CSF leakage. Our dural closure technique using collagen matrix has the following advantages.

First, a second operation is not required for harvesting autologous tissue grafts. Harvesting fat and/or fascia lata grafts from the abdomen or thigh may lead to postoperative morbidities, including postoperative pain, hematoma formation, or wound infection. Moreover, pedicled nasoseptal flap harvesting can result in postoperative nasal complications, including septal perforation, prolonged crusting, or cartilage necrosis [6, 8, 21]. Our sellar reconstruction method can eliminate these complications, minimizing the surgical trauma experienced by affected patients.

Second, the collagen matrix has large pores that can facilitate fibroblastic ingrowth, resulting in neomembrane formation [9, 15, 16]. In this study, neomembrane formation accompanied by neovascularization was also demonstrated on postoperative MRI (Fig. 3). Moreover, histopathological examination showed that neovascularization in the collagen matrix was already apparent at three weeks after implantation (Fig. 2e and f). These properties of collagen matrix in the early to middle postoperative period can lead to secure sellar reconstruction.

Third, the basis of our technique is multilayer closure, the significance of which has been reported in the literature [18] in dural closure using autologous tissue grafts. As mentioned above, collagen matrix has large pores; thus, high-flow CSF leakage cannot be managed with a single layer of collagen matrix. Therefore, our technique using two collagen matrixes as inlay and onlay grafts and using septal bone and a resorbable fixation mesh for rigid reconstruction seems to be reasonable.

In the only patient with postoperative CSF leakage in this study, the postoperative CSF leakage occurred in the area between the coagulated dura and the adjacent collagen matrix, which indicates that normal adjacent dura is essential for valid neovascularization into the collagen matrix and neomembrane formation. Indeed, neither neovascularity nor fibroblastic infiltration into the collagen matrix adjacent to the impaired dura was detected by histopathological examination (Fig. 2c and d). On the other hand, no postoperative CSF leakage was detected in the other fourteen patients in whom the normal dural edges were preserved. Therefore, our novel dural closure technique should be adopted in patients in whom normal dural edges are preserved. Moreover, patients with parasellar lesions that have previously been treated by radiation therapy should also not be considered candidates for this technique.

Conclusions

In this article, we demonstrated a novel dural closure technique using collagen matrix in extended eTSS, i.e., modified shoelace dural closure. Additional operations for harvesting autologous tissue grafts were not needed, reducing the surgical trauma. This technique could serve as an excellent option for sellar reconstruction in selected patients with a minimal rate of postoperative CSF leakage.

Declarations

Funding

The authors did not receive support from any organization for the submitted work.

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Availability of data and material

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Code availability

Not applicable

Author's contributions

Conceptualization and design: Yuichi Nagata; Data acquisition: Yuichi Nagata, Hiroo Sasaki, Akihiro Mizuno, Hideyuki Harada, and Kazuhito Takeuchi; Formal analysis and data interpretation: Yuichi Nagata and Kazuhito Takeuchi; Writing - original draft preparation: Yuichi Nagata; Writing - review and editing: Yuichi Nagata, Kuniaki Tanahashi, and Yoshio Araki; and Supervision: Kazuhito Takeuchi and Ryuta Saito. Yuichi Nagata has read and approved the final version of the manuscript on behalf of all authors.

Ethics approval

This study was performed upon approval by the institutional review board at Nagoya University (approval no.: 2020–0590).

Consent to participate

Informed consent was obtained from all patients included in the study.

Consent for publication

Informed consent for the publication of this article was obtained from patients.

