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Manuscript title:

CT perfusion imaging in the syndrome of the sinking skin flap before and after cranioplasty

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Abstract

The syndrome of the sinking skin flap (SSSF) has been described as one of the causes of neurological deficits after decompressive craniectomy We report a case of a 57-year-old woman with SSSF. Two years earlier, this patient, with no neurological deficits, underwent removal of the bone flap during treatment of an epidural abscess due to wound infection after a clipping operation for a ruptured aneurysm. The patient, who subsequently developed a sinking skin flap, gradually presented with gait disturbance and poor activity around one year before she came to our facility. On admission, neurological examination showed left hemiparesis and mild confusion. Cranioplasty with titanium mesh plate was performed. The cerebral blood flow value in CT perfusion imaging in the symptomatic hemisphere increased from 23 to 31 cc/100g/min, and the value in the contralateral side increased from 37 to 41 cc/100g/min after cranioplasty. CT perfusion imaging after cranioplasty revealed the improvement of cerebral blood flow not only on the symptomatic side but also on the contralateral side. The patient recovered well and was discharged without hemiparesis and confusion 2 weeks after cranioplasty. As far as we know, this is the first reported case of SSSF examined with CT perfusion imaging before and after cranioplasty.

Key words: cranioplasty; CT perfusion image; sinking skin flap syndrome

1. Introduction

The syndrome of the sinking skin flap (SSSF) has been described as one of the causes of new neurological deterioration after a large craniectomy [1, 2]. The mechanism of SSSF is considered to be caused by the relationship between atmospheric pressure, cerebrospinal fluid (CSF), and cerebral blood flow (CBF) at the bone defect site [1-4]. Dynamic CT and xenon CT have been reported to be valuable tools for evaluating CBF in SSSF [5, 6], but to date there has been no report of the use of CT perfusion imaging for this type of evaluation. We used CT perfusion imaging to monitor cerebral perfusion before and after cranioplasty in a patient with SSSF.

2. Case report

Four years before we saw the patient, a 57-year-old woman was admitted to another hospital due to subarachnoid hemorrhage (SAH). A ruptured aneurysm of the right middle cerebral artery was clipped, and external decompression of the right side was performed due to brain edema. Cranioplasty and ventriculoperitoneal shunt was performed 2 months after SAH, and the patient was discharged with no neurological deficits. However, the patient underwent the removal of the bone flap for a subcutaneous and epidural abscess caused by post-operative wound infection 2 years later. Initially, cranioplasty was planned 8 months after the removal of the bone flap. But MRI showed abnormal intensity suspecting epi- and subdural abscess formation. Several MRI studies were performed during next one year to confirm these finding to be non-specific granulation. The patient, who developed a sinking skin flap, gradually presented with gait disturbance and poor activity around one year before visiting our hospital. Two years after the bone flap removal, the patient was admitted to Hiroshima University Hospital under the diagnosis of SSSF.

On admission, neurological examination showed mild hemiparesis on the left side and mild confusion. We made a CT scan with a 16-detector row scan (LightSpeedQxi, General Electric Medical Systems). Pre-operative three-dimensional CT revealed a large bone defect and compressed brain (Fig. 1). An Advantage Workstation 4.1 (Perfusion 3, General Electric Medical Systems) was used for perfusion image analysis. The scanning protocol was as follows. Once we had selected the sections of interest, we obtained four contiguous 5-mm-thick slices per second in this area. Scanning was performed with continuous acquisition (cine) with 120 kVp and 100 mA for a duration of 40 sec with 1 rotation/sec, which allowed us to obtain 160 axial images 5 mm thick (40 images for 4 sections). We injected 40 ml of non-ionic contrast medium at an infusion rate of 5 ml/sec with a time delay of 5 sec from the beginning of the injection to the beginning of image acquisition. CT perfusion images before cranioplasty showed CBF values of the right and left hemispheres of 23.1 and 37.4 cc/100g/min, respectively (Fig. 2).

Cranioplasty with a titanium mesh plate was performed (Fig. 3). Neurological deficit with hemiparesis and confusion started to improve a few days post-operatively. We performed follow-up CT perfusion images one week after cranioplasty. The CBF values of the right and left hemispheres were 31.8 and 41.6 cc/100g/min, respectively (Fig. 4). The CBF values improved not only on the symptomatic side but also on the contralateral side after cranioplasty. The patient was discharged with no neurological deficits two weeks after cranioplasty.

