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Risk factors for wound dehiscence after surgery for epilepsy

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OBJECTIVE Wound dehiscence following craniotomy is a complication for which patients are subjected to additional procedures to achieve wound closure. During surgery for epilepsy, a craniotomy is performed at various sites to cure or palliate seizures in patients with intractable epilepsy. Collaborations between medicine and engineering have provided many surgical devices and materials for various stages of craniotomy, from skin incision to wound closure. The risk factors for wound dehiscence remain undetermined. Here, the authors attempt to identify risk factors associated with wound dehiscence after surgery for epilepsy.

METHODS They retrospectively reviewed the clinical records and operative notes of consecutive patients with intractable epilepsy who had undergone craniotomy to allow resective or disconnective surgery between 2015 and 2023 in the Department of Neurosurgery, Hiroshima University Hospital, and had a minimum follow-up of 1 year. The authors conducted a multivariate logistic regression analysis to determine the risk factors for wound dehiscence.

RESULTS The study population comprised 174 patients who had undergone corpus callosotomy (70 patients), cortical resection (CR; 65 patients), or CR via intracranial video electroencephalography monitoring (IVEEG; 39 patients). Wound dehiscence occurred in 14 patients (8.0%). Univariate analysis showed that wound dehiscence was associated with CR via IVEEG ($p = 0.0330$), electrocautery scalpels ($p = 0.0037$), T-shaped skin incisions ($p = 0.0216$), dural closure ($p = 0.0002$), and longer operative duration ($p = 0.0088$). Multivariate logistic regression analysis revealed that skin incision using an electrocautery scalpel ($p = 0.0462$, OR 9.38, 95% CI 1.04–84.74) and dural closure using nonabsorbable artificial dura ($p = 0.0078$, OR 6.29, 95% CI 1.63–24.31) were independent risk factors for wound dehiscence.

CONCLUSIONS Surgical devices and materials contribute to wound dehiscence after epilepsy surgery. To avoid wound dehiscence, the use of an electrocautery scalpel is not recommended when performing skin incisions, nor is dural closure using a nonabsorbable artificial dura.

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KEYWORDS wound dehiscence; epilepsy surgery; craniotomy; electrocautery scalpel; nonabsorbable dura

Surgical wound dehiscence following craniotomy is a complication for which patients are subjected to additional procedures to achieve wound closure.[1] Wound dehiscence contributes to prolonged hospital stays and associated psychosocial stressors for individuals and their families.[2] Although there is no clear definition of wound dehiscence, it is commonly defined as a loss of wound integrity that develops at least 2 weeks postoperatively and presents with various levels of tissue compromise.[2,3] When dehiscence occurs at the surgical site, urgent treatment is recommended due to the high risk of infection.[4]

Craniotomy is commonly performed during neurosurgery. As a characteristic of craniotomy, a bloodless cranial bone flap is left under the skin after wound closure, and a bloodless dural graft is placed under the bone flap. It is important to define risk factors for wound dehiscence to

ABBREVIATIONS CC = corpus callosotomy; CR = cortical resection; e-PTFE = expanded polytetrafluoroethylene; FSIQ = full-scale intelligence quotient; IVEEG = intracranial video electroencephalography monitoring; PGA = polyglycolic acid; SEEG = stereotactic electroencephalography; WAIS = Wechsler Adult Intelligence Scale; WISC = Wechsler Intelligence Scale for Children.

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avoid infection of the flap and grafts. Epilepsy surgery is a functional procedure that is performed to cure or palliate seizures in patients with intractable epilepsy.[5] In epilepsy surgery, a craniotomy is performed at various sites to accomplish focal cortical resection (CR) or disconnection, hemispherectomy, corpus callosotomy (CC), and placement of an intracranial electrode, among other objectives. The skin flap size, craniotomy size, and extent of dural opening often need to be large to allow placement of a subdural electrode or resection of the epileptogenic cortex, which can spread more extensively than a lesion visible on MRI.[6,7] Therefore, a dural graft is frequently placed at the dural closure site. Risk factors for impaired wound healing, such as a poor general condition, advanced age, malnutrition, or previous radiotherapy, can be excluded for most patients undergoing this type of surgery. Thus, when considering the risk factors for wound dehiscence, an association with surgical factors is expected to be greater in this cohort. Although resective surgery via invasive monitoring with implanted intracranial subdural electrodes has been found to increase the risk of focal infection,[8] to our knowledge, there are no published data on wound dehiscence after epilepsy surgery.