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Figures

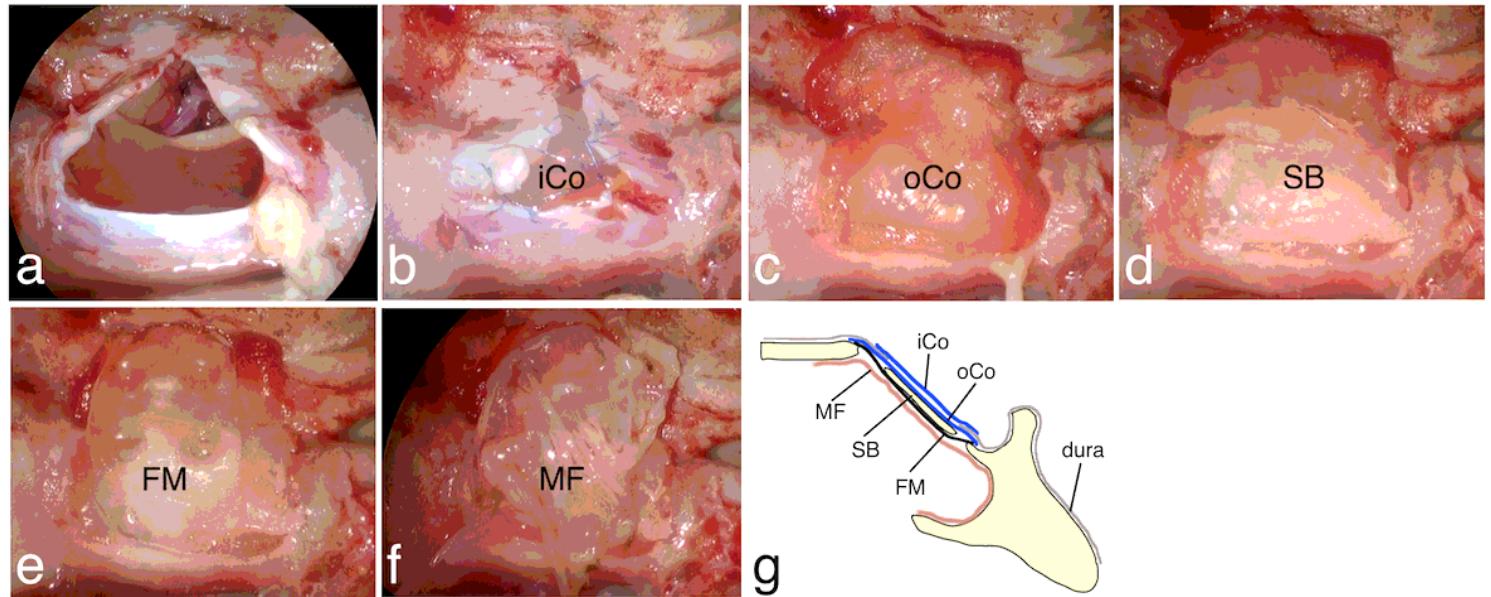


Figure 1

Intraoperative photos presenting the step-by-step process of modified shoelace dural closure. a) The dura mater from the sella turcica to planum sphenoidale is incised in an inverted “T” shape. b) Shoelace running suturing of the dura with an inlay collagen matrix (iCo); stitches are made alternately on both sides of the dura, minimizing the gap between the open edges of the dura. c) Another collagen matrix (onlay collagen matrix, oCo) is placed epidurally as an onlay graft and is fixed by laying its edges under the surrounding bone. d) Septal bone (SB) is placed onto the oCo. e) Then, rigid reconstruction is performed using a resorbable fixation mesh (FM). f) Finally, the bony window is covered with a pedicled sphenoid sinus mucosal flap (MF). g) Cross-sectional diagram of the method.

