International Journal of Pediatric Otorhinolaryngology 79 (2015) 411–418

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: www.elsevier.com/locate/ijporl

Radiological prevalence of superior and posterior semicircular canal dehiscence in children☆

Alexander J. Saxby [a], Claire Gowdy [b], Marcela Fandiño [a], Neil K. Chadha [a], Frederick K. Kozak [a], Michael A. Sargent [b], Jane Lea [a,*]

[a] Division of Pediatric Otolaryngology, Head and Neck Surgery, BC Children's Hospital, 4480 Oak Street, Vancouver, BC V6H 3N1, Canada
[b] Department of Radiology, BC Children's Hospital, 4480 Oak Street, Vancouver, BC V6H 3N1, Canada

ARTICLE INFO

Article history:
Received 30 October 2014
Received in revised form 28 December 2014
Accepted 1 January 2015
Available online 14 January 2015

Keywords:
Superior semicircular canal dehiscence
Posterior semicircular canal dehiscence
Semicircular canal dehiscence syndrome
Pediatric population
Computed tomography

ABSTRACT

Objective: Establishing the prevalence of semicircular canal dehiscence in a pediatric population using temporal bone CT imaging.
Study design: Retrospective analysis of all temporal bone CT scans during a 5-year period (2007–2012).
Methods: CT scan images were reformatted in the plane of the canals and assessed by two independent reviewers with a third to resolve disagreement. Detailed chart review was performed for those found to have dehiscence. Superior and posterior canals were classified as "dehiscent", "possibly dehiscent", "thin" or "normal" for each case.
Results: 649 temporal bones were assessed from 334 children (under 18 years of age). The prevalence rate of superior canal dehiscence (SCD) was 1.7% (3.3% of individuals). Posterior canal dehiscence (PCD) was present in 1.2% (2.1% of individuals). There were no cases of bilateral SCD, and one case of bilateral PCD. Age under 3 years was associated with a higher prevalence of thinning but not dehiscence. Congenital inner ear malformation was not related to a higher probability of dehiscence. The superior petrosal sinus was associated with the SCD in three cases (27.3%). Retrospective chart review highlighted possible vestibular symptoms in 3/11 patients with SCD (27.3%).
Conclusions: This forms the largest pediatric study of canal dehiscence to date. This study's prevalence rate is significantly lower than previous reports. The identified association with overlying venous structures may reflect the etiological process involved. The occurrence in children supports the hypothesis of a congenital predisposition for development of canal dehiscence syndrome.

1. Introduction

Superior semicircular canal dehiscence syndrome (SCDS) was first described by Minor in 1998 and results from an absence of bone overlying the superior semicircular canal in the petrous roof [1]. SCDS classically presents with "third window phenomenon" symptoms including aural fullness, conductive hyperacusis (i.e. pulsatile tinnitus, autophony) and pressure or sound induced vertigo [1].

Diagnosis of SCDS is based on clinical history and examination in combination with radiological evidence of dehiscent bone plus characteristic audiological and vestibular function test findings, most notably reduced threshold and high amplitude vestibular evoked myogenic potentials (VEMP). High resolution computed tomography (CT) is an integral diagnostic feature of SCDS. It is well recognized that not all patients with evidence of SCD will develop SCDS; the discrepancy may be due to errors in imaging accuracy or that additional critical events are required to make the bony dehiscence symptomatic. Direct clinical visualization of the petrous roof is not feasible, and therefore CT remains the most accepted method of assessing bone integrity in this area.

The prevalence of bony dehiscence in children is important to our understanding of the etiology of this condition. Some authors advocate a congenital predisposition, which may subsequently lead to symptomatic clinical disease in adulthood, whilst others propose that intact bone in childhood is later thinned by osteopenic processes [2,3] or microtrauma [4].

☆ *Presentation*: The results of this study were presented at the Canadian Society of Otolaryngology Head & Neck Surgery (CSO-HNS) Annual Meeting on June 2nd 2013 in Banff, Alberta, Canada and the 28th Barany Society Meeting on May 28th 2014 in Buenos Aires, Argentina.

* Corresponding author. Tel.: +1 604 875 2113; fax: +1 604 875 2498.
E-mail addresses: saxbyaj@gmail.com (A.J. Saxby), claire.gowdy@cw.bc.ca (C. Gowdy), fandino.marcela@gmail.com (M. Fandiño), nchadha@cw.bc.ca (N.K. Chadha), fkozak@cw.bc.ca (F.K. Kozak), msargent@cw.bc.ca (M.A. Sargent), jlea@cw.bc.ca (J. Lea).

http://dx.doi.org/10.1016/j.ijporl.2015.01.001
0165-5876/

Previous prevalence studies have employed a variety of radiological methods, resulting in a wide range of published prevalence rates [4–16]. We aimed to obtain a better estimate of the true prevalence by utilizing higher resolution imaging techniques in a larger sample size than has previously been studied with strict definition criteria. In addition we assessed correlation with congenital malformation, younger age and relationship with adjacent venous sinuses.

