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ORIGINAL ARTICLE - TUMOR - OTHER

Postoperative subdural hematoma with blood flow from an epidural hematoma through a tear at the suture point of an artificial dura substitute

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Abstract

Objective We have recently seen cases of postoperative epidural and subdural hematomas after duraplasty with an artificial dura substitute. In these cases, the epidural hematoma flowed into the subdural space through a tear at the suture point of the artificial dura substitute. In this study, whether such hematomas are specific to a certain artificial dura substitute was investigated, and the cause and risk factors were examined.

Methods In our institute, 46 patients underwent brain tumor extirpation with duraplasty with an artificial dura substitute; Gore-Tex and SEAMDURA were used as the artificial dura substitutes. Patients with postoperative hemorrhage after brain tumor extirpation with duraplasty with an artificial dura substitute were retrospectively analyzed. Moreover, suture strength was compared experimentally between Gore-Tex and SEAMDURA.

Results In patients who underwent brain tumor extirpation with duraplasty with an artificial dura substitute, the rate of postoperative hemorrhage was 8.6%. Epidural and subdural hematomas were seen in four patients after tumor extirpation with duraplasty with SEAMDURA, but there were none with Gore-Tex. Exposure of the superior sagittal sinus at craniotomy, older age, and longer operative time were seen more frequently in patients with hematoma than in patients without hematoma. The strength of the suture point was significantly weaker with SEAMDURA than with Gore-Tex ($P = 0.00016$).

Conclusions Postoperative epidural and subdural hematomas seem to be specific for SEAMDURA and may be caused by the weak suture strength of SEAMDURA. In cases of duraplasty, a nonabsorbable artificial dura substitute may be suitable.

Keywords Artificial dura substitute · Duraplasty · Postoperative hemorrhage

Introduction

In neurosurgery, duraplasty is needed when a large dural defect occurs. Several dura substitutes, such as autografts or artificial materials, have been used for duraplasty [16]. When duraplasty is performed, meticulous closure or watertight duraplasty is usually recommended to prevent leakage of cerebrospinal fluid [11]. Several artificial materials, such as expanded-polytetrafluoroethylene (e-PTFE), polyglycolic acid (PGA), or collagen matrix, have often been used because of their pliability and ease of use [16]. In Japan, Gore-Tex (WL Gore & Associates, Flagstaff, AZ, USA), which is a nonabsorbable artificial dura substitute made of e-PTFE, has been commonly used. SEAMDURA (GUNZE, Kyoto, Japan), which is an absorbable translucent artificial dura substitute made of poly-L-lactide copolymer and ε-caprolactone copolymeric film layered with PGA, has also been used. Some neurosurgeons prefer SEAMDURA because the condition of the brain's surface can be observed through SEAMDURA.

On the other hand, postoperative hemorrhage after craniotomy sometimes occurs, causing difficulties for both the patient and the neurosurgeon. Although investigations of risk factors for postoperative hemorrhage after craniotomy have been reported, there have been few studies of the relationships between postoperative hemorrhage and duraplasty with an artificial dura substitute. We have recently seen some cases of postoperative epidural and subdural hematomas requiring hematoma

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evacuation after brain tumor extirpation with duraplasty with SEAMDURA. In these cases, the epidural hematoma flowed into the subdural space through a tear of the SEAMDURA at the suture point. Based on this experience, several questions arose: whether duraplasty with an artificial dura substitute facilitated postoperative hemorrhage; whether the postoperative epidural and subdural hematomas that we had seen were specific to SEAMDURA; and if such postoperative hemorrhage was specific to SEAMDURA, whether SEAMDURA might have weaker suture strength than Gore-Tex, and what were the risk factors for such hemorrhage.

In this study, to answer these questions, patients with postoperative hemorrhage after brain tumor extirpation with duraplasty with an artificial dura substitute were retrospectively analyzed. Moreover, suture strength was compared experimentally between Gore-Tex and SEAMDURA.

Materials and methods

This study was approved by the institutional review board of our hospital. The prospectively maintained database of our hospital was searched for patients who underwent craniotomy between January 2012 and December 2017. Medical records, radiographic studies, and operative reports were reviewed retrospectively.