Collaborations between medicine and engineering have produced many surgical devices, materials, and implants for various stages of a craniotomy, from skin incision to wound closure. While the preferred surgical devices or materials may change over time in clinical settings, the best selection for each surgery remains elusive. Although risk factors for complications may contribute to wound dehiscence, they remain undetermined. Here, we attempt to identify the risk factors associated with wound dehiscence after epilepsy surgery. The outcome of interest was wound dehiscence that required surgical debridement of the skin or removal of an infected cranial bone flap. We hypothesized that not only the operative methods but also the surgical devices and materials contribute to the outcome.

Methods

Patients

We retrospectively reviewed the clinical records and operative notes of consecutive patients with pediatric or adult intractable epilepsy who had undergone epilepsy surgery with craniotomy between June 2015 and April 2023 in the Department of Neurosurgery, Hiroshima University Hospital, and who had been followed up for a minimum of 1 year postoperatively. Data from patients who had undergone subsequent radiation therapy and had a diagnosis of malignant brain tumor were excluded. This research was approved by the Ethics Committee for Clinical Research of Hiroshima University.

Patient-Specific Factors

Blood laboratory measurements were used to define preexisting anemia as a hemoglobin level < 13.7 g/dL for men and < 11.6 g/dL for women. Malnutrition was defined as a serum albumin concentration ≤ 3.5 g/dL. Obesity was defined as a BMI ≥ 30 kg/m^2. We performed a neuropsychological assessment for all patients preoperatively. The Wechsler Adult Intelligence Scale (WAIS) or Wechsler Intelligence Scale for Children (WISC) was applied according to both chronological and mental age. If the full-scale intelligence quotient (FSIQ) was ≥ 50, the patient was categorized as having an IQ ≥ 50. Patients with FSIQ scores < 50 or those who were ineligible for the WAIS or WISC because of developmental disorders, intellectual disability, or a chronological age < 5 years were categorized as non-IQ ≥ 50.

Surgical Environment

We performed the surgeries in the same operating room from June 2015 to April 2023. One supervisor (K.I.) was responsible for the surgical planning during this period. Two or three operators (K.K., Masaya Katagiri, and G.S.) performed the skin incisions, craniotomies, dural closures, bone reconstructions, and wound closures. All three operators were well-trained neurosurgeons with 8–15 years of experience as of June 2015.

Surgical Methods

The surgical methods were classified into 3 categories: CC, CR, and CR via intracranial video electroencephalography monitoring (IVEEG). CC was conducted using bilateral coronal skin incisions and bilateral frontal craniotomies. Focal CR, focal cortical disconnection, and hemispherectomy were all categorized as CR. The surgical site was variable, depending on the location of the assumed epileptogenic zone. In patients who had undergone CR via IVEEG, the first craniotomy was performed to implant an intracranial grid, strip, or depth electrode. CR was performed 2 weeks after the first craniotomy. The occurrence of wound dehiscence was monitored after the surgery with CR. A surgical robot system for stereotactic electroencephalography (SEEG) was introduced at our hospital in August 2022; therefore, only a limited number of patients underwent SEEG during the study period. The first craniotomy was performed several months after the SEEG monitoring; we included patients who had undergone CR after SEEG in the CR group.

Routine Surgical Procedures

For all patients, 1) antiseptic skin was prepared using an alcohol-based povidone-iodine solution immediately before the incision. 2) During skin incision, bipolar electrocautery was used for skin hemostasis. Skin clips were not used. 3) The galea aponeurotica, fascia, and muscle were incised by monopolar electrocautery with a needle tip. 4) After the pericranium was stripped from the bone, the craniotomy and dural opening were performed. 5) The intracranial procedures were performed under microscopy. 6) At the duraplasty stage, fibrin glue was used to avoid CSF leakage. 7) An autologous bone flap was used for bone reconstruction. 8) The galea, fascia, and muscle were sutured using absorbable surgical sutures (Vicryl, Ethicon). 9) Postoperative antibiotics were uniformly administered using a standard protocol.

