Risk of Skull Perforation with Halo Vest Skull Pins

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Abstract:

Introduction: A halo vest is an immobilization device widely used to stabilize the cervical spine. Pain and infection at the skull pin insertion site are common complications, but skull perforation is rare, and most published studies are case reports. This study aimed to identify risk factors for skull perforation by comparing patients who did and did not develop perforation.

Methods: Overall thickness and the thicknesses of the internal and external laminae of the skull at the skull pin insertion sites were measured on cranial computed tomography scans of 66 patients fitted with a halo vest. The results were compared between patients who did and did not develop perforation.

Results: Four patients developed perforations. All patients with perforation were older women, and their external and internal laminae were significantly thinner than those of patients who did not develop perforation.

Conclusions: The reported causes of skull pin perforation include infection around the pin, osteoporosis, and an enlarged frontal sinus. However, most patients with perforation in the present study were older women, and the cause was the thinning of the external and external laminae.

Keywords:

Skull perforation, Halo vest, Skull pin, Osteoporosis

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Introduction

External vertebral immobilization with a halo vest is commonly used in patients with cervical instability or dislocation, including those who have undergone long fusion and after pediatric cervical spinal surgery. Garfin et al. reported that complications related to halo vest pin insertion included pin-loosening in 36% of patients and pin site infection in 20%[1]. Van Middendorp et al. also reported that 29 of 239 patients (12%) developed an infection at a pin site[2]. Infection and pain around the pins are frequent complications. However, skull perforation is rare, with an incidence reported by Grafin et al. of only 1%[1]. Thus, most published studies of complications due to skull pins breaking through the skull are only scattered case reports of pneumocephalus, meningitis, epidural abscess, epidural hematoma, and symptomatic epilepsy[3-12]. This study aimed to conduct a risk analysis of skull perforation by skull pins through a retrospective review of cranial computed tomography (CT) scans of patients fitted with a halo vest.

Materials and Methods

A total of 106 patients had been fitted with a halo vest in our institution between July 2014 and July 2021, and the study subjects included 66 of these adult patients (47 men, 19 women; mean age 65.6 years) who had undergone cranial CT (5 pediatric cases with age below 12 years were excluded). The reason for halo vest use was cervical spine trauma in 55 cases (24 cases of dislocation fracture, 13 of cervical vertebral fracture, 12 of axis fracture, and 6 of Jefferson fracture), atlantoaxial subluxation in 4, cerebral palsy in 2, destructive spondyloarthropathy in 2, tumor in 2, and cervical myelopathy in 1.

The halo vest used was a PMT MR/CT Halo Vest System (OHWA TSUSHO Co., Ltd., Tokyo, Japan). The anterior skull pins were inserted 1 cm superior to the orbital rim above the lateral two-thirds of the orbit. The posterior skull

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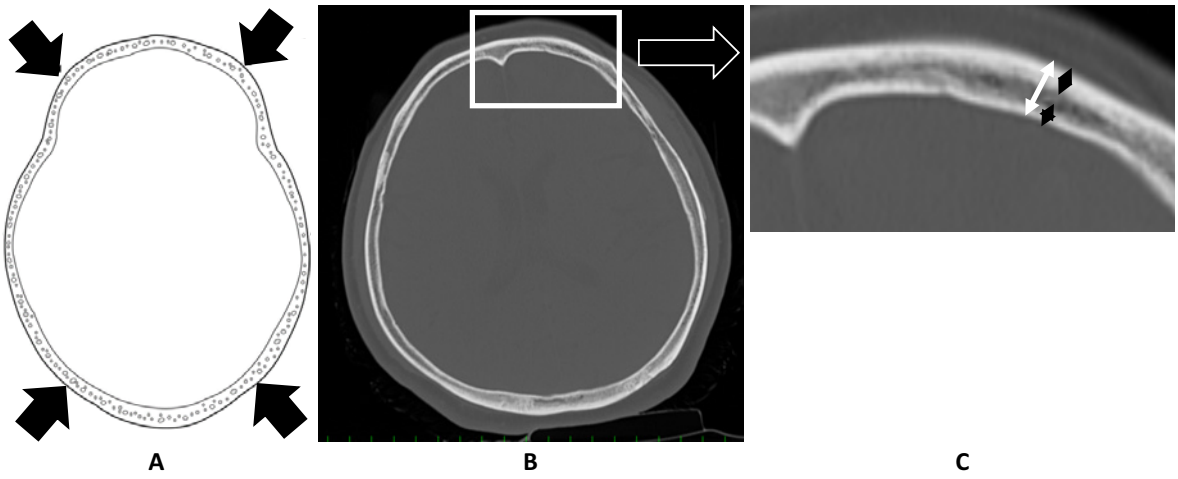

Figure 1.