Surgical procedure

After tumor extirpation, duraplasty with the artificial dura substitute was performed. Meticulous closure with a 3-0 nylon monofilament and fibrin glue was performed. Tack-up suture between the artificial dura substitute and bone flap was performed to avoid epidural hematomas. Subcutaneous drainage was placed in all cases. Five neurosurgeons operated as described above in this study.

Artificial dura substitutes

Two artificial dura substitutes, Gore-Tex and SEAMDURA, were used. The selection of artificial dura substitute was up to the attending neurosurgeon. In this study, the patients were divided into two groups according to the kind of artificial dura substitute used: Gore-Tex (G group) and SEAMDURA (S group).

Definition of postoperative hemorrhage

In this study, postoperative hemorrhage was defined as intracranial hemorrhage, including intraparenchymal, subdural, and epidural hematomas, that appeared within 1 week after the operation and required hematoma evacuation.

Patient population

A total of 46 patients underwent tumor extirpation duraplasty with an artificial dura substitute at our institute between January 2012 and December 2017. Among these 46 patients, Gore-Tex was used in 25 patients (G group), and SEAMDURA was used in 21 (S group). These 46 patients were analyzed, and their clinical characteristics are summarized in Table 1.

Study design

Clinical study

Clinical factors, including age, sex, diagnosis, and postoperative hemorrhage, were obtained from the patients' medical records. Surgical procedure, the kind of artificial dura substitute, and the experience of the five surgeons were obtained from operative reports. Locations of postoperative hemorrhage were obtained from radiographic records. First, the postoperative hemorrhage rate was compared between the G group and S group. Second, risk factors related to postoperative epidural and subdural hematomas after brain tumor extirpation were investigated in the S group.

Experimental study

To compare the strength of the suture point between the two groups, experimental validation was performed using $1 \times 3\text{-cm}^2$ oblong sheets of each artificial substitute. Suture was performed with a 3-0 nylon monofilament, with a 5-mm margin from the edge (Fig. 1a). With fixation at the opposite edge, the suture was pulled by a balance, and the weight at which the sheet of the artificial dura substitute split was measured (Fig. 1b). First, this protocol was performed immediately after suturing at room temperature. Second, it was done 48 h after incubation in 40 °C saline. Each procedure was repeated four times for each material and set.

Statistical analysis

Statistical analysis was performed using Fisher's exact test, the chi-squared test, Welch's *t* test, and the Mann-Whitney *U* test to compare the postoperative hemorrhage rate and clinical characteristics. All values are expressed as means and

Table 1 Comparison of the clinical characteristics between the Gore-Tex and SEAMDURA groups

	Gore-Tex (G group) $N = 25$	SEAMDURA (S group) $N = 21$	P value
Age (y)	63.6 ± 12.8	68.5 ± 11.3	0.16†
Sex (M:F)	11:14	10:11	0.7*
Exposure of the SSS	4	4	0.54*
Posterior fossa surgery	5	5	0.51*
Operation time (min)	297.4 ± 100	203.8 ± 77.6	0.0001†
Anticoagulant or antiplatelet medications	3	3	0.57*
Tumor pathology			0.52‡
Meningioma	18	11	
Glioma	4	3	
Metastatic	2	3	
Others	1	4	
Experience of the surgeon			0.50
1–9 years	3	0	
10–15 years	9	11	
16–20 years	6	10	
> 21 years	7	0	

† Student's t test, * Fisher's exact test, ‡ Chi-squared test, Mann-Whitney U test

