ORIGINAL ARTICLE doi: 10.2176/jns-nmc.2021-0355

Neurol Med Chir (Tokyo) 62, 203-208, 2022 Online March 16, 2022

Modified Shoelace Dural Closure with Collagen Matrix in Extended Transsphenoidal Surgery

Yuichi NAGATA,[1] Kazuhito TAKEUCHI,[1] Hiroo SASAKI,[1] Akihiro MIZUNO,[1] Hideyuki HARADA,[1] Kuniaki TANAHASHI,[1] Yoshio ARAKI,[1] and Ryuta SAITO[1]

[1]*Department of Neurosurgery, Nagoya University Graduate School of Medicine, Nagoya, Aichi, Japan*

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. Eighteen 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 17 patients but did occur in 1 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.

Keywords: dural closure, sellar reconstruction, shoelace closure, collagen matrix, DuraGen

Introduction

Endoscopic endonasal transsphenoidal surgery (eTSS) has become the first-line treatment for pituitary adenomas.[1-5] With the popularization of extended eTSS, various parasellar lesions, including craniopharyngiomas, meningiomas, and chordomas, have been safely and effectively resected via extended eTSS.[6-10] 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.[11-16] We have also reported on the usefulness of dural suturing using autologous tissue grafts.[17,18] 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.[18] 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 LifeSciences, Plainsboro, NJ,

Received November 8, 2021; Accepted January 13, 2022

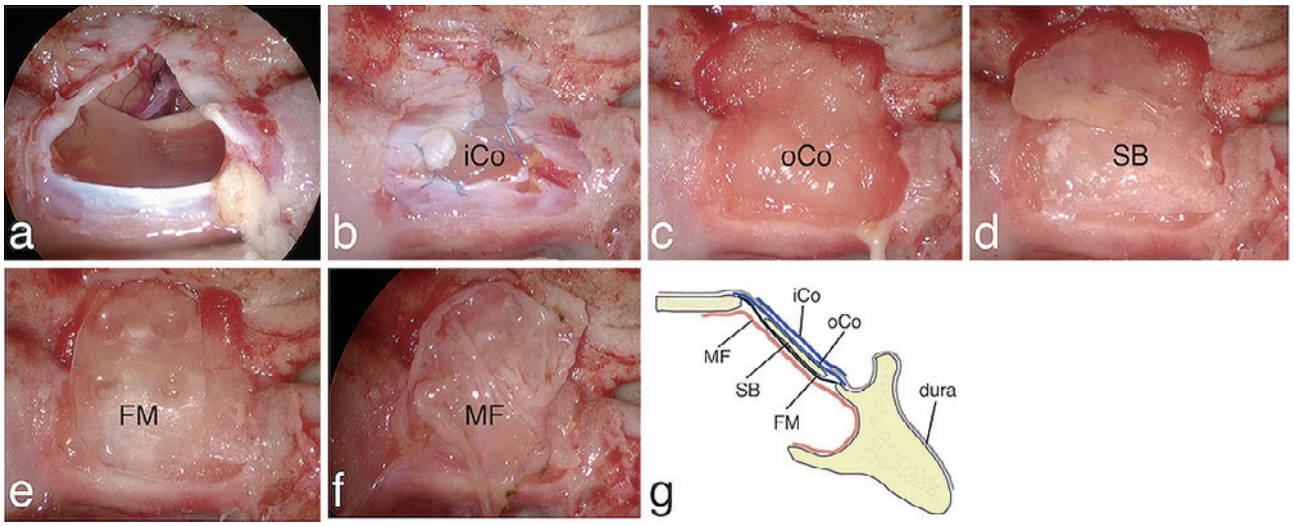

Fig. 1 Intraoperative photos presenting the step-by-step process of modified shoelace dural closure. a) The dura mater from the sella turcica to the planum sphenoidale is incised in an inverted "T" shape. b) Shoelace running suturing of the dura with an inlay collagen matrix (iCo); stitches are made 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 was covered with a pedicled sphenoid sinus mucosal flap (MF). g) Cross-sectional diagram of the method.

USA) 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 October 2021, patients who underwent sellar reconstruction using the modified shoelace dural closure technique with collagen matrix (DuraGen; Integra LifeSciences, Plainsboro, NJ, USA) 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 1 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 at 15°, 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.[18]