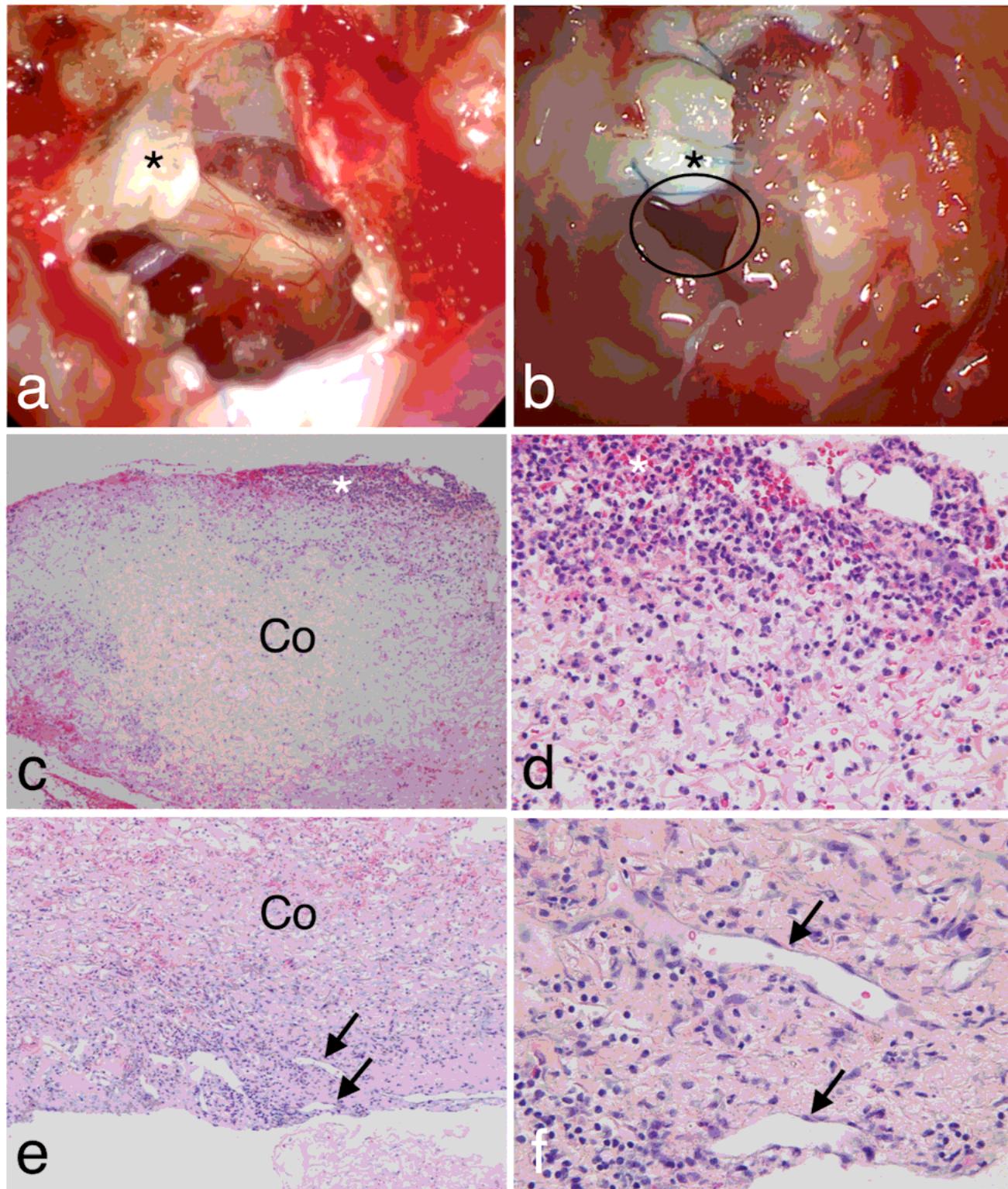


Figure 2

Intraoperative and histopathological findings of the patient with postoperative CSF leakage. a) Intraoperative photo after tumor resection via extended eTSS (first surgery). The dura of the tuberculum sella was sharply resected. The surrounding dura (black asterisk) was coagulated with bipolar forceps. b) Intraoperative photo of repeated surgery for dural repair. The area between the coagulated dura and the adjacent collagen matrix was detected as the CSF leakage point (black circle). The other part of the

collagen matrix was well adhered to the adjacent dura. c, d) Histopathological findings of the collagen matrix (Co) harvested from the CSF leakage area. Moderate inflammatory cell infiltration was detected on the surface of the collagen matrix (white asterisk). Neovascularization and fibroblast infiltration into the collagen matrix were not detected. (Hematoxylin and eosin staining, C: $\times 100$, D: $\times 400$.) e, f) Histopathological findings of the collagen matrix harvested from the non-CSF leakage area. Neovascularization (black arrow) and fibroblast infiltration into the collagen matrix were apparent on the surface of the collagen matrix. (Hematoxylin and eosin staining, E: $\times 100$, F: $\times 400$.)