3. Discussion

SSSF is characterized by neurological deficits with the skin depression at the site of the cranial defect, which develop several weeks to months after a large craniectomy [1, 2]. Yamaura et al [1] reported that 30% of patients with a depressed skin flap after external decompression showed improved neurologic symptoms after cranioplasty. On the other hand, a syndrome characterized by subjective symptoms such as headache, dizziness, undue fatigability, and vague discomfort is known as the syndrome of the trephined (ST) [4]. Symptoms of SSSF and ST improve rapidly after cranioplasty. Therefore, the mechanism of the onset of symptoms of both syndromes may be similar [7].

The mechanism of SSSF has been speculated to be the result of the combined effects of atmospheric pressure, CSF, and CBF [1-7]. Yamaura et al [1, 2] explained that the skin flap in cranial bone defect has sunk due to atmospheric pressure, and the cerebral tissue becomes deformed, resulting in disturbance of the local cerebral circulation and cerebral dysfunction. Stula et al [3] observed a decrease in CSF pressure and the collapse of brain structures on CT for patients with lateral craniectomies. All of their patients with neurologic deficits after craniectomy showed improvement of their neurologic deficit following cranioplasty. Stula et al suggested that the atmospheric pressure acting on the unprotected brain compressed the brain and that cranioplasty normalized this situation [3]. Dujovny et al [8] described an increase in CSF motion using MRI after cranioplasty. For CBF study, dynamic CT and xenon CT have been reported as tools for evaluating the CBF before and after cranioplasty [5, 6]. Suzuki et al [5] examined the changes in the CBF using dynamic CT before and after cranioplasty in 6 externally decompressed patients. Five of the 6 patients showed improvement in neurological signs after cranioplasty. The dynamic CT showed the improvements of CBF not only on the side of the lesion but also on the contralateral side after cranioplasty in all patients. Maekawa et al [6] reported the changes in the CBF using xenon CT before and after cranioplasty in 8 externally decompressed patients. Five of the 8 patients showed improvement in neurological signs after cranioplasty. The xenon CT in all patients revealed the increase of the bilateral CBF after cranioplasty. In addition, the authors reported that even though bilateral CBF was decreased or did not change on the day after cranioplasty, bilateral CBF increased beginning on the following day [6]. Dynamic CT and xenon CT have already showed the improvement of CBF after cranioplasty in SSSF. However, to our best knowledge, there is no reported case using CT perfusion imaging as a tool to evaluate the CBF in SSSF.

CT perfusion imaging has been used recently for the quantitative measurement of the CBF based on improved helical scanning, multi-detector CT, and advances in the software used to analyse the data. CT perfusion data involves only the sequential acquisition of cerebral CT sections achieved on an axial mode during less invasive intravenous administration of iodinated contrast material. The data is easily analyzed by software, which produces a color-map of CBF, CB volume, and mean transit time. On the other hand, the CBF map from xenon CT has proved to be quantitative and accurate, but the imaging necessitates excellent collaboration from the patient [9-11]. Wintermark et al [11] reported a good correlation between CT perfusion imaging of CBF and xenon CT. But there has been only their one study that actually validated absolute CBF values from CT perfusion by another technique [11]. For this reason, the validity of the quantitative CBF values from CT perfusion imaging should be evaluated by more studies.

In the present case, neurological deficits appeared within one year and cranioplasty was performed two years after the craniectomy. After cranioplasty, neurological signs improved and CT perfusion imaging revealed improvement of the CBF in bilateral hemispheres, as reported previously [5, 6]. Cranioplasty was useful for not only cerebral protection but also for the improvement of CBF and neurological deficits, because the CBF disorder in SSSF was reversible [5, 6]. If control-imaging of the CBF was performed at an early stage after decompressive craniectomy, follow-up CBF imaging might detect a change of CBF, even in a patient without new neurological deficits. CT perfusion imaging will likely become more important and widespread in the evaluation the CBF, because this type of imaging is an accurate and easy-to-perform technique for assessing brain perfusion [11]. CT perfusion imaging might be a good monitor for the evaluation of CBF and for determining the prognosis of SSSF.