Optional Surgical Procedures

1) At the skin incision stage, we optionally used a cold scalpel or electrocautery scalpel (Bonimed microneedle,

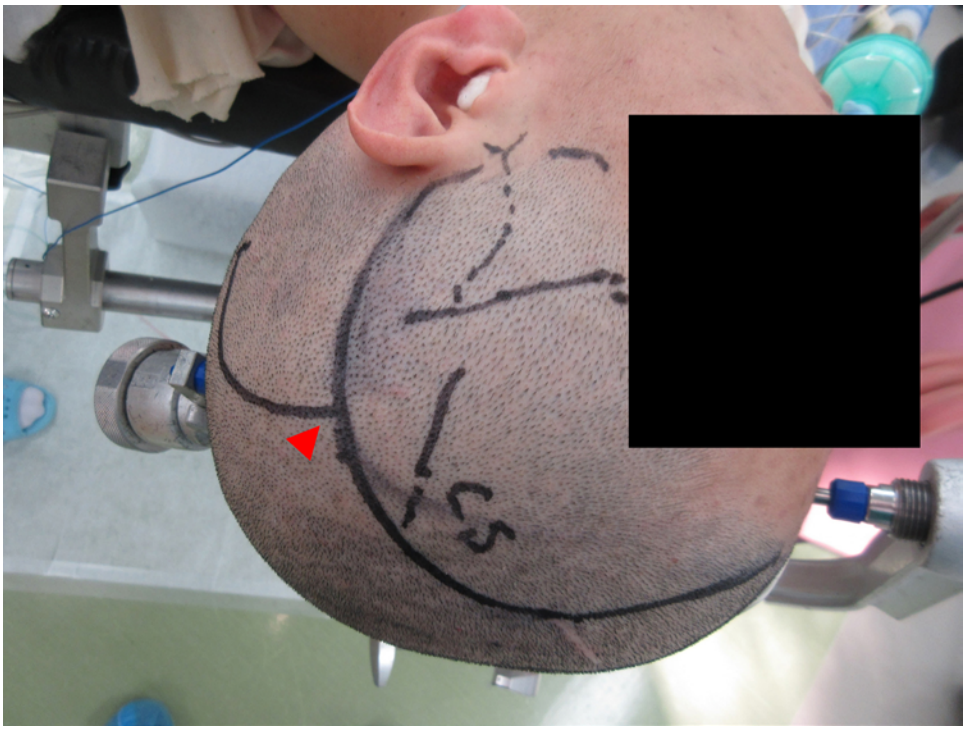

FIG. 1. Case 12. The skin incision plan, with the T-shaped region indicated by an *arrowhead*. Figure is available in color online only.

Muranaka Medical Instruments Co. Ltd.). Only the tip of the sharp needle electrode was allowed to contact the skin when using an electrocautery scalpel. 2) A T-shaped skin incision was made if needed, typically when we planned a large craniotomy to expose a wide area of the cortical surface (Fig. 1). 3) At the dural closure stage, if primary closure was impossible, we optionally used autologous grafts, absorbable artificial dura, or nonabsorbable artificial dura. The options for absorbable artificial dura included Seamdura (Gunze Medical Division), which is a translucent dural substitute made of poly-L-lactide copolymer and ε-caprolactone copolymeric film layered with polyglycolic acid (PGA); DuraWave (Gunze Medical Division), which is a nonwoven fabric made of PGA; and DuraGen (Integra Life Sciences), which is a chemically cross-linked collagen foam made from bovine tendons. We used Gore-Tex (Gore Medical), which is made of expanded polytetrafluoroethylene (e-PTFE) as a nonabsorbable artificial dura. 4) Wounds were closed using a skin stapler or nylon sutures.

After 2019, we preferred to use a cold scalpel for skin incisions and a nylon suture for wound closure. At that time, this switch was an attempt to prevent wound dehiscence and infection. The dural grafts were selected on a case-by-case basis, considering their advantages, disadvantages, pliability, and ease of use. While other artificial dura options were available throughout the study period, DuraGen has only been available since 2020. We counted the number of optional surgical procedures selected in the first half of the study period from June 2015 to May 2019 and in the second half of the study period from June 2019 to April 2023.

Definition of Wound Dehiscence

Wound dehiscence in the present study was defined as follows: 1) the rupturing or splitting apart of the margins of wound closure, occurring 1 week to 1 year postoperatively; and 2) the need for additional surgical procedures, including skin debridement and removal of infected cranial bone flaps, to achieve wound healing.

Data Collection

Data for the following potential predictors were collected from the clinical records and operative notes: age, sex, preexisting diabetes status, anemia status, malnutrition status, obesity status, use of a steroid, current cigarette smoking status, number of antiseizure drugs, IQ status, repeat incision of the prior operative scar, operative methods (CC, CR, CR via IVEEG), operative position, methods of skin incision (cold scalpel, electrocautery scalpel), presence of a T-shaped incision, dural closure technique (primary closure/autologous graft, absorbable artificial dura, nonabsorbable artificial dura), methods of wound closure (skin stapler, nylon suture), and operative duration. The maximum diameter of the craniotomy was measured retrospectively on postoperative CT images. The outcome of interest was the presence of wound dehiscence.

