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Original Article

The relationship between post-traumatic ossicular injuries and conductive hearing loss: A 3D-CT study

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ABSTRACT

Purpose. – After a trauma, the conductive ossicular chain may be disrupted by ossicular luxation or fracture. Recent developments in 3D-CT allow a better understanding of ossicular injuries. In this retrospective study, we compared patients with post-traumatic conductive hearing loss (CHL) with those referred without CHL to evaluate the relationship between ossicular injuries and CHL. We also assessed the added value of 3D reconstructions on 2D-CT scan to detect ossicular lesions in patients surgically managed.

Methods. – The CT scans were performed using a 40-section spiral CT scanner in 49 patients with post-traumatic CHL ($n = 29$) and without CHL ($n = 20$). Three radiologists performed independent blind evaluations of 2D-CT and 3D reconstructions to detect ossicular chain injury. We used the *t*-test to explore differences regarding the number of subjects with ossicular injury in the two groups. We also estimated the diagnostic accuracy and the inter-rater agreement of the 3D-CT reconstructions associated to 2D-CT scan.

Results. – We identified ossicular abnormality in 14 patients out of 29 and in one patient out of 20 in the CHL and non-CHL groups respectively. There was a significant difference regarding the number of subjects with ossicular lesions between the two groups ($P \leq 0.01$). The diagnostic sensitivity of 3D-CT reconstructions associated with 2D-CT ranged from 66% to 100% and the inter-reader agreement ranged from 0.85 to 1, depending of the type of lesion.

Conclusion. – The relationship between ossicular lesion and the presence of CHL tightly correlated. 3D-CT reconstructions of the temporal bone are useful to assess patients in a post-traumatic context.

Introduction

Post-traumatic conductive hearing loss (CHL) is a frequent functional disorder and radiologists should be aware of the possibility of ossicular lesions being responsible for such audiometric finding. However, the relationship between ossicular lesions and CHL remains unclear [1,2]. The first examination to perform in patients with persistent CHL is multidetector computed tomography (CT) after hemotympanum resorption [3], at least three weeks after the trauma.

From a therapeutic point of view, surgical treatment of luxation of the middle ear ossicles is recommended to be carried out within months of the initial trauma, because delayed ossiculoplasty are assumed to be associated with adhesion or fibrosis [2]. The precise assessment of ossicular damage is crucial and determines, depending on whether the malleus, incus and stapes are injured or not, the most suitable surgical technique to use [4].

The incudo-stapedial (IS) joint is the most commonly affected by ossicular luxation, as diagnosed upon post-traumatic exploration of the middle ear by a ENT surgeon [2,5]. By contrast, radiological data traditionally failed to obtain such incudo-stapedial luxation incidence, probably related to the associated hemotympanum [1].

Abbreviations: CHL, conductive hearing loss; 2D-CT, computed tomography with 2D reconstructions; 3D-CT, computed tomography with 3D reconstructions; IM, incudo-malleolar; IS, incudo-stapedial.

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Besides IS injuries, the incudo-malleolar (IM) joint is frequently involved in post-traumatic CHL. On 2D-CT scan, a luxation or subluxation is defined by a lack of osseous continuity between malleus head and incus body. When both IM and IS disarticulations occur, the incus is dislocated [6]. However, the anatomy of the temporal bone is complex and these lesions may be difficult to diagnose.

New complementary techniques have recently emerged, such as 3D reconstructions allowing the visualization of the tympanic cavity [7–10]. Virtual otoscopy through 3D reconstruction provides a different view on ossicular chain anomalies in traumatic conditions [11,12]. By providing an accurate preoperative assessment of the ossicular chain, this technique may be helpful in determining the precise location of an injury, including complex and unusual forms [13].

The aim of our study was to assess the lesions that may be responsible for post-traumatic CHL and evaluate the added value of 3D-CT reconstructions on detecting ossicular injuries.

Methods

Patients

The study protocol was approved by our institutional review board for a retrospective study (IRB 5891).

Patients aged 18 years or over, were included in this study if they had (a) a history of unilateral extra-labyrinthine temporal bone fracture between January 2012 and December 2015, and (b) have successfully undergone a temporal bone CT scan with 2D acquisition and 3D reconstructions. Patients who had no otolaryngology consultation and surgical management of ossicular lesion were then eliminated from this study. Initially, 50 patients divided into two groups were included in this study. However, one patient with IS joint lesion that was not surgically managed was excluded. The CT imaging data of 49 patients was then analyzed.

Forty-nine patients divided into two groups were included in this study.

