Histological Examination of Expanded Polytetrafluoroethylene Artificial Dura Mater at 14 Years After Craniotomy
—Case Report—

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Abstract

Expanded polytetrafluoroethylene (ePTFE) porous material (GORE® PRECLUDE® Dura Substitute) does not degenerate or deteriorate in vivo, and is currently used as artificial dura mater. This material does not adhere well to the surrounding tissues, but cerebrospinal fluid leakage along the suture line has been observed in several cases. We describe a case of craniotomy for tumor resection performed 14 years after dural repair with ePTFE sheet. Histological examination of the ePTFE sheet revealed that the sheet was structurally intact, with no evidence of tissue adhesion or cellular infiltration. However, collagen deposition was observed around the suture thread. When the suture thread was removed the collagen was also removed, and the original needle hole appeared again. No significant changes were observed in the features of the ePTFE sheet even 14 years postoperatively. The formation of fibrous tissue around the needle hole was important in preventing cerebrospinal fluid leakage.

Key words: cerebrospinal fluid leakage, expanded polytetrafluoroethylene, tissue adhesion, artificial dura mater, craniotomy
Introduction

Artificial dural substitute made from expanded polytetrafluoroethylene (ePTFE) porous material, GORE® PRECLUDE® Dura Substitute (W.L. Gore & Associates, Inc., Flagstaff, Arizona, USA), has been commonly used as artificial dura mater since the material does not degenerate or deteriorate and does not adhere to the surrounding tissue.\(^9\,^{16}\) However, cerebrospinal fluid leakage along the suture line has been observed in several cases.\(^8\,^{16}\,^{17}\) Various measures, such as the mesh-and-glue technique\(^9\) using GORE-TEX® Suture (W.L. Gore & Associates, Inc.; needle/thread ratio = 1.0\(^{17}\)) and laying ePTFE sheet under the autologous dura mater,\(^6\) have been undertaken to prevent such cerebrospinal fluid leakage. Long-term results for use of ePTFE sheet have been reported after 15–65 months. Operation findings and imaging tests did not show adhesion between the ePTFE sheet and the surrounding tissue.\(^3\,^{4}\,^{10}\) However, the histological changes associated with the insertion of ePTFE sheet as artificial dura mater at more than 10 years after surgery remain unclear.

We describe a case of craniotomy for tumor resection in a patient in whom ePTFE sheet had been previously inserted 14 years ago, which allowed examination of the histological changes in and around the artificial dura mater, specifically at the suture region that has been implicated in cerebrospinal fluid leakage and adhesion.

Case Report

A 70-year-old male suffering from headache, gait disturbance, and memory disturbance presented with tumor regrowth to our institution. The patient had undergone resection of a meningioma in the outer circle of right calvarium via craniotomy 14 years ago, with insertion of ePTFE sheet as artificial dura mater. The margins were sutured with autologous dura mater and ePTFE sheet, separately, in different areas.

Craniotomy was performed for the removal of the recurrent tumor. The previously used ePTFE sheet was entirely removed after separation of the surgical sutures from the autologous dura mater and replaced with a new artificial dura during the resection of the recurrent tumor. The removed artificial dura measured approximately 8.0 × 5.0 cm, and consisted of 2 sections sutured with simple interrupted sutures. The material was essentially devoid of soft tissue, with only scattered foci of flat tan-yellow tissue plaques of tissue. The sample was sectioned for microscopic examination as follows: across the suture line (Section A), across one of the suture holes along the periphery (Section B), across peripheral suture holes (Section C), and longitudinally across the membrane joining the suture line (Section D) (Fig. 1).

Histological examination with hematoxylin and eosin (HE) and trichrome (collagen) stain found that the ePTFE sheet biomaterial was structurally intact with no evidence of tissue adhesion or cellular infiltration. Multiple small

Fig. 1 Photograph of the expanded polytetrafluoroethylene sheet specimen. A, B, C, and D indicate the lines along with the sample was cut to form Sections A, B, C, and D, respectively, for histological examination.

Fig. 2 Photomicrographs showing a deposit of proteinaceous tissues with small numbers of embedded degenerate cells adjacent to the biomaterial (A), and multiple foci of mineralization but no tissue within the biomaterial (B). This indicates that the tissue did not infiltrate the biomaterial. Hematoxylin and eosin stain, original magnification ×200 (A), ×100 (B).