Statistical Analysis

Statistical analyses were performed using JMP 16 (SAS Institute Inc.). The dependent variable was wound dehiscence after epilepsy surgery. The independent variables included in the model were sex, age at surgery, presence

TABLE 1. Surgical characteristics among 174 patients with intractable epilepsy who underwent craniotomy to allow resective or disconnective surgery

Variable	Value
Op method	
CC	70 (40.2)
CR	65 (37.4)
CR via IVEEG	39 (22.4)
Op position	
Supine	164 (94.3)
Park bench or prone	10 (5.7)
Repeat incision of prior op scar	
Yes	19 (10.9)
No	155 (89.1)
Method of skin incision	
Electrocautery scalpel	97 (55.7)
Cold scalpel	77 (44.3)
T-shaped skin incision	
Yes	15 (8.6)
No	159 (91.4)
Craniotomy diameter in mm	96 (60–172)
Dural closure	
Primary closure/autologous graft	82 (47.1)
Absorbable artificial dura	68 (39.1)
Nonabsorbable artificial dura	24 (13.8)
Method of wound closure	
Skin stapler	83 (47.7)
Nylon suture	91 (52.3)
Op duration in mins	545.5 (167–1079)

Values are expressed as number (%) or median (range).

of diabetes, anemia, obesity, current smoking status, use of steroids, IQ, number of antiseizure drugs, repeat incision of the prior operative scar, operative method, operative position, method of skin incision, a T-shaped skin incision, craniotomy diameter, dural closure, method of wound closure, and operative duration. Univariate and multivariate analyses were performed to determine factors associated with the dependent variable.

Univariate analyses were performed using a Pearson chi-square test for categorical variables, and a Mann-Whitney U-test was used for continuous variables. Variables with $p \leq 0.25$ in the univariate analysis were included in the multivariate logistic regression analysis. Stepwise backward elimination was executed, and variables with $p < 0.1$ were retained. We conducted a binary logistic regression analysis to develop risk prediction models. Odds ratios are reported with 95% confidence intervals and p values. A two-tailed test result in which $p < 0.05$ was considered significant.

Results

Patient Characteristics

We included data from 174 patients (67 female) who met the inclusion criteria for the study. The median age at surgery was 24 years (range 1–63 years). All patients were treated with antiseizure drugs for intractable epilepsy. The median number of antiseizure drugs used was 3 (range 1–6). None of the patients had diabetes or were using a steroid. Only 1 patient (0.6%), whose serum albumin level was 3.5 g/dL, was malnourished. Although we identified anemia in 25 patients (14.4%), hemoglobin levels > 10 g/dL were detected in 23 of the 25 patients. Eleven patients (6.3%) were obese with a BMI ≥ 30 kg/m^2, and 10 patients (5.7%) were current cigarette smokers. We categorized 81 patients (46.6%) as non-IQ ≥ 50. There were no other underlying diseases that would disturb wound healing. All patients underwent the surgery during the chronic phase of their epilepsy.

Surgical complications other than wound dehiscence were identified in 3 patients: epidural hematoma after CC, intraoperative brain swelling during CR, and venous infarction after CC. None of the 3 patients had wound dehiscence. The patient with an epidural hematoma underwent hematoma evacuation on the day after CC. Bone was not reconstructed in the patient with intraoperative brain swelling. None of the 174 patients had unexpected neurological deficits after the epilepsy surgery.

Surgical Factors

Surgical factors are summarized in Table 1. The operative methods were CC in 70 patients (40.2%), CR in 65 (37.4%), and CR via IVEEG in 39 (22.4%). Only 1 patient in the CR group underwent SEEG 6 months before the craniotomy. Surgery was performed with 164 patients (94.3%) in the supine position and 10 patients (5.7%) in the park bench or prone position. The scar from prior surgery was incised in 19 patients (10.9%). A skin incision was made using an electrocautery scalpel in 97 patients (55.7%), while a cold scalpel was used in 77 (44.3%). A T-shaped skin incision was made in 15 patients (8.6%). The median craniotomy diameter was 96 mm (range 60–172 mm) overall. The median craniotomy diameter was 97 mm (range 67–127 mm) in patients who had undergone CC, 90 mm (range 70–135 mm) in those who had undergone CR, and 117 mm (range 60–172 mm) in those who had undergone CR via IVEEG. Dural closure was performed using primary suture or autologous graft in 82 patients (47.1%; 4 patients with primary suture; 70 patients with pericranium, galea, or fascia of the temporal muscle; and 8 patients with fascia of the thigh), absorbable artificial dura in 68 patients (39.1%; 24 patients with Seamdura, 4 patients with DuraWave, and 40 patients with DuraGen), and nonabsorbable artificial dura in 24 patients (13.8%). Wound closure was achieved with skin stapling in 83 patients (47.7%) and nylon suturing in 91 (52.3%). The median operative duration was 545.5 minutes (range 167–1079 minutes).

