Clinical Feasibility of Multiplanar Reconstruction Images of Temporal Bone CT in the Diagnosis of Temporal Bone Fracture with Otic-Capsule-Sparing Facial Nerve Paralysis

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Received: 17 October 2011 / Accepted: 26 December 2011 / Published online: 6 January 2012
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Abstract The aim of this study is to evaluate the feasibility of multiplanar reconstructive (MPR) imaging of temporal bone CT in the diagnosis of temporal bone fracture with oticapsule-sparing facial nerve paralysis. Twelve patients with traumatic facial nerve paralysis with otic-capsule sparing and temporal bone fractures were selected. Multiplanar reconstruction images were obtained with the V-works 4.0 software program (Cybermed, Seoul, Korea) using axial scanning of high-resolution temporal bone CT of the fracture line. The clinical profiles of the patients displaying temporal bone fractures were examined in relation to the findings. Multiplanar images of the fracture line provided information regarding the direction of the external force that fractured the temporal bone. The fracture line was more continuous in the MPR images than in the axial view. All patients showed an imaginary extended fracture line directed toward the otic capsule. The direction of the fracture line toward the middle ear cavity is important, as it may suggest insult to the otic capsule. The MPR image parallel to the fracture line of the temporal bone provides a guideline for the vector of the force that induced the fracture. Thorough investigation of the critical

organs during surgical exploration is recommended if the direction of the fracture in the MPR image points toward the otic capsule in the middle ear even if the fracture line relative to the otic capsule is not well defined in the axial or CT view.

Keywords Temporal bone · Fracture · Computed tomography · Multiplanar reconstruction

Introduction

The classification of temporal bone fracture is of great importance in planning treatment, forecasting prognosis, understanding the associated complications, and educating the patient. New classifications have been suggested that focus on the clinical features of the patients. The latest two classifications of temporal bone fracture were designed by considering insults to the otic capsule [1] and petrous bone [2]. Both of these approaches focused on whether the end of the fracture line reached the critical organs. Thus, a thorough examination of the fracture line is important to evaluate temporal bone fracture. Computed tomography is known for its usefulness in the accurate diagnosis of temporal bone fractures. However, the fracture line does not appear in only one slice of the axial or coronal view, but rather takes diverse directions through multiple slices. The advantage of multiplanar reconstructive (MPR) CT imaging of the temporal bone is its production of multidirectional images of temporal bones without additional radiation exposure. This is particularly important in the case of facial nerve paralysis, as radiological findings may not be correlated with clinical features, and delayed and incomplete facial nerve paralysis may develop despite an intact facial nerve canal.

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The objective of this study was to investigate the feasibility of MPR CT imaging of the temporal bone in cases of otic-capsule-sparing facial nerve paralysis in temporal bone fractures.

Materials and Methods

Twelve patients (15%) with traumatic facial nerve paralysis were selected from 80 cases of temporal bone fractures diagnosed from 2007 to 2010 at Uijeongbu St. Mary's hospital of Korea (Table 1). The exclusion criteria included a history of temporal bone surgery, previous head trauma, bilateral injury, a previous history of facial nerve paralysis, and otitis media. A high-resolution CT scan of the temporal bone was obtained in 1-mm sections with a CT scanner (Somatom Definition AS + 128; Siemens, Seoul, Korea). The length and width of the temporal bone CT were 800 and 2,800 units, respectively. The FOV (field of view) was $512 \times 512 \text{ mm}^2$. The serial oblique images were acquired rectangular to a fracture line with 0.5 mm intervals in the axial temporal bone scan using a three-dimensional reconstruction software program (Cybermed, Seoul, Korea). The ranges of newly reformatted images include external auditory canal laterally, internal auditory canal medially, temporomandibular joint (TMJ) anteriorly, and mastoid cavity posteriorly (Fig. 1). The imaginary point where the extended

fracture line met the otic capsule was investigated radiologically. Facial nerve paralysis was evaluated based on the direction of the fracture line of the temporal bone.