A: Skull thickness is measured at the halo pin insertion sites on axial CT images. Measurement sites (black arrows) are made at the left and right anterior and posterior insertion sites.

B: The skull in the actual CT is shown. Figure 1. C is an enlargement of the white square.

C: The overall thickness (white double arrow) and the thicknesses of the external and internal laminae (black double arrow) are measured.

Table 1. List of Skull Pin Perforation Cases.

Age (years), sex	73, F	86, F	76, F	74, F
Disease	RA, atlantoaxial subluxation	Odontoid process fracture	Odontoid process fracture	Odontoid process fracture
Perforation site	Right anterior	Left posterior	Right anterior	Left posterior
Perforation period (days)	8	6	1	5
Treatment	Pin site moved	Bone fragment removal by craniotomy	Pin site moved	Pin site moved
Insertion torque	6 inch-pounds	6 inch-pounds	6 inch-pounds	6 inch-pounds

pins were inserted in the posterolateral skull: 1 cm superior to and 1 cm posterior to the top of the auricle.

For the adult patients, the skull pins were inserted at an insertion torque of 6-8 inch-pounds using a torque wrench, and the halo ring was immobilized by four skull pins inserted in the bilateral anterior and posterior regions.

Cranial CT images were imported into ShadeQuest/ViewR software (Fujifilm Medical Solutions Corporation, Tokyo, Japan), and the overall skull thickness and the thicknesses of the external and internal laminae at the skull pin insertion sites were measured in axial views. Measurements were taken by three board-certified spine surgeons. The intraclass correlation coefficient (2.1) was 0.922. The patients who developed perforation, defined as penetration of the internal lamina by a skull pin, were compared with those who did not. Measurements were conducted at the bilateral anterior and posterior pin insertion sites (Fig. 1).

Statistical analysis

Statistical analysis was conducted by the unpaired t-test using the statistical software package BellCurve for Excel 2015 (Social Survey Research Information Co., Ltd., Tokyo, Japan). The level of significance was set at $p<0.05$.

Ethical considerations

This study was approved by the institutional review board, and patient consent for inclusion in the study was obtained through the opt-out method. The study design was also reviewed and approved by the institutional ethics committee (approval No. O-1401). The procedures concur with the ethical standards of the responsible committee on human experimentation (institutional and national) and the Helsinki Declaration of 1975, as revised in 2013. Information regarding the conduct of this study was disclosed, and research subjects were allowed to refuse inclusion in this study. The patients who did not want to participate were not enrolled in this study.

Results

Four of the 66 adult patients (6%) developed skull perforation. Table 1 shows the details of all perforated cases. Of the four patients with skull perforation, one had an atlantoaxial subluxation associated with rheumatoid arthritis (RA)