Selection of Optional Surgical Procedures in the First and Second Study Periods

The selection of optional surgical procedures in the first and second half of the study period is shown in Table 2. For skin incisions, while an electrocautery scalpel was

TABLE 2. Selection of optional surgical procedures in the first and second study periods

Variable	June 2015–May 2019	June 2019–April 2023	p Value
Method of skin incision			
Electrocautery scalpel	91	6	**<0.0001**
Cold scalpel	0	77	
T-shaped skin incision			
Yes	10	5	0.2881
No	81	78	
Dural closure			
Primary closure/autologous graft	53	29	**<0.0001**
Absorbable artificial dura	17	51	
Nonabsorbable artificial dura	21	3	
Method of wound closure			
Skin stapler	78	5	**<0.0001**
Nylon suture	13	78	
Wound dehiscence			
Yes	12	2	**0.0108**
No	79	81	

Boldface type indicates statistical significance.

used for all patients in the first half of the study, a cold scalpel was used for most patients in the second half ($p < 0.0001$). The frequency of absorbable artificial dura use increased, and that of the primary suture or autologous graft and nonabsorbable dura decreased in the second half of the study period ($p < 0.0001$). While a skin stapler was used for most patients in the first half of the study period, a nylon suture was mostly used in the second half of the study period ($p < 0.0001$).

Wound Dehiscence

Wound dehiscence occurred in 14 patients (8.0%). The characteristics of the patients with wound dehiscence are summarized in Table 3. Of these 14 patients, 4 were required to undergo removal of the cranial bone flap due to infection. In the remaining 10 patients, wound healing was attained after skin debridement. In 12 of the 14 patients, wound dehiscence occurred in the first half of the study period. All 4 patients with bone flap removal had the infection characterized by bacteriological culture. The culture was positive for methicillin-resistant *Staphylococcus epidermidis* in 2 patients and for *S. aureus* in 1 patient. We found no bacteria in the 1 patient who had been treated with antibiotics. Among the 10 patients without bone flap removal, a culture was performed for 5 patients and was negative for bacteria.

The operative methods were CR via IVEEG in 6 patients, CR in 5 patients, and CC in 3 patients. An electrocautery scalpel was used for skin incisions in 13 of the 14 patients. A T-shaped skin incision was made in 4 patients. The median craniotomy diameter was 105 mm (range 70–148 mm; Table 4). Dural closure was performed using an autologous graft in 4 patients, absorbable artificial dura in 3 patients, and nonabsorbable artificial dura in 7 patients. The median operative duration was 633.5 minutes (range 489–1017 minutes). The median time from

TABLE 3. Characteristics of patients with wound dehiscence

Case No.	Age (yrs)/Sex	Op Method	Resected Area	Method of Skin Incision	T-Shaped Skin Incision	Craniotomy Diameter (mm)	Dural Closure	Op Duration (mins)	Tx	Time From Surgery to Tx (days)
1	15/F	CR via IVEEG	Rt F	Electrocautery	Yes	148	Nonabsorbable AD	671	Debridement	31
2	40/M	CR	Lt T	Electrocautery	No	83	Autologous graft (head)	640	Debridement + BF removal	23
3	25/M	CR via IVEEG	Lt FT	Electrocautery	Yes	109	Nonabsorbable AD	753	Debridement + BF removal	119
4	33/M	CR via IVEEG	Rt T	Electrocautery	No	138	Nonabsorbable AD	777	Debridement + BF removal	77
5	20/F	CC	NA	Electrocautery	No	90	Absorbable AD (DW)	498	Debridement	21
6	18/F	CR via IVEEG	Rt PT	Electrocautery	Yes	114	Autologous graft (thigh)	914	Debridement	21
7	25/M	CR	Rt PTO	Electrocautery	No	125	Nonabsorbable AD	1017	Debridement	78
8	22/M	CC	NA	Electrocautery	No	101	Autologous graft (head)	489	Debridement	13
9	1/M	CR via IVEEG	Rt CP	Electrocautery	No	99	Nonabsorbable AD	504	Debridement	98
10	50/F	CR	Rt T	Electrocautery	No	93	Autologous graft (head)	562	Debridement	56
11	3/F	CR	Rt hemisphere	Electrocautery	No	125	Nonabsorbable AD	910	Debridement	19
12	28/M	CR via IVEEG	Lt T	Electrocautery	Yes	148	Nonabsorbable AD	627	Debridement + BF removal	111
13	7/F	CR	Rt T	Electrocautery	No	70	Absorbable AD (SD)	624	Debridement	11
14	20/M	CC	NA	Cold scalpel	No	75	Absorbable AD (DG)	581	Debridement	25