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

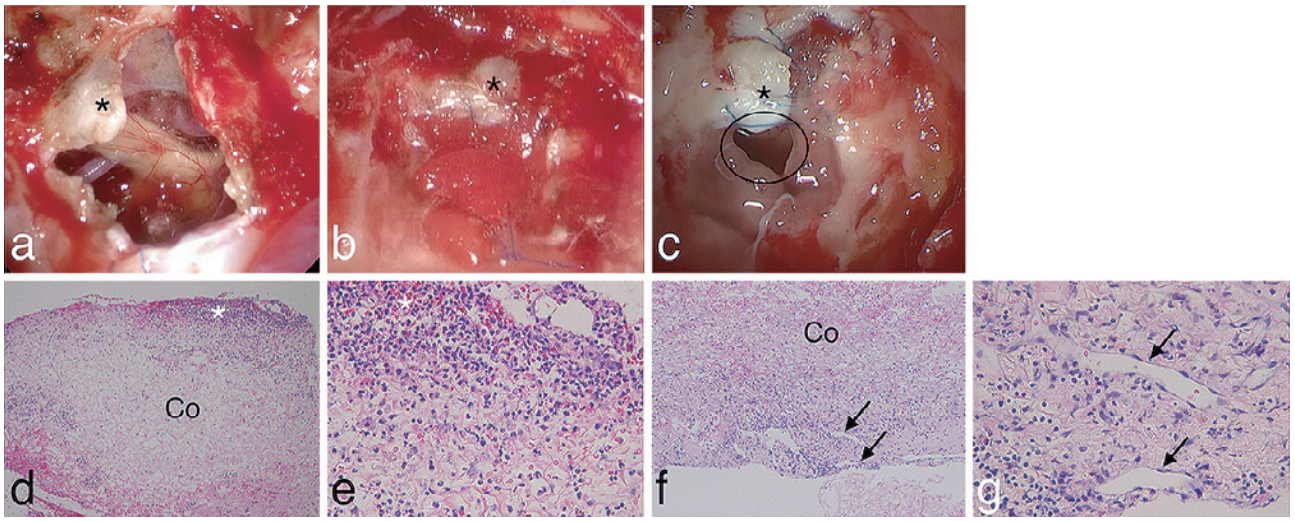

Fig. 2 Intraoperative and histopathological findings of the patient with postoperative CSF leakage. a) Intraoperative photo after tumor resection via extended eTSS (first surgery). The dura of the tuberculum sellae was sharply resected. The surrounding dura (black asterisk) was coagulated with bipolar forceps. b) Intraoperative photo after modified shoelace dural closure with an inlay collagen matrix (first surgery). The dura mater was tightly sutured with the inlay collagen matrix, minimizing the gap between the open edges of the dura. Black asterisk: coagulated dura. c) Intraoperative photo of repeated surgery for dural repair. The area between the coagulated dura (black asterisk) 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. d, e) Histopathological findings of the collagen matrix (Co) harvested from the CSF leakage area. Moderate inflammatory cell infiltration was detected on the surface of the Co (white asterisk). Neovascularization and fibroblast infiltration into the Co were not detected. (Hematoxylin and eosin staining, d: ×100, e: ×400.) f, g) Histopathological findings of Co harvested from the non-CSF leakage area. Neovascularization (black arrow) and fibroblast infiltration into the Co were apparent on the surface of the Co. (Hematoxylin and eosin staining, f: ×100, g: ×400.)

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. Cross-sectional diagram of the method is shown in Fig. 1g. 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 18 patients underwent modified shoelace dural closure after lesionectomy via extended eTSS. The patients included nine males and nine females, with a mean age of 50.6 years (range, 9-74 years) at the time of surgery. The clinical diagnosis was craniopharyngioma in 10 patients; pituitary adenoma, meningioma, and Rathke's cleft cyst in 2 patients; and sellar arachnoid cyst and xanthogranuloma in 1 patient. Three cases of craniopharyngioma and one case of pituitary adenoma were recurrent cases. Intraoperative CSF leakage was classified as grade 3 based on Esposito's CSF leak grading system[19] in all patients.

Postoperative CSF leakage was detected in one patient with tuberculum sellae meningioma. In this case, the dura of the tuberculum sellae, which was the tumor origin, was sharply resected; the surrounding dura was coagulated with bipolar forceps in the first surgery (Fig. 2a and b). 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. 2 c). The 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. 2d and e). On the other hand, neovascularization and fibroblast infiltration into the

