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SHORT COMMUNICATION

Dynamic cine imaging of the Eustachian tube using four-dimensional computed tomography

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Abstract

Background: Imaging the Eustachian tube has proven difficult as it has an anatomical orientation that is not aligned with standard planes. In addition, the Eustachian tube is a dynamic structure, opening briefly during a variety of physiological manoeuvres.

Case report: A 54-year-old healthy and asymptomatic man underwent computed tomography utilising an area detector scanner. Multiplanar reconstruction was performed at 1 mm intervals. In addition, dynamic clips were constructed to demonstrate air and its movement in the field. Images and video were acquired whilst a Valsalva manoeuvre was being performed.

Conclusion: Although imaging techniques have been able to visualise the Eustachian tube well in the closed state, it may be more useful to have it imaged whilst open. Area detector computed tomography scanners can be used to acquire four-dimensional images. This allows dynamic imaging of the region, to assist in the diagnosis of various types of Eustachian tube dysfunction.

Key words: Four-Dimensional Computed Tomography; Eustachian Tube; Valsalva Maneuver

Introduction

The Eustachian tube is an organ that connects the nasopharynx to the middle-ear cavity, with primary functions of ventilation, drainage and protection of the latter. Recent reviews have shown that as comprehension of Eustachian tube function has increased, so have the range of treatment options available for Eustachian tube dysfunction.[1]

Imaging the structure has proven difficult as it has an anatomical orientation that is not aligned with either the axial, coronal or sagittal planes. In addition, the Eustachian tube is normally closed and actively opens during manoeuvres such as swallow and yawning, before once again passively closing. Dysfunction occurs when the normal physiology is impaired, and there is either deficient opening or closing of the Eustachian tube.

Case report

A 54-year-old healthy and asymptomatic man with no significant otorhinological history, who was the senior author in this article (MB), underwent computed tomography (CT) utilising an area detector CT scanner (Aquilion One; Toshiba Medical Systems, Otawara, Japan). The temporal bone region was scanned using a 320-row detector with 0.5 mm slice thickness, in dynamic mode, with continuous exposure at 80 kVp and 50 mA. Scanning was performed for a total of 2.75 seconds, with 0.275 seconds per rotation for a total of 10 rotations. Multiplanar reconstruction in all three planes was performed at 1 mm × 1 mm intervals. In addition, dynamic clips were constructed with colon presets to demonstrate air and its movement in the field.

The images were acquired whilst a Valsalva manoeuvre was being performed, in order to demonstrate the possibilities of this mode of imaging. Still frames taken from the cine sequence are shown in Figure 1. The pertinent anatomical features are outlined in Figure 2. Images were also acquired during a respiratory cycle, a swallow and a yawn.

A short video, available on *The Journal of Laryngology & Otology* website, shows a four-dimensional cine sequence of the right ear during a Valsalva manoeuvre, displaying the propagation of an air bolus from the nasopharynx to the middle ear through the Eustachian tube (Appendix 1).

Discussion

Although imaging techniques have been able to visualise the Eustachian tube well in the closed state, it may be more useful to have it imaged whilst open. Recent studies have used CT,[2] or magnetic resonance imaging[3] to image the Eustachian tube whilst an attempt is made by the patient to force it open and keep it so using a Valsalva manoeuvre. Whilst this certainly can provide a useful comparison with baseline scans, it offers no insight into the dynamic changes that occur between the open and closed states.

Area detector CT scanners can be used to acquire four-dimensional CT images. The fourth dimension of time can be captured because of a cone-beam X-ray source coupled with a large detection area, and this can be acquired in a very short period of time. This has previously been utilised to image the Eustachian tube, specifically to diagnose when it is patulous by analysing dynamic changes that