The first group (non-CHL group) included patients ($n = 20$) without CHL after the trauma. The mean age of this group was 41.5 years (±9.7), with a female to male ratio of 7:13, while patients had normal auditory testing.

The second group ($n = 29$) included patients with CHL (CHL group). The mean age of this group was 46.3 years (±11.3), with a female to male ratio of 9:23. In this group, 19 patients suffered from left CHL and 11 patients had unilateral right CHL.

Fourteen patients out of 29 with CHL due to trauma had undergone exploration of the middle ear under general anesthesia during the study period to surgically check the imaging findings.

Imaging

The CT was performed using a 40-section spiral CT scanner (Philips 40; Philips Healthcare®) with the following parameters: 0.5 mm collimation, 0.27 incrementation, 0.375 pitch, 0.55 mm section thickness, 140 kV, 300 mAs, a 90 cm field of view and a 1024 × 1024 matrix. The initial data sets were then reconstructed at 0.2 mm intervals with iterative reconstructions [14,15]. Both ears were reconstructed separately. Three-dimensional volume-rendering CT images were generated from the original 2D data using Philips Intellispace Portal®. All the CT scans were performed between three weeks and one year after the initial trauma to ensure that the hemotympanum was resorbed. A neuroradiology fellow or a post-processing technologist obtained all reformatted images. The application of different soft-tissue and bone algorithms to the 3D reformation permitted multiprojectional display of the ossicular chain including joints with the volume-rendering technique. The post-processing lasted between 5 and 10 minutes. The first step was semi-automatic with software removal and detection of the ossicular chain on 3D reconstructions. We then visually checked the results to ensure that the entire chain was actually included in the 3D reconstructions by comparing 2D and 3D region of interest. The 3D reconstructions were obtained for all patients.

Analysis

Three radiologists (one senior, a neuroradiologist with a certificate of Added Qualification, and two fellows from the university) performed independent blind evaluations of CT scans. On 2D-CT acquisition, IS joint can be analyzed with coronal oblique reconstructions (perpendicular to the oval windows) and axial stapes plane, showing a contact between the lenticular process of the incus and the head of the stapes [16,17]. In the coronal oblique plane, the ossicular chain represents a “V”, made by the long process of the incus and the stapes (Fig. 1). On 3D-CT reconstructions, we directly studied the close contact between the stapes and the incus. We defined an incudo-stapedial luxation as a “gap” between the incus and stapes on 2D acquisition or 3D reconstructions.

Concerning IM joint, the head of the malleus and the body of the incus should be in close contact on the 2D-CT axial and sagittal views [1] and 3D-CT reconstructions (Fig. 2). Otherwise, a luxation or subluxation of the incudo-malleolar joint is defined by a lack of osseous continuity. For IM luxation analysis, we analyzed width at half maximum of density peak [18]. The second analysis with both 3D-CT reconstruction and 2D-CT acquisition was performed at least one month after the first analysis on 2D-CT scans.

Statistics

Between-group comparisons were analyzed with the Student's *t*-test for continuous data to assess significant differences regarding the number of subjects with ossicular injury.

Pearson χ^2 test was used for categorical data to explore the correlation between the post-traumatic CHL and the ossicular injuries in both groups and to assess the correlation between the ossicular injuries and the antecedents of mastoid surgery.

We calculated the sensitivity and specificity of 3D-CT reconstructions added to 2D-CT scan and of 2D-CT scan alone, for each reader, taking surgical exploration as gold standard. Inter-rater agreement on detecting ossicular injuries with 3D-CT scan was estimated by using Fleiss coefficient.

We considered *P*-values of < 0.05 as significant. Data were analyzed using SPSS software v22.0 (IBM, Inc., Armonk, New York, USA).

We defined the presence of IS luxation, IM luxation, Incus dislocation as the dependent variables.

Results

Ossicular lesion prevalence using 3D-CT reconstructions associated with 2D-CT scans in the two groups

In the non-CHL group, 19 patients (95%) did not present with ossicular injuries. One patient (5%) referred with IM luxation on 2D acquisition and 3D reconstructions, as previously defined.

In the CHL group, 15 patients (52%) did not display any ossicular luxation or dislocation, 9 patients (31%) had an IM luxation (Fig. 3), 7 patients an IS luxation (24%) and 4 patients (14%) had an incus dislocation. Among the patients with ossicular post-traumatic lesion, 3 patients (21%) referred with antecedents of temporal bone surgery for chronic ear pathologies (Figs. 4 and 5).