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Figure legends

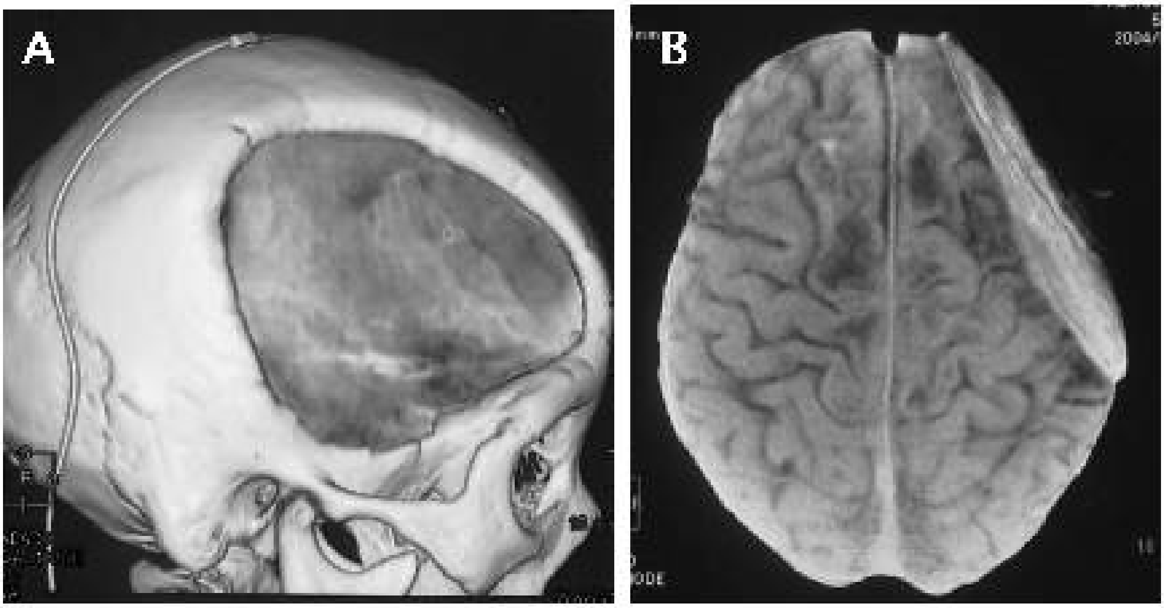

Fig. 1

(A) The pre-operative bone image of three-dimensional CT with a lateral view showed a compressed brain and cranial bone defect by fronto-temporo-parietal craniectomy.

(B) The pre-operative surface anatomy scanning image on three-dimensional CT with a superior view showed a compressed brain.

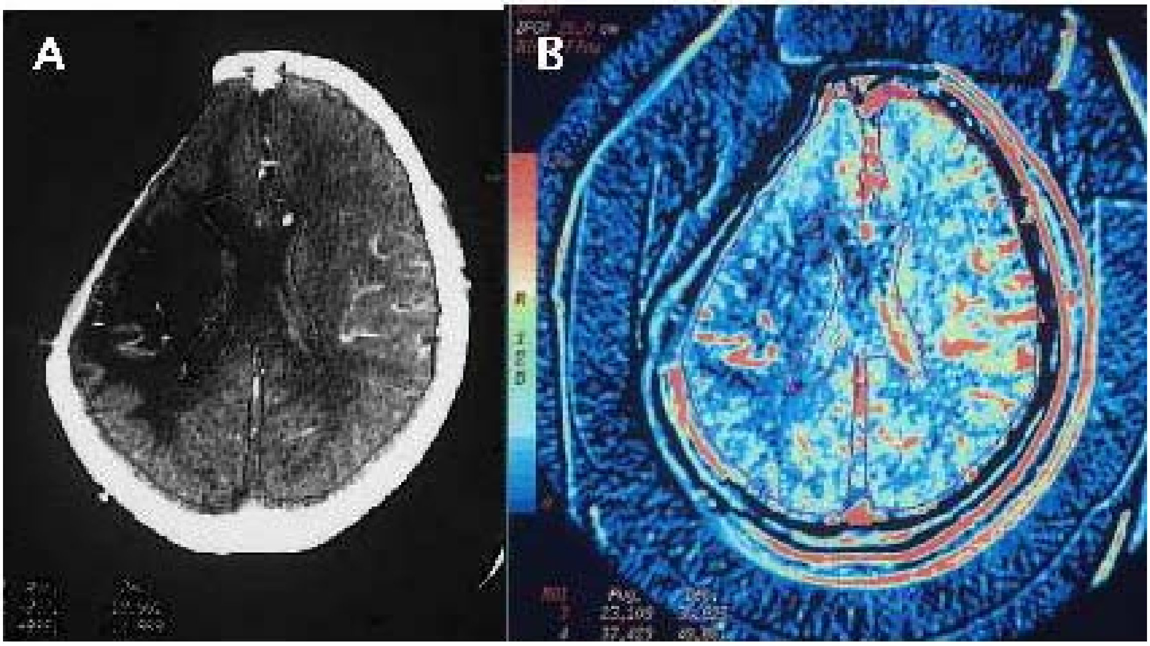

Fig. 2

(A) The enhanced CT image was one of four axial slices used to make a cerebral blood flow map from CT perfusion data. The pre-operative CT showed cerebral infarction in the right hemisphere and bone defect by fronto-temporo-parietal craniectomy.

(B) The CBF values of the right and left hemispheres on the CBF map were 23.1 and 37.4 cc/100g/min, respectively.

