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Risk Factors of Titanium Mesh Exposure: Experience from a Tertiary Referral Center

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ABSTRACT

Introduction: Titanium mesh is commonly used to reconstruct the cranium in cranioplasty procedure. Although it is generally well-tolerated, erosion of the overlying soft tissue due to the implant exposure remained as a major risk that could impair patients' outcome. This study aimed to investigate the potential risk factors of titanium mesh exposure.
Methods: Medical records from patients who underwent titanium mesh cranioplasty within the period of July 2016 to July 2020 were retrieved. Patients' demographic and characteristics were reviewed to investigate the potential risk factors in titanium mesh exposure.
Results: Twenty-three patients were included in this study with the mean age of 44.6 (±10.9) years. Fourteen patients (60.9%) acquired titanium mesh exposure in less than 6 months after cranioplasty surgery. In majority, the duration of surgery were more than 3 hours (65.2%). Intraoperative blood loss volume was less than 500 cc in 8 patients (34.8%), 500-1000 cc in 8 patients (34.8%), and more than 1000 cc in 7 patients (30.4%). Nineteen patients had bone defect of >10 cm and the indications for craniectomy were tumor resection in 56.5% patients, followed by infection in 17.4%. The sign of infection was present in 12 patients (52.2%). Only 2 patients (8.7%) had radiotherapy after cranioplasty. One patient was diagnosed with polycythemia vera.
Conclusion: Titanium mesh exposure following cranioplasty surgery is a complication that might affect the patients' overall outcome. Female predominance, long surgery duration, excessive intraoperative blood loss might be correlated with higher risk of titanium mesh exposure.

Keywords: Risk factor, titanium mesh exposure, female predominance, long surgery duration, excessive blood loss.
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INTRODUCTION

Defects of the neurocranium cause major risks for neurotrauma, herniation, trephined syndrome, and impaired neurologic and psychological function.[1,2] Reconstruction of the defect, also known as cranioplasty, is often warranted to restore cranial integrity, function, and esthetics. It could be performed by using autologous bone grafts or alloplastic implants, such as titanium mesh. Presently, titanium mesh is the most common choice of implant due to its inherent characteristics, including biocompatibility, minimal computed tomography (CT) artifact, malleability, strength, and lightweight.[3,4] Titanium alloy surfaces are thought to minimize bacterial adhesion and therefore became the preferred implant material in contaminated or previously infected sites.[5]

Previous studies that focused on cranioplasties using titanium mesh implants have reported significant complications immediately and delayed postoperative periods, including infections, extradural hematomas, new-onset seizures, and implant exposure.[6-11] Exposure is a particularly serious complication that compromises the esthetic outcome of the primary procedure and poses the risk of secondary infection.[7,9,11] Implant removal and revision surgeries are necessary when exposure of the cranioplasty implant occurs, with or without infection.[6-11] The risk factors for titanium mesh exposure have not adequately been investigated.[9] This study determined titanium mesh exposure's characteristics and clinical aspects in cranioplasty patients.

METHODS

In this study, medical records from 23 patients diagnosed with titanium mesh exposure in July 2016 – July 2020 were retrieved. Research ethics board approval was obtained from the institutional review board at Hasan Sadikin General Hospital.

All surgeries were performed in accordance with the standard protocols in neurosurgery. The cranial defect was defined by subperiosteal exposure of the circumferential bony margin of the skull defect. The defect was reconstructed by manually shaping the titanium mesh implant with or without a bone flap as its template. Soft tissue coverage was performed using a tension-free approximation of scalp flaps over the cranioplasty implant. In all patients, suction drains were used.

Retrieved information from patients' medical records included patients' sex, age, time interval between cranioplasty and mesh exposure, the time interval between craniectomy and cranioplasty, duraplasty, surgery duration, intraoperative blood loss volume, size of bone defect, the indication of craniectomy, smoking status, the sign of infection, cranial bone involved, the use of bone flap, and radiotherapy. The interval between craniectomy and cranioplasty was

divided into 3 groups: 0 days (craniectomy and cranioplasty were performed in the same surgery), 1-90 days, and >90 days. The size of the bone defect was measured in the longest axis, divided into 2 groups: >10 cm and < 10 cm. Signs of infection were defined by evidence of frank purulence as described in examination and/or operative records. Exposure was defined as a visible outline of mesh on the scalp.