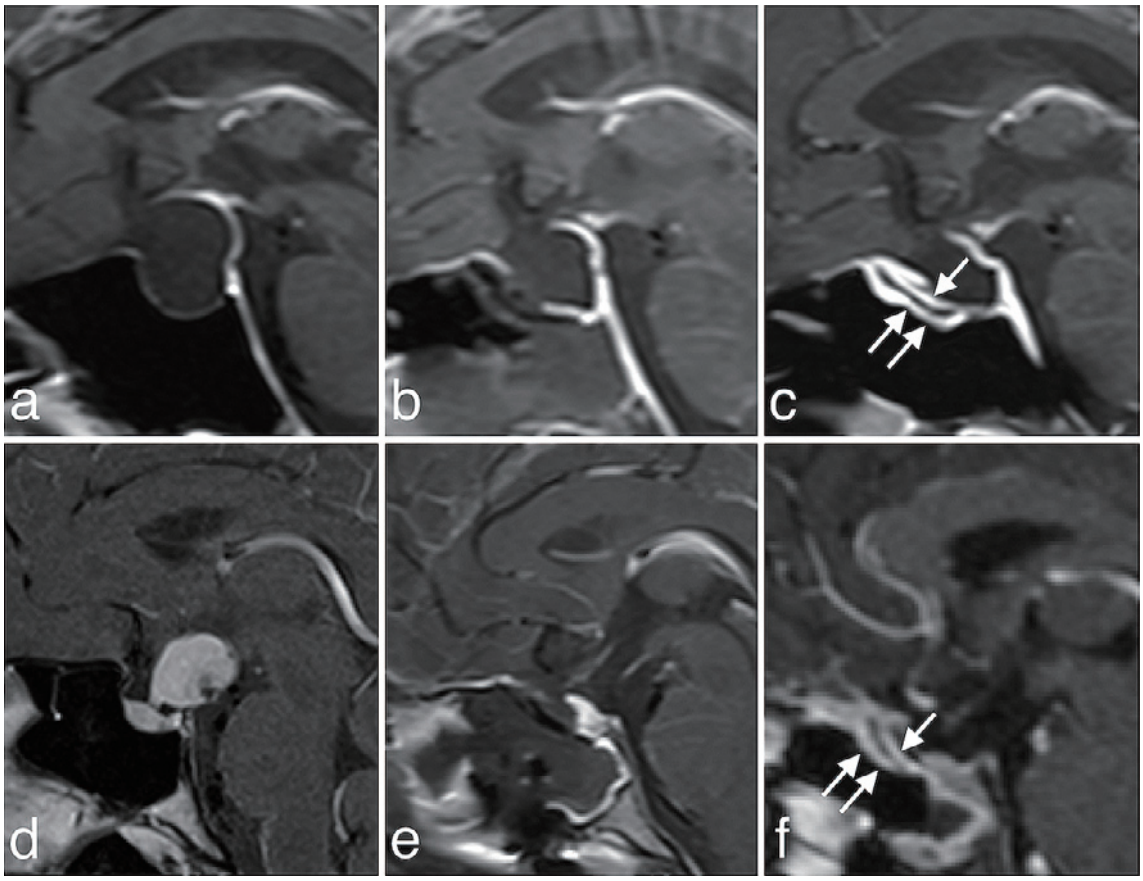

Fig. 3 Preoperative and postoperative gadolinium-enhanced T1-weighted sagittal MRI of the patient with a sellar arachnoid cyst (a–c) and the patient with a craniopharyngioma (d–f). a) Preoperative MRI showing a cystic sellar lesion with suprasellar extension. b) Postoperative MRI obtained 1 week after cyst fenestration via extended eTSS showing no enhancement of the collagen matrix implanted for sellar reconstruction after gadolinium injection. c) Postoperative MRI obtained 6 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. d) Preoperative MRI showing a solid suprasellar lesion. e) Postoperative MRI obtained 1 week after tumor resection via extended eTSS showing no enhancement of the collagen matrix implanted for sellar reconstruction after gadolinium injection. f) Postoperative MRI obtained 6 months after tumor resection showing clear enhancement of the sphenoid sinus mucosal flap (white double arrow) and the neomembrane (white arrow), indicating neovascularization of the neomembrane.

collagen matrix were apparent on the surface of the collagen matrix harvested from the non-CSF leakage area (Fig. 2f and g).

Clear enhancement of the neoplastic dura mater after gadolinium injection was detected in 8 of 10 patients who underwent 6-month postoperative MRI (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;[6-10] 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 a 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.[15,20,21] 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.[22-24] 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 3 weeks after implantation (Fig. 2f and g). These properties of the 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[25] in dural closure using autologous tissue grafts. As mentioned above, the 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 appears to be reasonable.

In the only patient with postoperative CSF leakage in this study, 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. 2d and e). On the other hand, no postoperative CSF leakage was detected in the other 17 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 not be considered candidates for this technique.

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

Supplementary Material

https://doi.org/10.2176/jns-nmc.2021-0355

Acknowledgments

None.

Abbreviations

CSF: cerebrospinal fluid, eTSS: endonasal transsphenoidal surgery, MRI: magnetic resonance imaging

Clinical Trial Registration

None.

Data availability

None.

Conflicts of Interest Disclosure

All authors have no conflict of interest.

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Corresponding author: Yuichi Nagata, M.D., Ph.D.
Department of Neurosurgery, Nagoya University Graduate School of Medicine, 65 Tsurumai-cho, Showa-ku, Nagoya, Aichi 466-8550, Japan.
e-mail: you1ngta@gmail.com