2. Materials and methods

2.1. Study design

Retrospective case series. Analysis was made of all CT scans of the temporal bone undertaken at British Columbia Children's Hospital (Vancouver, Canada), followed by a retrospective chart review of any patient found to have canal dehiscence. Approval was obtained from the University of British Columbia Children's and Women's Research Ethics Board (Research protocol: H12-00582).

Inclusion criteria:

- Temporal bone CT scans for any indication.
- Scans performed between Jan 2007 and Jan 2012.
- Age of patient: under 18yrs at the time of the CT scan.

Exclusion criteria:

- Inadequate CT images:
  - Slice thickness >0.65 mm
  - Movement artifact
  - Vestibular organ not fully imaged
- Vestibular organ abnormality:
  - Congenital malformation of the semicircular canals or vestibule
  - Acquired abnormality (e.g. ossification, neoplasia, surgery).

2.2. Radiological imaging

The CT scanner used for all cases in the study was a Philips MX 16 (Cleveland Ohio). Slices were acquired helically in the axial plane at nominal 0.65 mm slice thickness. They were obtained at 50% overlap (0.325 mm). All scans were obtained at 120 kVp and 200 mAs on bone (ultrahigh) resolution.

The primary images were retargeted in the axial and coronal planes to a 70 mm field of view at a 512 matrix for voxel size of 0.32 mm × 0.14 mm × 0.14 mm (0.32 = slice thickness, 0.14 = inplane resolution). The retargeted axial scans were then reformatted in the plane of Pöschl (parallel to the plane of the superior semicircular canal) and in the plane of Stenver (perpendicular to the plane of the superior semicircular canal), using "Voxar 3D" software, version 6.3 (Barco Medical). The reformatted 0.32 mm slices were non-overlapped. All reformatting was performed by the senior pediatric neuroradiologist (MS).

All scans were provided for viewing at a window level of 500 HU and width of 4000 HU with the option for the reader to alter windows as necessary.

2.3. Study protocol

2.3.1. Screening

CT scans were first assessed using standard axial and coronal images and were classified as either "*Normal*" or "*Abnormal*". "*Abnormal*" was defined as any sign of bony thinning in the region of the semicircular canals. This wide definition was deliberate so as to include all potentially dehiscent cases in further assessment. Only scans showing thick bone throughout the screening images were classified as "*normal*". All "*abnormal*" scans plus a random selection of 50 "*normal*" scans, for quality assurance of the screening method, went on to be reformatted in the parallel (Pöschl) and perpendicular (Stenver) planes of the superior canal.

2.3.2. Reformatted images

The reformatted images were assessed by two independent reviewers; one fellowship trained neurotologist (AS), one fellowship trained pediatric radiologist (CG), with a third senior pediatric neuroradiologist (MS) to settle any disagreement by majority consensus. Reviewers were blinded to the axial/coronal screening classification, the indications for the scan, and the original radiological report.

2.3.3. Classification

Each temporal bone was classified in one of 4 categories: "*Normal*", "*Thin*", "*Possibly Dehiscent*" and "*Dehiscent*" for both the superior canal and posterior canal (see Table 1 and Fig. 1). Deliberately strict criteria were applied for a scan to be called dehiscent. The "*possibly dehiscent*" category was used to differentiate those scans in which there was evidence of a bony defect on at least one image, but did not meet the diagnostic criteria of at least two sequential images and one in the perpendicular plane. If a dehiscence was found, the length was measured in the plane parallel to the canal.

2.3.4. Subgroup analysis

Subgroup analysis included review of those patients with an inner ear abnormality not affecting the vestibular organ. Age under 3 years was also analyzed as a subgroup, based on the histological studies of Carey et al. [17] which suggested 3 years to be the point at which bone growth of the inner ear reaches adult proportions.

2.3.5. Retrospective chart review

Review of audiological data, clinical history and examination with attention to vestibular symptomatology was undertaken for all patients found to have dehiscence. Demographic information, indications for scan, and the original radiology reports were all recorded and analyzed.

2.4. Statistical analysis

Agreement between reviewers was calculated using the Cohen's Kappa coefficient. In situations where subgroup analysis was performed, difference between subgroups was assessed using Fisher's exact test using $p = 0.05$ to indicate statistical significance (QuickCalc, GraphPad Software Inc.). Random selection of cases screened as "normal" for reformatting in the plane of

Table 1
Classification criteria. The following criteria were applied to the reformatted images. Images were assessed by two reviewers independently (AS, CG), with a third (MS) used to settle disagreement by majority consensus. Reviewers were blinded to axial/coronal screening results, scan indications and original radiological reports.

Classification	Definition
Dehiscent	Dehiscent bone on 2 consecutive images in the perpendicular plane PLUS at least 1 image in the corresponding parallel plane
Possible dehiscence	Dehiscent bone on image(s) in only one plane, but not in the other plane
Thin	No dehiscence in either plane but bone coverage is minimal
Normal	No dehiscence in either plane and bone coverage is plentiful