Table 1 Demographics of patients of traumatic otic-capsule-sparing facial nerve paralysis with temporal bone fracture

Case	Sex	Age (year)	Side	Fracture types	Fracture sites	H–B grade	Onset time of paralysis after fracture (days)
1	F	29	Rt	L	2, 3	3	12
2	M	19	Lt	T	3, 4	2	15
3	M	36	Lt	L	4	4	4
4	M	35	Rt	M	3, 4	2	9
5	M	18	Rt	L	4	4	4
6	M	48	Lt	L	2, 3	3	6
7	M	57	Lt	L	3, 4	4	14
8	M	35	Lt	L	3, 4	2	5
9	M	55	Lt	M	1, 3, 4	2	14
10	M	37	Rt	T	2, 3, 4	4	28
11	M	54	Lt	M	2, 3, 4	2	15
12	F	17	Rt	T	1	4	5

Rt right, *Lt* left, *L* longitudinal, *T* transverse, *M* mixed, *1* petrous, *2* non-petrous middle ear, *3* mastoid, *4* external auditory canal, *H–B* grade House-Brackmann grade of facial nerve paralysis

Fig. 1 The divisions of reformatted images acquired from the axial temporal bone scan include external auditory canal laterally, internal auditory canal medially, temporomandibular joint anteriorly, and mastoid cavity posteriorly. The reformatted images were obtained from the imaginary blue lines of 0.5 mm intervals

Results

The twelve subjects showed no fracture-line insult to the otic capsule and displayed facial nerve paralysis following trauma. The fracture types were longitudinal ($n = 6$), transverse ($n = 3$), and mixed fractures ($n = 3$). Only two subjects had petrous bone fractures. However, in all cases, the medial end of the fracture line reached the middle ear cavity. The fracture lines were traced with MPR imaging from lateral to medial. All the extended lines of the fracture were directed toward the otic capsule where the tympanic segment of the facial nerve passed.

As in case 2 (Fig. 2-a, b), even when the fracture line did not reach the otic capsule and no soft tissue was observed in the middle ear cavity, MPR images indicated that the fracture line involved both the anterior and posterior canal wall, suggesting that an external force may have damaged the ossicle and tympanic segment of the facial nerve. In case 7 (Fig. 3-a, b), the direction of the fracture line in the anterior external auditory canal wall pointed toward the tympanic segment of the facial nerve in the MPR image. In case 9 (Fig. 4-a, b), the MPR image showed a defined fracture line in the anterior canal wall, and the image of the tympanic segment of the facial nerve was obscured by dense soft tissue in the middle ear cavity judged to be a hematoma. In case 12 (Fig. 5-a, b), the fracture line involved the petrous bone and TMJ. The MPR images aided in the identification of the direction of the fracture line through the TMJ, and it appears that the direction of force may have caused the delayed facial nerve paralysis.

Discussion

Temporal bone fractures may induce severe complications due to their complexity and the density of nearby critical organs. The major complications are sensory neural hearing loss, conductive hearing loss, perilymphatic fistula, vascular injury, CSF leaks, and facial nerve paralysis [3]. Thus, the classification of temporal bone fractures for surgical planning and prognosis is recommended to be based on the clinical features.

The otic capsule includes the critical auditory sensory organs (i.e., cochlea, vestibule, semicircular canals). Thus, if the fracture line reaches those organs, it may induce sensorineural hearing loss [4], CSF otorrhea, or facial nerve paralysis [5, 6]. According to a classification based on petrous bone involvement, Ishman reported that petrous bone fractures result in ten times greater likelihood of CSF leak and three times greater likelihood of facial nerve injury compared with non-petrous bone involvement [2]. Thus, it is important to identify where the fracture line ends, particularly when it is directed toward the critical organs.

Fig. 2 a (Case 2) A delayed type of facial nerve palsy occurred 15 days after trauma, despite the absence of a fracture line in the otic capsule and of soft tissue in the middle ear cavity. Two fracture lines are shown in anterior wall of the Lt external auditory canal (white arrows) in the axial view of the Lt temporal bone CT. Green arrow in blue circle means the rectangular direction to imaginary line which defines reformatted image. **b** (Case 2) Reformatted images from the axial CT of Fig. 2a. MPR images provided information on a fracture line involving both the anterior and posterior canal wall (white arrow heads) and showed that the external force may have caused insult to the ossicle (white arrow) and tympanic segments of the facial nerve (black arrow head), which pass through the mastoid canal into the mastoid segment of the facial nerve (black arrow)

Facial nerve paralysis occurs in 7–50% of temporal bone fractures [1, 5]. The perigeniculate portion of the facial nerve is most vulnerable due to its anatomical position [7, 8]. Facial nerve paralysis may be evoked by bony compression due to edematous swelling. Prognostic factors of traumatic facial palsy are the severity and onset time of facial nerve paralysis. Incomplete and delayed types of facial nerve paralysis present a better prognosis [2, 9].