Fig. 3 Photomicrographs showing an empty suture hole at the periphery of the specimen (A: hematoxylin and eosin stain, original magnification ×20) and another suture hole in the expanded polytetrafluoroethylene sheet filled by multifilamented suture within which fine collagen (blue green) fibrils are integrated (B: trichrome stain, original magnification ×20). The higher magnification view indicates that the suture consists of orange-red fibrils and the collagen is blue-green (C: trichrome stain, original magnification ×40).

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foci of mineralization were noted within the biomaterial. No evidence of inflammation was observed. Section A consisted of two portions of the ePTFE sheet with a central suture hole. The biomaterial was structurally intact with no tissue adhesion. A thin film of proteinaceous tissue containing a small number of embedded degenerate cells was found adjacent to the biomaterial (Fig. 2). Section B consisted of a single section of ePTFE sheet. Histological findings were similar to those in Section A, except for the presence of numerous small foci of mineralization within the interstices of the biomaterial. No trichrome-stained tissue was observed (Fig. 2).

Overall, the needle holes contained remnants of multi-filamented suture integrated with a small number of fine collagenous fibrils. Section A included an empty suture hole from the periphery of the specimen. Positive trichrome staining was observed in small regions in both Sections C and D, which contained membrane with suture holes with remnants of multi-filamented suture. Fine trichrome-positive collagen fibrils were embedded within the suture (Fig. 3).

**Discussion**

ePTFE material has been used for various purposes in different parts of the body; for example, large-caliber vascular replacements,\(^1\) pericardial closure following coronary bypass grafting,\(^1\) abdominal wall substitute in hernia repair,\(^2\) and patch angioplasty following carotid endarterectomy.\(^3\) Microscopic examination of ePTFE grafts inserted into the iliac arteries of rats and removed between 3 and 22 months postoperatively identified long-term histological change.\(^4\) In addition, anastomotic intimal hyperplasia was minimal and a few smooth muscle cells extended 100–200 μm onto the graft.\(^5\) Collagen deposition and neovascular proliferation were observed in the inner portion of Gore-Tex, using an animal model. Partial calcification and tissue degeneration were also observed.\(^6\) Cadaveric dura had been used in dural repair, but the risk of Creutzfeldt-Jakob disease was reported with the use of cadaveric dura in 1980.\(^7\) Nowadays, cadaveric dura is not used, and has been replaced by artificial dura mater. The long-term use of ePTFE sheet as artificial dura mater in vivo still required study to determine its efficacy.

In the present case, we removed an ePTFE sheet 14 years after tumor resection via craniotomy and examined its histological features. Our findings revealed that even 14 years after insertion, the ePTFE sheet membrane showed only the presence of small foci of mineralization, and no tissue adhesion or cellular infiltration. ePTFE sheet is known not to adhere easily to the surrounding tissues; this characteristic did not change even after the long period of 14 years. Our findings demonstrate the in vivo stability of ePTFE sheet.

Absence of adhesion is advantageous for surgery that requires repeat operation (for example, decompressive craniotomy), but this characteristic tends to result in cerebrospinal fluid leakage. ePTFE sheet has very low adhesiveness to fibrin glue and surrounding tissue.\(^8\) Fluid leakage has been reported to occur easily when ePTFE sheet is used, possibly because of the formation of only a thin layer of fibrous tissue.\(^9\) The formation of fibrous tissue along the dura mater is important for preventing the cerebrospinal fluid leakage. When fascia is used for overcoming this defect in the original dura mater, stable fibrous tissue is formed in the surroundings postoperatively within 1 week; therefore, fluid leakage does not occur easily. Improvement of cell adhesion and prevention of cerebrospinal fluid leakage by ion beam irradiation of ePTFE membrane was also reported.\(^10\)

In our study, we observed collagen deposition around the suture holes and the suture material. Such collagen is considered to act as a barrier that stops the leakage of spinal fluid from the needle hole. However, collagen was not observed in the needle hole that formed after the suture was removed. The collagen was possibly removed along with the suture. Apparently the presence of fibrous tissue, such as the thin layer of collagen, is involved in the prevention of cerebrospinal fluid leakage.

This histological study of ePTFE sheet removed 14 years after craniotomy revealed foci of mineralization but no tissue adhesion or cellular infiltration. Collagen deposition was observed around the suture line, which prevented the flow of cerebrospinal fluid through the needle holes. Removal of the suture thread displaced the surrounding collagen, with reappearance of the original needle hole.

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**Conflicts of Interest Disclosure**

None. All authors who are members of The Japan Neurosurgical Society (JNS) have registered online Self-reported COI Disclosure Statement Forms through the website for JNS members.

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