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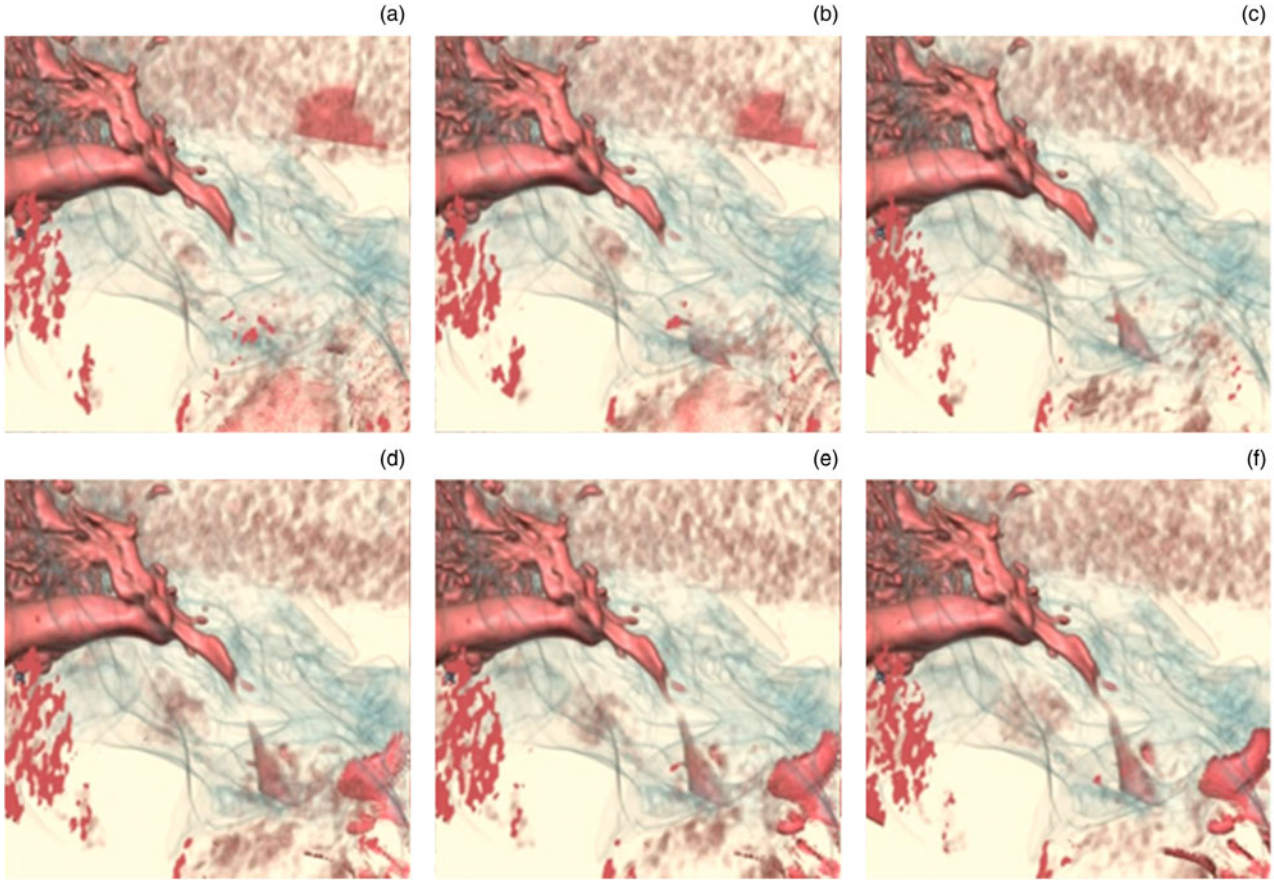

FIG. 1

Multiple frames of a Eustachian tube cine sequence during a Valsalva manoeuvre on the right ear, displaying the propagation of an air bolus from the nasopharynx to the middle ear. Parts (a) – (f) indicate chronological order.

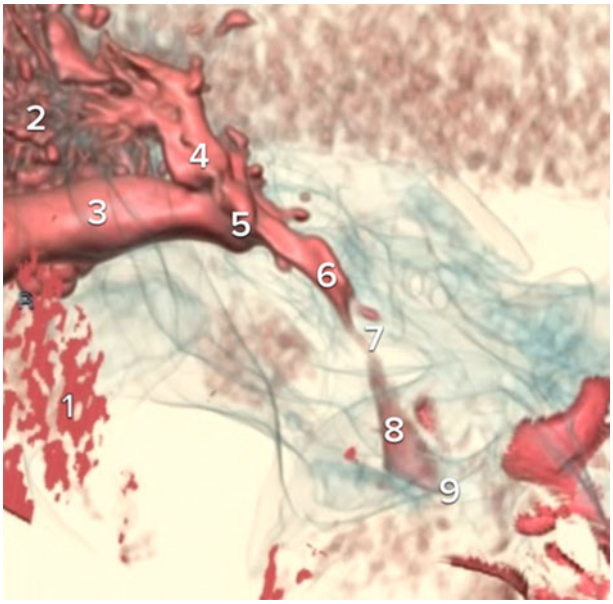

FIG. 2

Single frame of a Eustachian tube cine sequence during a Valsalva manoeuvre on the right ear, with pertinent structures labelled: 1 = mastoid tip, 2 = mastoid, 3 = external auditory canal, 4 = antrum, 5 = tympanic cavity, 6 = protympanum/bony Eustachian tube, 7 = Eustachian tube isthmus, 8 = cartilaginous Eustachian tube and 9 = nasopharynx.

occur in suspected patients during sniffing.[4] In the diseased state, the Eustachian tube would be expected not to display complete patency along its length, despite manoeuvres undertaken to encourage it to open such as swallowing, yawning or a Valsalva manoeuvre.

Having launched in 2007, the technology is gradually becoming more widely available, with Toshiba manufacturing its 1000th 320-row area detector CT scanner in 2015.[5] The main limitation is the cost of the CT scanner, which is estimated at around £1.8 million GBP.[6]

This imaging technology provides a fourth dimension to CT sequences of the Eustachian tube, allowing dynamic imaging of the region, to assist in the diagnosis of various types of Eustachian tube dysfunction. The time taken to perform the imaging is minimal and, given the low tube current and peak kilovoltage, radiation dose reduction is significant compared with conventional CT imaging of the Eustachian tube.

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Appendix 1 Supplementary video material

A short video, demonstrating the cine sequence from multiplanar three-dimensional reconstruction of four-dimensional computed tomography during a Valsalva manoeuvre on the right ear, which displays the propagation of an air bolus from the nasopharynx to the middle ear through the Eustachian tube, is available online at *The Journal of Laryngology & Otology* website, at https://doi.org/10.1017/S0022215116009257.

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