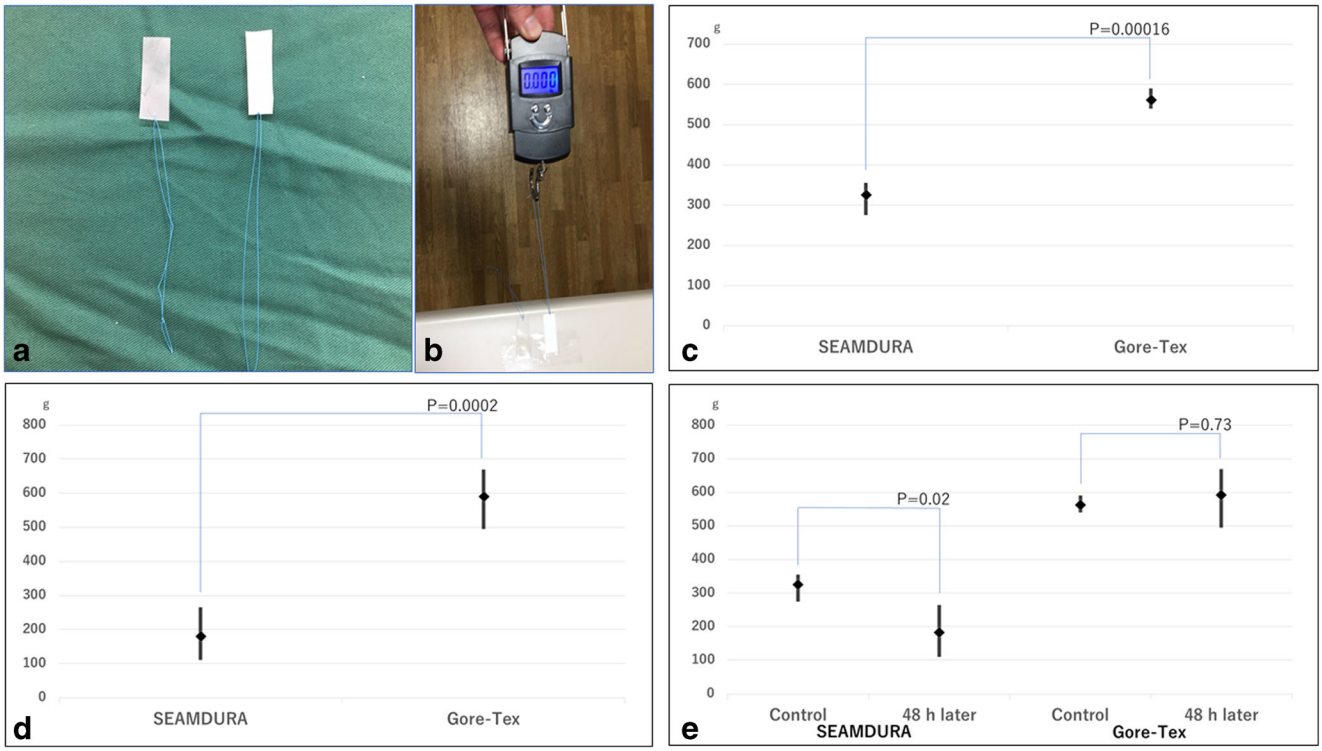

Fig. 1 Experimental comparison of the strength of the suture point. **a** 1 × 3-cm^2 oblong sheets of artificial substitutes with suture with a 3-0 nylon monofilament and a 5-mm margin from the edge (left: SEAMDURA, right: Gore-Tex). **b** Measuring the weight of splitting the sheet of the artificial dura substitute by a balance. **c** The strength of the suture point is significantly weaker with SEAMDURA than with Gore-Tex immediately after the suture ($P = 0.00016$). **d** The strength of the suture point is significantly weaker with SEAMDURA than with Gore-Tex 48 h after incubation in 40 °C saline ($P = 0.0002$). **e** After incubation in 40 °C saline, although the strength of the suture point shows no change with Gore-Tex ($P = 0.73$), it is significantly weaker with SEAMDURA ($P = 0.02$)

standard deviation. Differences were considered significant for values of $P < 0.05$. All statistical analyses were performed using Statcel version 4 (OMS Publishing, Saitama, Japan) and EZR (Easy R) [10].