AD = artificial dura; BF = bone flap; CP = centroparietal; DG = DuraGen; DW = DuraWave; F = frontal; FT = frontotemporal; NA = not applicable; PT = parietotemporal; PTO = parietotemporooccipital; SD = Seamdura; T = temporal; Tx = treatment.

TABLE 4. Univariate analysis for the risk of wound dehiscence

Variable	Wound Dehiscence	No Wound Dehiscence	p Value
Sex			
Male	8	99	0.7785
Female	6	61	
Age at surgery in yrs	21 (1–50)	25 (1–63)	0.4067
Op method			
CC	3	67	
CR	4	61	
CR via IVEEG	7	32	**0.0330**
Op position			
Supine	14	150	>0.999
Park bench or prone	0	10	
Repeat incision of prior op scar			
Yes	2	17	0.6532
No	12	143	
Method of skin incision			
Electrocautery scalpel	13	84	**0.0037**
Cold scalpel	1	76	
T-shaped skin incision			
Yes	4	11	**0.0216**
No	10	149	
Craniotomy diameter in mm	105 (70–148)	95 (60–172)	0.1410
Dural closure			
Primary closure/ autologous graft	4	78	
Absorbable artificial dura	3	65	
Nonabsorbable artificial dura	7	17	**0.0002**
Method of wound closure			
Skin stapler	9	74	0.2661
Nylon suture	5	86	
Op duration in mins	633.5 (489–1017)	538 (167–1079)	**0.0088**

Values are expressed as number or median (range), unless indicated otherwise. Boldface type indicates statistical significance.

surgery to treatment for wound dehiscence was 28 days (range 11–119 days).

Univariate and Multivariate Analyses

Univariate analysis demonstrated that wound dehiscence was significantly associated with CR via IVEEG ($p = 0.0330$), electrocautery scalpels ($p = 0.0037$), T-shaped skin incisions ($p = 0.0216$), and nonabsorbable artificial dura ($p = 0.0002$). A longer operation was also associated with wound dehiscence ($p = 0.0088$; Table 4). No patient-specific variables were significantly associated with the outcome.

TABLE 5. Multivariate logistic regression analysis for the risk of wound dehiscence

Method	OR	95% CI	p Value
Skin incision			
Cold scalpel	Reference		
Electrocautery scalpel	9.38	1.04–84.74	**0.0462**
Dural closure			
Primary closure/autologous graft	Reference		
Absorbable artificial dura	1.89	0.37–9.59	0.4445
Nonabsorbable artificial dura	6.29	1.63–24.31	**0.0078**

Boldface type indicates statistical significance.

Two variables were retained after stepwise backward elimination: the method of skin incision and the method of dural closure. Multivariate logistic regression analysis revealed that skin incision using an electrocautery scalpel ($p = 0.0462$) and dural closure using nonabsorbable dura ($p = 0.0078$) were the independent risk factors that most accurately predicted wound dehiscence (Table 5). A skin incision made with an electrocautery scalpel was associated with greater odds of wound dehiscence than a skin incision made with a cold scalpel (OR 9.38, 95% CI 1.04–84.74). Dural closure using nonabsorbable dura was associated with greater odds of wound dehiscence than closure using a primary suture or autologous graft (OR 6.29, 95% CI 1.63–24.31). However, there was no significant difference between dural closure using absorbable dura and dural closure by primary suture or autologous graft.