Descriptive summaries and data analysis were performed using IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. (Armonk, NY: IBM Corp).

RESULTS

We identified 23 patients diagnosed with titanium mesh exposure in the study periods. The demographics and defect characteristics of the study population are presented in Table 1. The mean age of the study population was 44.6 (±10.9) years, and 17 (73.9%) were females. The median time from cranioplasty to mesh exposure was 86 days (range 25–3255). This time interval was divided into ≤6 months and >6 months groups, and the result was 60.9% (14/23) of patients suffered from titanium mesh exposure less than 6 months after cranioplasty surgery. The time interval between craniectomy and cranioplasty were 0 day in 13 patients (56.5%), 1-90 days in 3 patients (13.0%), and >90 days in 7 patient (30.4%). Duraplasty was performed by using either a pericranial graft in 11 patients (47.8%) and a dural substitute in 8 patients (34.8), while 4 patients (17.4%) did not undergo duraplasty. The majority of patients had surgery duration > 3 hours (15/23, 65.2%), and the remaining had ≤ 3 hours duration of surgery (8/23, 34.8%). Intraoperative blood loss volume were <500 cc in 8 patients (34.8%), 500-1000 cc in 8 patients (34.8%), and >1000 cc in 7 patients (30.4%). Nineteen patients had a large bone defect (>10 cm), and 4 patients had a size < 10 cm bone defect.

The indications for craniectomy were tumor resection in 56.5% (13/23) of patients, followed by infection in 17.4% (4/23) of patients, and 8.7% (2/23) for traumatic brain injury, failed the previous cranioplasty, and open depressed fracture cases, respectively. A history of smoking was not identified in 65.2% of the cases. The sign of infection was presented in 12 patients (52.2%). Most of the patients (11/23, 47.8%) had large cranial bone involved in cranioplasty (frontotemporoparietal), followed by frontotemporal (21.7), frontal (17.4%), frontoparietal (8.7%), and parietal (4.3%).

Table 1. Demographic, Characteristics and Clinical Aspects of Titanium Mesh Exposure.

Variables	Total (n=23)	%
Mean age	44,6 (±10,9)	
Sex		
Male	6	26.1
Female	17	73.9
Interval between cranioplasty and mesh exposure (days)	86 (± 765,4)	
Interval between cranioplasty and mesh exposure		
≤ 6 months	14	60.9
> 6 months	9	39.1
Interval between craniectomy and cranioplasty		
0 day	13	56.5
1 - 90 days	3	13.0
> 90 days	7	30.4
Duraplasty		
No	4	17.4
Pericranial graft	11	47.8
Dural substitute	8	34.8
Surgery duration		
≤ 3 hours	8	34.8
> 3 hours	15	65.2
Intraoperative blood loss volume		
< 500 cc	8	34.8
500 - 1000 cc	8	34.8
> 1000 cc	7	30.4
Size of bone defect		
≤ 10 cm	4	17.4
> 10 cm	19	82.6
Indication of craniectomy		
Traumatic brain injury	2	8.7
Tumor resection	13	56.5
Open depressed fracture	2	8.7
Failed previous cranioplasty	2	8.7
Infection	4	17.4
Smoking status		
Currently/formerly	8	34.8
Never	15	65.2
Signs of infection		
Present	12	52.2
Not present	11	47.8
Cranial bone involved		
Frontal	4	17.4
Parietal	1	4.3
Frontoparietal	2	8.7
Frontotemporal	5	21.7
Frontotemporoparietal	11	47.8
The use of bone flap		
Yes	4	17.4
No	19	82.6
Radiotherapy		
Yes	2	8.7
No	21	91.3
Comorbidities		
Cancer	2	8.7
Polychytemia vera	1	4.3

Most patients (19/23, 86.2%) underwent cranioplasty with titanium mesh only, without a bone flap as a template. Only 2 patients (8.7%) underwent radiotherapy after cranioplasty. Meanwhile, only 3 patients had comorbidities, including malignancy in 2 patients and polycythemia vera in 1 patient.

Patients with tumor resection surgery were predominantly females (*p=0.022*), and had longer surgery duration (*p=0.000*) and more intraoperative blood loss volume (*p=0.003*) in comparison to the non-tumor group.

Table 2. Risk factors for Titanium Mesh Exposure based on Indications of Craniectomy.