Fig. 3 a (Case 7) A delayed type of facial nerve palsy occurred 14 days after trauma. Soft tissue density (*white arrow*) caused by the hematoma after trauma is evident in the middle ear cavity in the axial images. **b** (Case 7) Reformatted images from the axial CT of Fig. 3a. Soft tissue density (*white arrow*) estimated to hematoma after trauma is evident in the middle ear cavity. The direction of the *fracture line* (*white arrow head*) in the anterior external auditory canal wall pointed to the tympanic segment of the facial nerve, which pass through the mastoid canal into the mastoid segment of the facial nerve (*black arrow*)

The fracture line in the MPR image was more continuous than that derived from the axial view, where the continuity of the line was disrupted (Fig. 1). The MPR image also provided certainty with respect to whether the fracture line caused insult to components of the otic capsule. In the diagnosis of maxillofacial fractures with MPR imaging using axial scanning, the sensitivity and specificity of diagnosis were 91.7 and 93.8%, respectively. This was superior to those for the axial image and 3D CT [10]. However, the reformatted images were influenced by the

Fig. 4 a (Case 9) A delayed type of facial nerve palsy occurred 14 days after trauma. *Fracture lines* were present in anterior external auditory canal and mastoid cavity (*arrow heads*) in the axial images. **b** (Case 9) Reformatted images from the axial CT of Fig. 4a. The tympanic segment of the facial nerve (*black arrow head*) was obscured by the soft tissue image of the middle ear cavity. *Fracture line* (*white arrow heads*) encroaching the TMJ were cleared in these images. *Black arrow* indicate the mastoid portion of the facial nerve

resolution quality of the original data [11]. In studies of the coronal MPR image of the petrous bone, Venema [12] recommended that the 0.5-mm collimation of the axial spiral CT could be replaced by the direct coronal sequential CT obtained with a 0.5- or 1.0-mm section thickness. Mazziotti [13] emphasized the feasibility of the coronal oblique MPR image parallel to the basal turn of the cochlea in the evaluation of the retrotympanum and hypotympanum to complete the standard CT examination. In particular, the MPR image played an important role in the surgical planning for cochlear implantation.

Fig. 5 **a** (Case 12) A delayed type of facial nerve palsy occurred 5 days after trauma. The *fracture line* involved the petrous portion of the temporal bone through the TMJ and zygomatic arch (*arrows*). **b** (Case 12) Reformatted images from the axial CT of Fig. 5a. MPR images helped to identify the direction of the *fracture line* through the TMJ (*arrow heads*) and the direction of the force that caused the delayed facial nerve paralysis

In this study, no case of facial paralysis showed a fracture line in the otic capsule on conventional axial or coronal scans. In the MPR image, however, we could estimate whether the fracture was directed toward the otic capsule where the tympanic segment of the facial nerve travels. A 1-mm-thick axial scan slice is recommended for the routine analysis of temporal bone fracture. However, a small fracture line may be missed in a 1-mm slice of a CT scan despite the radiologist's experience. The MPR image provides a hint of the direction of the external force that caused the fracture. Thus, the estimated extended line based on the force vector may suggest the possibility of a fracture even when none is seen on CT.

Vascular injury with temporal bone fracture, such as traumatic pseudoaneurysm or the laceration of the internal carotid artery, may be fatal [14, 15]. Thus, further studies using CT angiogram or MRI/MRA are recommended. The MPR images may be helpful to support the emergent examination when considering patients' clinical presentation.

This study highlights the possibility of assessing the involvement of critical organs based on the direction of the fracture line as determined by MPR, which may be correlated with the initial clinical symptoms or delayed complications. This may be helpful when planning for exploratory surgery. There are some limitations to this study. A larger data set is required, and we could not exclude the possibility that facial nerve paralysis may have been induced by blunt trauma without a direct fracture line. Taken together, these findings suggest that identification of the direction of the fracture line may increase sensitivity in detecting the development of facial nerve paralysis. Thus, further studies with a larger data set are recommended.

In our study, twelve cases of traumatic facial paralysis in otic-capsule-sparing temporal bone fracture were studied in which MPR images showed a fracture line whose extension was estimated to approach the otic capsule. In the case of a temporal bone fracture into the middle ear cavity, MPR imaging parallel to the fracture line is recommended for further evaluation.

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