Discussion

Previously, few case series in the literature have described surgical wound dehiscence. Although there is generally a lack of clear definitions of wound dehiscence in the literature, several potential causes have been identified for various surgical sites and procedures, including wound infection, poor general condition, advanced age, malnutrition, multiple surgeries at the same site, previous irradiation, diabetes, and obesity.[1–4,9] One literature review reported a surgical wound dehiscence rate ranging from 1.3% to 9.3% following various surgical procedures on various body parts.[2] Few studies have reported the rate of wound dehiscence after scalp incisions for neurosurgical procedures. Di Rienzo et al. reported a 2.2% wound dehiscence rate among patients in their 50s following neurosurgical procedures such as decompressive craniotomy, cranioplasty, craniotomy for tumor removal, and vascular disease.[3] However, to our knowledge, there have been no previous reports on wound dehiscence following epilepsy surgery. Candidates for epilepsy surgery tend to be younger and in better general condition than those for other surgeries. The patients whose data were included in the present study, whose median age was 24 years, had no underlying disease that could disturb wound healing. In patients who undergo epilepsy surgery, risk factors can be more strongly influenced by surgical procedures, devices, and materials than by the patient-related factors. In our patients, the median craniotomy diameter was 96 mm (range

60–172 mm). Although there are few reports detailing craniotomy size, a standard size of 30–45 mm is typically assumed for tumor resection.[10] The craniotomy size in our epilepsy surgery is larger than that for general neurosurgical procedures. In addition to recommendations for epilepsy surgery, our findings may be especially informative for neurosurgical procedures involving the removal of a large tumor or decompressive craniotomy for trauma. Our higher wound dehiscence rate may be due, at least in part, to the longer skin incisions required for more extensive craniotomies and longer operations than those for general neurosurgical procedures.

Skin Incision Using an Electrocautery Scalpel

While electrocautery/diathermy is commonly used for dissecting fascia and muscle layers and achieving hemostasis,[11,12] the use of electrocautery for creating the initial skin incision remains controversial.[13] The use of an electrocautery scalpel on a skin incision can create a thermal burn, resulting in wound-related complications.[14] Some data from animal models have shown that electrocautery skin incisions cause increased problems for wound healing.[15–18] In 2008, the National Institute for Health and Clinical Excellence published guidelines advising against the use of electrocautery skin incisions to avoid surgical site infections.[19] Despite these previous reports and guidelines, electrocautery is increasingly used for skin incisions in various fields, including general,[20] abdominal,[14] neck,[21,22] plastic,[23,24] orthopedic,[25] gynecological,[26] and neurological surgery.[27] The cited articles have advocated electrocautery as a safe and effective means of creating skin incisions that can reduce bleeding and save operative time. Furthermore, meta-analyses have shown no significant difference between electrocautery and conventional scalpel incisions in terms of postoperative wound complications.[13,28]

For the risk of scalp wound dehiscence after craniotomy, only one previous study reported that additional craniotomy, additional radiosurgery, and antiangiogenic treatment are risk factors in patients who undergo tumor resection.[4] In contrast with other clinical studies of various surgical sites, we found that electrocautery skin incisions are a risk factor for wound dehiscence after epilepsy surgery. In our procedures, the scalp skin incision was not linear but curved, and the skin flap was inverted and pulled from the cranium during surgery. Because the elasticity of the skin flap decreases over time under these conditions, the skin on both sides of the incision becomes tense when suturing if the skin flap is large. Our results indicate that the use of electrocautery for scalp skin incisions should not be recommended in surgery for epilepsy.

Dural Closure Using Nonabsorbable Dura

In Japan, several synthetic materials, such as e-PTFE, PGA, or collagen matrix, have often been used to repair the dura because of their pliability and ease of use.[29,30] Wound dehiscence is associated with infection at surgical sites.[31,32] Data in the present study showed that the use of nonabsorbable artificial dura made of e-PTFE is associated with a high risk of wound dehiscence in epilepsy surgery. We noted cases in 4 patients with a combination of wound dehiscence and epidural infection, which resulted in bone flap removal. A nonabsorbable artificial dura made of e-PTFE synthetic microporous material with a porosity < 3 μm was used in 3 of the 4 patients.[33] Repairing the dural defect with an e-PTFE sheet relies on encapsulation of the artificial dura by connective tissue.[34] A single-layer reactive membrane is observed in the acute stage. A thin fibrous membrane develops, surrounding the sheet in the chronic stage.[35] Several studies have reported that using such materials can lead to postoperative cranial infections.[31,35–37] Malliti et al. compared patients who had undergone duraplasty using a microporous polyester urethane dura substitute (Neuro-Patch, n = 61) versus a pericranium graft (n = 63) and reported that the deep wound infection rates in the Neuro-Patch and pericranium groups were 15% and 5%, respectively.[31] However, all types of absorbable artificial dural substitutes we used in our study were replaced with dura-like biological tissue. Narotam et al. reported a much lower incidence of deep wound infection (1 of 79 patients, 1.3%) using DuraGen, which is made of a collagen matrix.[34] They suggested that the collagen matrix has an optimized pore size of 50–150 μm for fibroblast ingrowth and enhances natural biological healing through its 3D matrix structure. In our patients who had undergone surgery for epilepsy, the shape of the bone flap was usually 3D due to the large craniotomy. Because e-PTFE has almost no elasticity, it is difficult to reconstruct the dura to be compliant with the shape of the bone flap. While tight dural reconstruction can cause postoperative epidural dead space, loose reconstruction can cause pleating of nonabsorbable dura, which can also cause dead space (Fig. 2). The persistence of these dead spaces can be a source of infection that causes wound dehiscence in the late phase. In contrast, DuraGen conforms closely to the brain surface after irrigation because the redundant