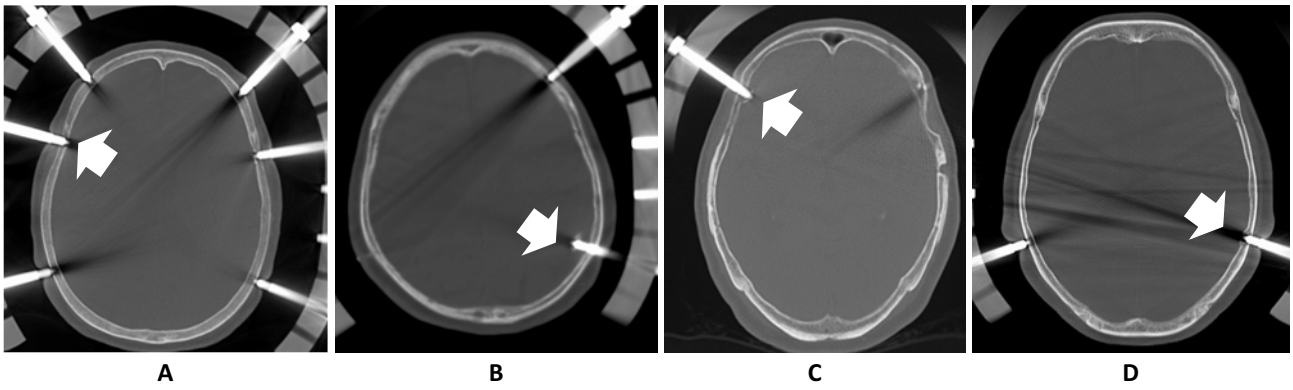

Figure 2. Cranial CT images of the four adults who developed perforation. The white arrow shows where the halo pin penetrated the skull.
A: 73-year-old woman with atlantoaxial subluxation associated with rheumatoid arthritis.
B: The 86-year-old woman with axial fractures underwent brain surgery to remove a small bone fragment that had migrated inside the skull.
C: 76-year-old woman with axial fractures.
D: 74-year-old woman with axial fractures.

(Fig. 2A), and three had an axial fracture (Fig. 2B, 2C, 2D). The mean age of the 66 adult patients was 77.2 years in the perforation group and 64.9 years in the nonperforation group, a difference that was not significant. However, the patients who developed perforation were older, and all were women. There were no significant differences of left-right difference in the perforation site, but the perforation could be slightly anterior in the anterior-posterior direction. Perforation occurred on days 1, 5, 6, and 8 after halo placement, respectively; only one case, a 74-year-old woman, had more pain after tightening, suggesting that tightening caused the perforation. In all remaining cases, no tightening was performed. Pain complaints were present from the beginning of the application, suggesting that perforation may have occurred with the first halo application. The perforated site was treated with pin removal in all cases, but an 86-year-old woman needed brain surgery to remove a small bone fragment that had migrated inside the skull. Insertion torque was 6 inch-pounds for all cases (Table 1).

The skull thickness measured on CT of the adult patients was 5.05 mm (perforation group)/5.59 mm (nonperforation group) (p=0.479) in the right anterior region, 6.07 mm/5.85 mm (p=0.763) in the left anterior region, 6.26 mm/6.99 mm (p=0.381) in the right posterior region, and 6.05 mm/7.18 mm (p=0.150) in the left posterior region, with no significant difference evident in all locations. The thickness of the external lamina was 1.58 mm (perforation group)/2.12 mm (nonperforation group) (p=0.037) in the right anterior region, 1.57 mm/2.20 mm (p=0.014) in the left anterior region, 1.51 mm/2.53 mm (p=0.012) in the right posterior region, and 1.45 mm/2.59 mm (p=0.002) in the left posterior region, significantly thinner at all locations in the patients who had developed perforation. The thickness of the internal lamina was 1.26 mm (perforation group)/1.66 mm (nonperforation group) (p=0.046) in the right anterior region, 1.18 mm/1.81 mm (p=0.014) in the left anterior region, 1.23 mm/1.84 mm (p=0.019) in the right posterior region, and 1.13 mm/1.86 mm (p=0.006) in the left posterior region, significantly thinner at all locations in patients who had developed perforation (Table 2).

Discussion

To the best of our knowledge, no previous study has measured the thicknesses of the external and internal laminae of the skull in relation to skull pin perforation. The most important aspects of the present study are the findings that the adult patients who developed skull pin perforation were older women with significantly thinner external and internal lamellae.

Halo vest immobilization is used to treat cervical spinal trauma. It is also used to reduce preoperative spinal deformity and as a supplementary postoperative stabilizer after cervical spinal surgery. Its use is contraindicated in a skull fracture, infection, or severe soft tissue injury at an insertion site[13]. Regarding skull pin insertion complications in a study of 179 patients, Garfin et al. reported that complications related to the use of a halo external skeletal-fixation device were pin-loosening in 36% of cases, pin site infection in 20%, pressure sores under either a plastic vest or a plaster cast in 11%, nerve injury in 2%, and dural penetration in 1%. They also reported that 180 of the 716 pins used (25%) had become loosened at least once, and an infection had developed at 67 pin sites (9%)[1]. Van Middendorp et al. also reported that 29 of 239 patients (12%) developed infection at a pin site, and pin site infection was significantly associated with skull pin penetration[2]. Skull pin-related complications are very common, but the frequency of penetration is only 1%[1]. Yet, most reports of skull pin perforation are case reports. The most commonly reported reason for skull pin perforation is perforation caused by infection around the pin[3-8]. Kingma and Papagelopoulos et al. reported cases of

Table 2. Overall Skull Thickness on CT.