Variables	Indications of craniectomy		*P*
	Tumor	Non tumor	
Sex (Total)			0.022*
Male	1 (4.3%)	5 (21.7%)	
Female	12 (52.2%)	5 (21.7%)	
Duraplasty			0.071
No	1 (4.3%)	3 (13.0%)	
Pericranial graft	5 (21.7%)	6 (26.1%)	
Dural substitute	7 (30.4%)	1 (4.3%)	
Surgery duration			0.000*
≤ 3 hours	0 (0%)	8 (34.8%)	
> 3 hours	13 (56.5%)	2 (8.7%)	
Intraoperative blood loss volume			0.003*
< 500 cc	1 (4.3%)	7 (30.4%)	
500 - 1000 cc	5 (21.7%)	3 (13.0%)	
> 1000 cc	7 (30.4%)	0 (0%)	
Size of bone defect			
≤ 10 cm	1 (4.3%)	3 (13.0%)	0.281
> 10 cm	12 (52.2%)	7 (30.4%)	
Sign of infection			
Present	8 (34.8%)	4 (17.4%)	0.414
Not present	5 (21.7%)	6 (26.1%)	

DISCUSSION

Malleable titanium mesh is a common choice of synthetic materials in cases where a patient's original skull flap cannot be used for cranioplasty. Titanium implants are strong, malleable, and noninflammatory. They are associated with a very low infection rate compared to other materials, whereas negatives include observed imaging artifacts and heat conduction (which leads to temperature-dependent headaches).[12-15] However, previous studies focusing on cranioplasties using titanium mesh implants have reported significant complications in the immediate and delayed postoperative periods, including infections, extradural hematomas, new-onset seizures, and implant exposure.[5,6,8-12] Infection and mesh exposure can cause cranioplasty failure, necessitating reoperation.[1,9,11,12]

In our study, most mesh-exposed patients were middle-aged or elderly women. Mikami *et al.* reported that middle-aged or elderly women with surgical site infections after initial surgery might be at high risk for exposure to titanium implants.[16] The scalp skin around the craniotomy site of these patients is often thin and fragile. Thus, the titanium mesh is more susceptible to ischemia due to chronic pressure and irritation below. Ischemia could lead to scalp ulcerations.[17] The median time from cranioplasty to mesh exposure in our study was 86 days (range 25–3255). This result was similar to a previous study by Girgis *et al.* They reported that the median interval from the date of cranioplasty to the date of presentation with infectious symptoms was 99 days, with values ranging from 1 to 2919 days.[18]

The interval between craniectomy and cranioplasty in patients who didn't undergo a single stage of craniectomy-cranioplasty was grouped either less than 90 days and more than 90 days. We found that 13.0% of patients had early cranioplasty (<90 days), and 30.4% of patients had late cranioplasty (>90 days). Some previous studies comparing early and late cranioplasty concluded that there were no significant differences in complications between early vs. late, including the infection rate and mesh exposure.[5,19-22] Some previous studies stated that large skull defects are associated with more complications following cranioplasty, including mesh exposure and infection.[2,4,12,23] Our findings were quite similar to those previous studies, describing that most cases of titanium mesh exposure had a large bone defect, which was more than 10 cm, involving a large cranial bony area of the frontotemporoparietal.

In this study, most of the cases of titanium mesh exposure had the previous duraplasty either using a pericranial graft or a dural substitute. Zhang et al. previously reported no significant difference between non-duraplasty vs duraplasty group of patients who received cranioplasty after decompressive surgery for severe head trauma.[19] Our study found that most titanium mesh exposure cases had a previous long duration of surgery of more than 3 hours. However, some authors described that the duration of surgery didn't correlate with the risk of titanium mesh exposure.[11,23,24]

Fifteen patients had no smoking history, and only 2 patients underwent radiotherapy. Smoking and radiotherapy are risk factors for wound healing failure,[25] though these were not apparent in this study. Our study found signs of infection in 52.2% of mesh exposure cases. This finding was similar to a previous study by Lee et al. that reported that 61.5% of mesh exposure cases were presented with infection.[24]