Results

Comparison of the rate of postoperative hemorrhage between Gore-Tex and SEAMDURA

The overall postoperative hemorrhage rate after brain tumor extirpation with duraplasty with an artificial dura substitute was 8.6% (4/46). In the G group, no patients developed postoperative hemorrhage after tumor extirpation. On the other hand, in the S group, four patients (19%) had postoperative hemorrhage. In all cases, the epidural hematoma flowed into the subdural space through a tear of the artificial dura substitute at the suture point after tumor extirpation. The clinical characteristics of these four cases are summarized in Table 2. Comparing Gore-Tex with SEAMDURA, the rate of such epidural and subdural hematomas was significantly higher in the S group than in the G group (19% vs. 0%, $P = 0.03$ by Fisher's exact test).

Risk factors for postoperative epidural and subdural hematoma after brain tumor extirpation with duraplasty with SEAMDURA

Comparing the clinical characteristics between patients with and without postoperative epidural and subdural hematomas after brain tumor extirpation with duraplasty with SEAMDURA (Table 3), the patients with hematomas were significantly older and had longer operation time than patients without hematomas. Exposure of the superior sagittal sinus (SSS) at craniotomy was also more frequently performed in the patients with hematomas than in the patients without hematomas. Anticoagulant or antiplatelet medication was more frequently taken in patients with hematomas, though this difference was not significant. There were no differences in sex, posterior fossa surgery, tumor pathology, and experience of the surgeons.

Comparison of the strength of the suture point

The strength of the suture point was significantly weaker in the S group than in the G group, both immediately after the suture ($P = 0.00016$) and 48 h after incubation in 40 °C saline ($P = 0.0002$) (Fig. 1c, d). After incubation in 40 °C saline, although the strength of the suture point was not changed in the G group, it became significantly weaker in the S group ($P = 0.02$) (Fig. 1e).

Discussion

Does duraplasty with an artificial substitute facilitate postoperative hemorrhage after brain tumor extirpation?

Postoperative hemorrhage after craniotomy that requires surgical evacuation is reported to occur in 0.8–6.9% of cases [2, 4, 5, 12–15, 17]. In our institute, the overall postoperative hemorrhage rate after craniotomy was 2.2%, comparable to other reported results. However, the present rate of postoperative hemorrhage after brain tumor extirpation with duraplasty with an artificial dura substitute was greater than that after overall craniotomy (8.6 vs. 2.2%). Hence, there is a possibility that duraplasty with an artificial substitute facilitates postoperative hemorrhage after brain tumor extirpation. Although Huang et al. [7] reported that postoperative hemorrhage after decompressive craniectomy for severe traumatic brain injury was more often encountered in patients with an artificial dura substitute, there are no reports of an artificial dura substitute facilitating postoperative hemorrhage after brain tumor extirpation. The present study showed that postoperative hematoma was seen only after duraplasty with SEAMDURA. Because no patients developed postoperative hemorrhage after duraplasty with Gore-Tex, SAEMDURA rather than an

Table 2 Summary of the characteristics of patients with postoperative hemorrhage

Case No.	Age (y)	Sex	Anticoagulant or antiplatelet medications	Artificial dura substitute	Diagnosis	Surgical procedure	Hematoma location	Time between the primary operation and hematoma evacuation (days)
1	70	F	–	S	Falx meningioma	Tumor extirpation	EDH + SDH	1
2	72	F	–	S	Convexity meningioma	Tumor extirpation	EDH + SDH	4
3	78	M	+	S	Cerebellar anaplastic glioma	Tumor extirpation	EDH + SDH	3
4	81	M	–	S	Convexity meningioma	Tumor extirpation	EDH + SDH	3

EDH, epidural hematoma; *S*, Seamdura; *SDH*, subdural hematoma

Table 3 Comparison of the clinical characteristics between patients with and without postoperative subdural hematomas after tumor extirpation with duraplasty with SEAMDURA

	Postoperative epidural and subdural hematoma (+) $n = 4$	Postoperative epidural and subdural hematoma (−) $n = 17$	P value
Sex (M:F)	2:2	7:10	0.58*
Age (y)	75.2 ± 5.1	67 ± 11.9	0.05†
Exposure of the SSS	3 (75%)	1 (5%)	0.01*
Posterior fossa surgery	1 (25%)	5 (29%)	0.68*
Operation time (min)	272.7 ± 32.9	187.5 ± 76.6	0.04†
Anticoagulant or antiplatelet medications	2 (50%)	1 (5%)	0.07*
Tumor pathology			0.47‡
Meningioma	3	8	
Glioma	1	2	
Metastatic tumor	0	3	
Others	0	4	
Experience of the surgeon			0.91
1–9 years	0	0	
10–15 years	2	9	
16–20 years	2	8	
> 21 years	0	0	

SSS, superior sagittal sinus

* Fisher's exact test, † Welch's t test, ‡ Chi-squared test, Mann-Whitney U test

artificial substitute may facilitate postoperative hemorrhage after brain tumor extirpation.