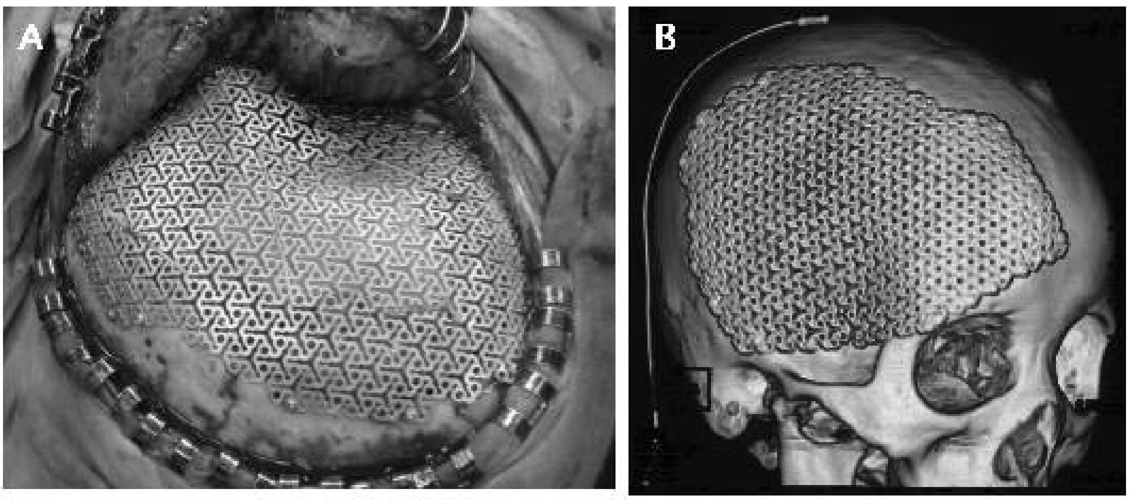

Fig. 3

(A) The intraoperative photograph showed that the cranial bone defect was covered by a titanium mesh plate.

(B) The post-operative bone image of the three-dimensional CT with an oblique view showed that the titanium mesh plate overspread the cranial bone defect.

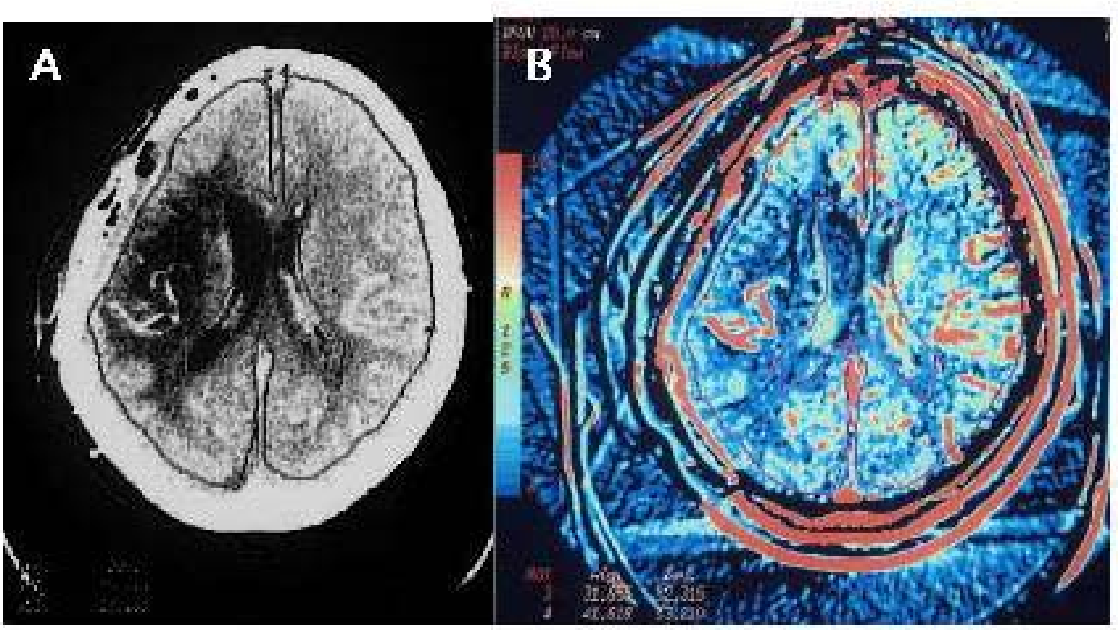

Fig. 4

(A) The enhanced CT image was one of four axial slices used to make a cerebral blood flow map from CT perfusion data. The post-operative CT showed an improvement of the brain compression and no new lesion.

(B) The CBF values of the right and left hemispheres on the CBF map were 31.8 and 41.6 cc/100g/min, respectively.