		Perforation group	Nonperforation group	*p*-value
Overall skull thickness (mm)	Right anterior	5.05±1.36	5.59±1.44	*p*=0.479
	Left anterior	6.07±2.03	5.85±1.26	*p*=0.763
	Right posterior	6.26±1.01	6.99±1.62	*p*=0.381
	Left posterior	6.05±0.79	7.18±1.51	*p*=0.150
External lamina thickness (mm)	Right anterior	1.58±0.19	2.20±0.49	*p*=0.037
	Left anterior	1.57±0.16	2.20±0.49	*p*=0.014
	Right posterior	1.51±0.18	2.53±0.76	*p*=0.012
	Left posterior	1.45±0.15	2.59±0.70	*p*=0.002
Internal lamina thickness (mm)	Right anterior	1.26±0.13	1.66±0.38	*p*=0.046
	Left anterior	1.18±0.18	1.81±0.49	*p*=0.014
	Right posterior	1.23±0.20	1.84±0.49	*p*=0.019
	Left posterior	1.13±0.17	1.86±0.51	*p*=0.006

perforation caused by poor bone quality due to ankylosing spondylitis[9,10], and Medhkour et al. reported a patient with osteoporosis[11]. Cheong et al. reported a case of perforation in which an enlarged frontal sinus had caused thinning of the bone cortex[12]. Reported complications due to skull pin perforation include cerebral abscess, epileptic seizures, and pneumocephalus due to penetration of an enlarged frontal sinus[3-12].

Nabil et al. inserted halo pins into the skulls of cadavers of elderly people at a range of different torques, and they found that perforation did not occur at torques of 8-12 inch-pounds[14,15]. Therefore, they stated that insertion at 8 inch-pound torque is safe. Rizzolo et al. divided 102 patients who had undergone treatment with a halo vest device into those in whom the pins had been inserted at torques of 8 inch-pounds and 6 inch-pounds, and they compared the two groups[16]. Their statistical analysis showed no significant differences in halo pin-loosening, infection, pain, or scarring, but there was a trend toward a high complication rate in the 8 inch-pounds group. Thus, their current protocol considers halo pin insertion at 6 inch-pound torque[16]. In our hospital, we conducted skull pin fixation in adult patients at a torque of 6-8 inch-pounds, but perforation occurred in four of our patients despite the skull pin fixation being applied at a torque of 6 inch-pounds. All four patients who developed perforation were older women, with a mean age of 77.2 years (73-86 years). One of these patients had been taking steroids (prednisolone 2 mg daily) for RA. Since the external and internal laminae of the skull were remarkably thin on CT in all four patients who developed perforation, the thickness of the skull should be checked on preoperative CT before performing pin fixation in older women, if possible. If the external lamina is ≤2.5-mm thick, then fixation at a torque of 4 inch-pounds should be considered.

In the present series of patients, there were four cases of skull pin perforation. They experienced localized severe pain at the skull pin insertion site. The 86-year-old patient required neurosurgical intervention to remove a small bone fragment that had migrated within the skull. Fortunately, she recovered with no neurological deficits. The other three patients did not develop any complications, such as cerebral abscess, epilepsy, or pneumocephalus, and the pins were removed and refixed at different sites with no problems.

Limitations

The present study had some limitations. The study's sample size of 66 cases was small. Moreover, the number of skull pins and the insertion torque varied among the patients. Lastly, this was not a randomized study.

Conclusions

Skull pin perforation occurred in 4 of 66 adult patients (6%). The causes of skull pin perforation include old age, female sex, and osteoporosis-induced thinning of the external and internal laminae.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Author Contributions: All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Hideaki Hamanaka and Takuya Tajima. The first draft of the manuscript was written by Hideaki Hamanaka, and all authors commented on the manuscript's previous versions. All authors read and approved the final manuscript.

Ethical Approval: This study followed the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Miyazaki University (Date: 8.15.2023/ No O-1401).

Informed Consent: The authors affirm that human research participants provided informed consent to publish the images in Fig. 1, 2.

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