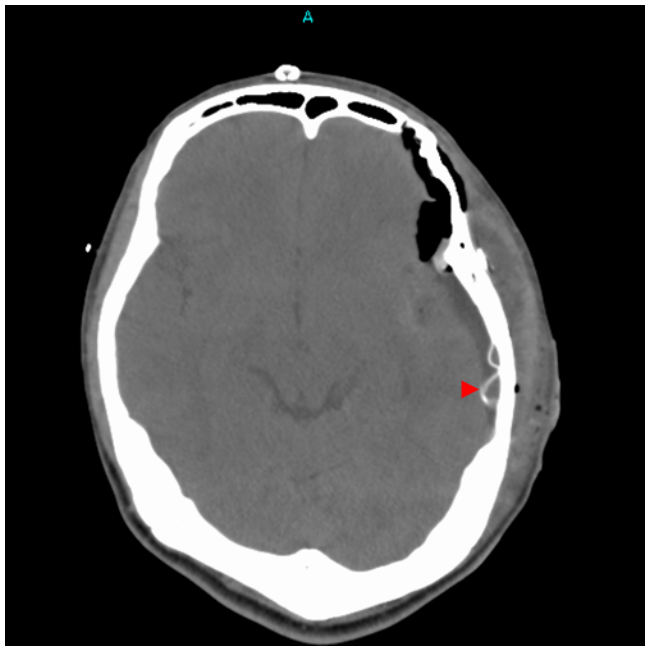

FIG. 2. Case 12. Postoperative CT scan showing pleating of the nonabsorbable artificial dura (*arrowhead*). Figure is available in color online only.

part is deflated.[38] It is advantageous that no epidural space typically persists after dural repair using the absorbable dura.[34]

Study Limitations

The present study has several limitations. Its retrospective use of information from clinical records and operative notes limits its findings to associations. Because the number of patients was small, we examined postoperative wound dehiscence from 1 week to 1 year. There may be different causes of wound dehiscence between the early and late phases of healing. Because the sample of patients who underwent primary dural closure was small, we categorized primary dural closure and closure using an autologous graft into the same group. Similarly, because there was considerable variation in the frequency of DuraGen, Seamdura, and Dura Wave use, we consolidated these treatments into the same group as absorbable dura. Differences between products may have influenced the outcome. Our preference for the optional surgical procedures changed over time. Although the surgical environment did not change during the study period, other potential factors may have been influenced by the passage of time. For example, the learning curve for surgeon skills is difficult to assess. Moreover, we did not consider the intradural operative technique. Other minor differences or variations in surgical technique may have influenced the outcome. An extensive prospective multicenter randomized study is warranted to support our findings.

Conclusions

Surgical devices and materials contribute to wound dehiscence after epilepsy surgery. Our results suggested that to avoid wound dehiscence, the use of an electrocautery scalpel on a scalp skin incision is not recommended, nor is dural closure using nonabsorbable dura. When dural closure by primary suture or autologous graft is difficult, the use of absorbable artificial dura is recommended.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Iida, Kagawa. Acquisition of data: Iida, Kagawa, Hashizume, Seyama, Askoro. Analysis and interpretation of data: Iida, Kagawa, Seyama, Askoro, Orihashi. Drafting the article: Kagawa, Askoro. Critically revising the article: Iida, Kagawa, Okamura, Orihashi. Reviewed submitted version of manuscript: Iida, Kagawa, Okamura. Approved the final version of the manuscript on behalf of all authors: Iida. Statistical analysis: Askoro, Orihashi, Akita. Administrative/technical/material support: Iida, Seyama. Study supervision: Iida, Horie.

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