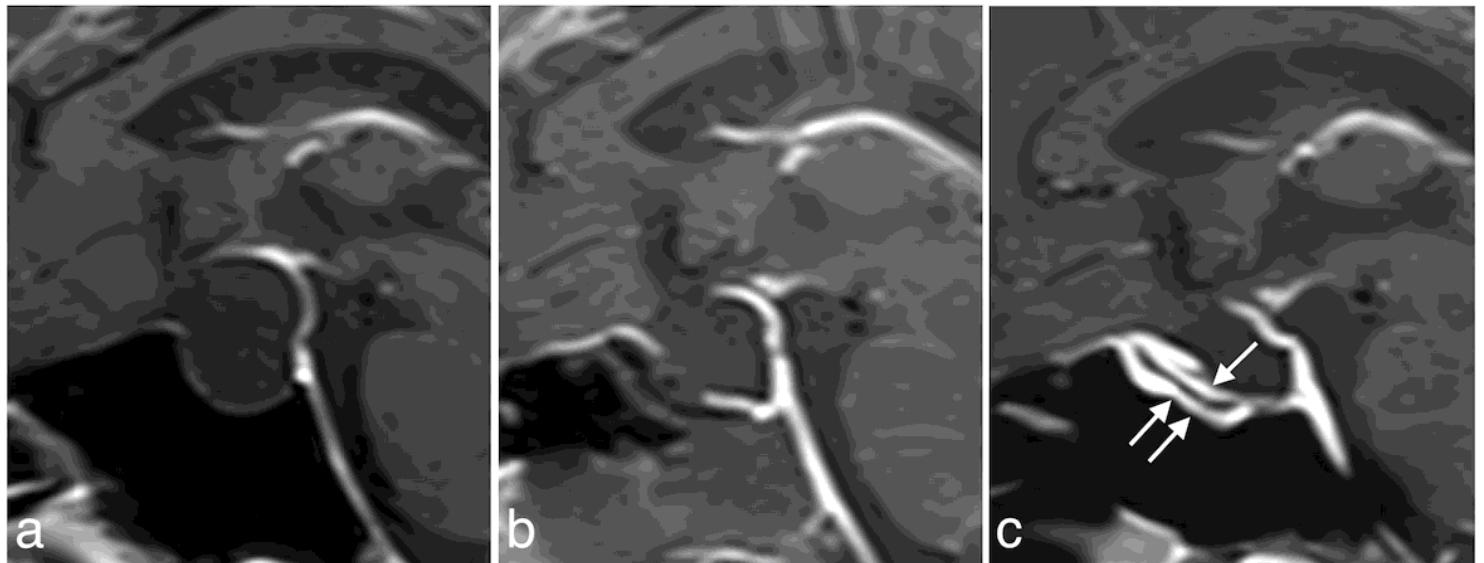


Figure 3

Preoperative and postoperative gadolinium-enhanced T1-weighted sagittal MRI of the patient with a sellar arachnoid cyst. a) Preoperative MRI showing a cystic sellar lesion with suprasellar extension. b) Postoperative MRI obtained one week after cyst fenestration via extended eTSS showing no enhancement of the collagen matrix implanted for sellar reconstruction after gadolinium injection. c) Postoperative MRI obtained six months after cyst fenestration showing clear enhancement of the sphenoid sinus mucosal flap (white double arrow) and the neomembrane (white arrow), indicating neovascularization of the neomembrane.

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