Mechanism of epidural and subdural hematomas in the present cases

Most reported cases of postoperative hemorrhage are intraparenchymal or epidural hematomas, and subdural hematoma is rare [6, 9, 12, 14]. The present results showed that the epidural hematoma flowed into the subdural space through a tear of SEAMDURA in four patients, indicating that such hematomas were specific to SEAMDURA. Hence, it was thought that SEAMDURA might have low suture strength. In fact, the experimental study showed that the suture strength of SEAMDURA was significantly weaker than that of Gore-Tex. Furthermore, the suture strength of SEAMDURA became significantly weaker with time. These results prove that the suture may break due to a decrease in the suture strength of SEAMDURA with time. In addition, such hematomas occurred after tumor extirpation yielding a large dead space in the subdural space; under these circumstances, expansion of the brain might be weak, unlike after decompressive craniectomy. As a result, the pushing force of the epidural hematoma might increase gradually and injure the suture a few days after the operation. The epidural hematoma might then flow into the subdural space through the tear.

Risk factors for postoperative epidural and subdural hematomas

The present results showed that older age, long operative time, and exposure of the SSS when using SEAMDURA might be risk factors for such postoperative hematoma. Risk factors for postoperative hematoma development, such as hypertension, old age, usage of antiplatelet, anticoagulant, or non-steroidal anti-inflammatory drugs, preoperative mannitol administration, excessive alcohol use, and hemorrhagic diathesis, have been previously reported [1, 3–5, 12–14]. Regarding operative procedures, emergent surgery, long operative time, tumor extirpation, high intraoperative blood loss, and hematoma evacuation for traumatic intracranial hemorrhage have been reported as risk factors [2, 4, 6, 8, 14, 17]. Although old age and long operation time have been reported as risk factors for postoperative hemorrhage, exposure of the SSS has not been reported. Neurosurgeons see larger asymptomatic subcutaneous and epidural hematomas after craniotomy with exposure of the SSS than after other craniotomies without exposure of the SSS. In such cases, oozing from the SSS may facilitate hematoma formation. Hence, such postoperative hematomas may tend to occur when the SSS is exposed at craniotomy. On the other hand, there was one case of postoperative subdural hematoma after posterior fossa surgery. It was anticipated that posterior fossa surgery might be a risk factor. Because more muscles surround the posterior fossa than the anterior fossa, it was presumed that oozing from the occipital muscles might

facilitate epidural hematoma formation. However, the present results showed that posterior fossa surgery was not a risk factor.

A less experienced surgeon may be a risk factor for postoperative hemorrhage because of poor hemostatic technique. However, the present results showed no relationship between experience of the surgeon and the rate of postoperative hemorrhage.

Limitations

This study has some limitations. Because only a few patients were studied, the statistical analyses and generalizability are limited, and over-interpretation of the results should be avoided. Moreover, there is a possibility of bias in patients' background characteristics and selection of artificial dura substitute.

Conclusion

Duraplasty with SEAMDURA may facilitate postoperative hemorrhage. The occurrence of the postoperative epidural and subdural hematomas described is specific for SEAMDURA and may be caused by the weak suture strength of SEAMDURA. In cases of duraplasty after brain tumor extirpation, a nonabsorbable artificial substitute such as Gore-Tex may be suitable. When duraplasty with SEAMDURA is performed, it is better to exclude older patients, and operations requiring a long time or exposure of the SSS.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This was a retrospective analysis. For this type of study, formal consent is not required.

Informed consent None.

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