Surprisingly, most cases of mesh exposure were patients who underwent tumor resection with a single stage of craniectomy-cranioplasty surgery. In contrast, some authors stated that the titanium mesh exposure rate following benign and malignant tumor resection was low and not significant, and caused by problems with the reconstructed soft tissue rather than the mesh itself.[26,27] From our study, tumor resection patients who had titanium mesh exposure were

predominantly females, had surgery duration of more than 3 hours and had more blood loss volume intraoperatively, significantly different from the non-tumor group. From a theoretical point of view, longer surgical time is considered a risk factor for infection and failure.[28] Matsuno *et al*. analyzed the factors influencing bone graft infection and failure after delayed cranioplasty.[29] However, there was no statistically significant difference between each group, so the association between increased surgical time and increased infection and failure rate was only suspected but not confirmed. Anatomically, the vascular supply of scalp skin might be associated with the appearance of scalp ulcerations.[17] Prolonged surgical time and intraoperative anemia could lead to relative ischemia to the skin flap during the surgery. After the surgery, chronic pressure and irritation by the titanium mesh below the skin could further lead to the ischemia condition of the skin resulting in scalp ulcerations and titanium mesh exposure.[16,17]

For the cases of titanium mesh exposure following the non-tumor indication such as traumatic brain injury, open fractures, infection and failed previous craniotomy, the possible reasons are: first, infected granulation tissues are fragile and have insufficient tissue perfusion; second, repeated surgery causing lack of normal vascular supply to the skin and subcutaneous tissue.[16,17] Both can cause skin ischemia leading to scalp ulceration and titanium mesh exposure.

To decrease the skin flap complication, including wound complication and implant exposure, Di Rienzo et al. recommended making the skin flap shape be tailored to the patient's anatomy, especially in cases where vascularization may be already compromised (previous surgery on the same side of decompression, scars, irregular scalp lesions as in trauma). Even if time spending, isolation, and preservation of the superficial temporal artery and the surrounding veins should always be sought, it requires just a few more minutes. Still, it significantly reduces the risks of compromise of flap circulation. This technique should also be applied to the occipital, supraorbital, and supratrochlear arteries. They also suggested periodically relieving pressure on the retracted flap during surgery to protect flap microcirculation. They also recommended minimization of skin clamps (they prefer hydrogen peroxide soaked gauzed wrapped along flap borders) and bipolar coagulation and no use of monopolar coagulation. They believe that the incidence of these complications may be significantly reduced by using a strategy based on accurate preoperative planning, adoption of intraoperative solutions aimed at the preservation of flap vascularization, accurate wound care in the immediate post-craniectomy and post-cranioplasty period, optimized temporization of cranioplasty, full consideration of previous surgeries, especially where conditions predisposing to a higher risk of complication are observed (e.g., sinking flap syndrome).[30]

The strengths of this study are that it sheds light on simple characteristics and clinical aspects of titanium mesh exposure, a serious complication for which the causes have not been adequately elucidated in the literature. There are limitations to this study, however. First, as this is a retrospective study, biases in retrospective study designs may be present, such as selection and informational biases. Furthermore, the sample size in this study was limited. Another limitation is that other risk factors identified in the literature for titanium implant exposure, such as repeated procedures[9] and preoperative infections[31], were not examined in this study. Furthermore, this study did not look at all patients who had undergone cranioplasty without any complication, including titanium implant exposure, and also other possible risk factors of cranioplasty failure such as poor nutrition, poor hygiene, delayed inflammatory reaction and poor neurological status.[16,24,31,32]

Exposure following titanium mesh cranioplasty cannot be considered a minor event because it adversely affects patient outcomes. Several factors may involve in this event, including surgery duration and intraoperative blood loss volume, especially in middle-aged and elderly women who underwent tumor resection surgery. Accurate preoperative planning, scalp vascularization preservation during surgery, surgical time optimization, and accurate wound care are needed to prevent such complications. A further study assessing other potential risk factors of titanium mesh exposure is needed.

CONCLUSION

Titanium mesh exposure following cranioplasty surgery is a complication that might affect the patients' overall outcome. Female predominance, long surgery duration, excessive intraoperative blood loss might be correlated with higher risk of titanium mesh exposure. Accurate preoperative planning, preservation of scalp vascularization during surgery, optimization of the surgical time and accurate wound care are needed to prevent such complication.

CONFLICT OF INTEREST

All authors declared that there is no conflict of interest regarding the publication of this article.

ETHICS APPROVAL

This research was approved by the Health Research Ethics Committee of the Faculty of Medicine, Padjadjaran University. Letter of Exemption Ref. No. 37.65/HPPD.35/LL/2021.

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AUTHORS CONTRIBUTION

All authors contributed equally in the research and writing process of this article

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