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# Evaluation of velopharyngeal closure by 4D imaging using 320-detector-row computed tomography



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## KEYWORDS

Cleft palate;  
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4D-CT;  
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**Summary** *Objective:* Current imaging techniques for velopharyngeal closure (VPC) evaluation are two-dimensional, static, or distressing, thus necessitating multiple procedures to understand this three-dimensional and dynamic area. We validated the use of a novel four-dimensional (4D) computed tomography (CT) technique for the morphological and kinematic evaluation of VPC in cleft palate patients based on dynamic volume scanning with 320-detector-row CT.

*Methods:* Five patients aged 4–10 years (40% males) with persistent velopharyngeal insufficiency post palatoplasty underwent conventional tests (cephalometry and video-nasal endoscopy) and 4D-CT. For each patient, complete multiplanar reconstruction, 4D airway CT, and 4D-CT endoscopy data for all scanning phases were compared with cephalometric and video-nasal endoscopy data. The movements of the velum and posterior pharyngeal walls were graded by each modality.

*Results:* 4D airway CT revealed higher anatomical detail than cephalometry, additionally providing dynamic images. 4D-CT endoscopy and video-nasal endoscopy were in agreement for all patients regarding the patterns of VPC, with complete visualization of VPC in five versus one patient, respectively. 4D airway CT and cephalometry showed a discrepancy in one case, wherein grading by cephalometry was overestimated. 4D-CT was also useful in determining the width and length of a proposed pharyngeal flap. The examination time (mean  $\pm$  standard deviation (SD), seconds), including patient preparation time, was  $224 \pm 73$ ,  $492 \pm 145$ , and

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718 ± 123 for cephalometric radiographs, CT, and video-nasal endoscopy, respectively. The mean estimated radiation dose during 4D-CT was 4.44 ± 1.64 mSv.

**Conclusions:** 4D-CT provides detailed morphological and kinematic analysis of VPC and may offer advantages over conventional procedures.

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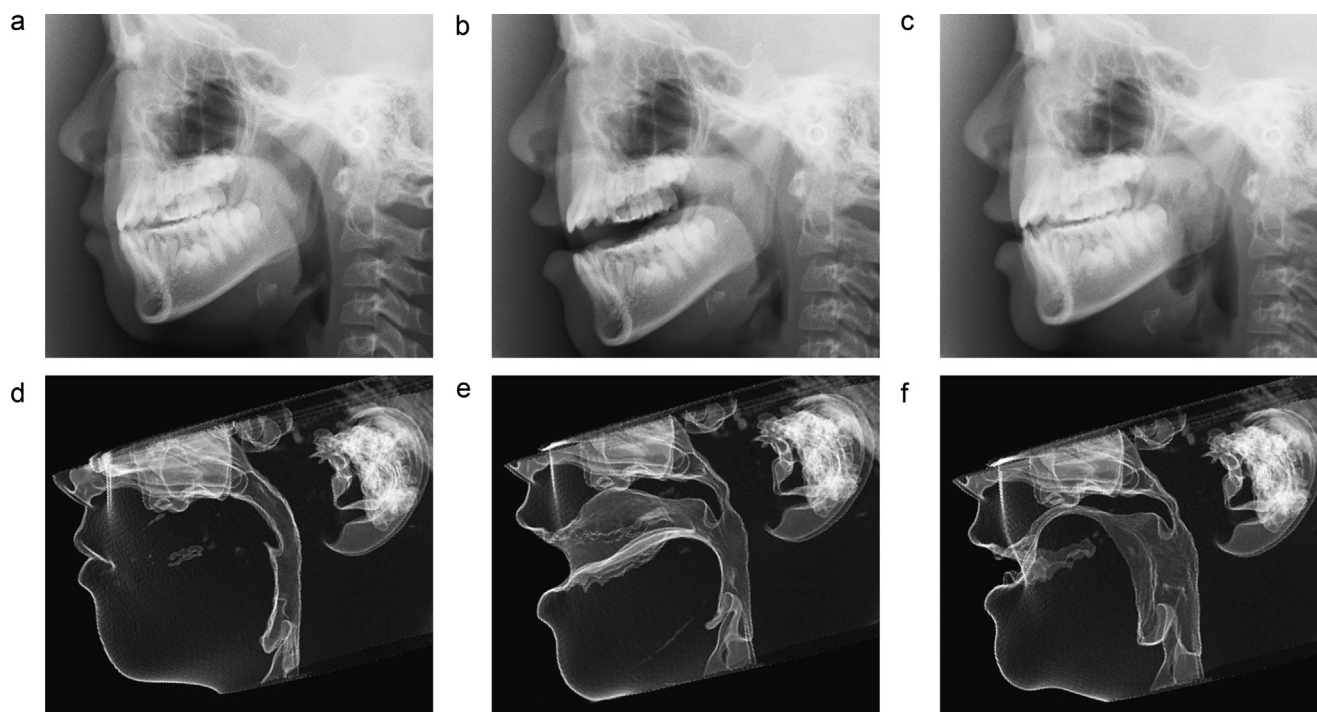
## Introduction

The functional goal of cleft palate surgery is to facilitate normal velopharyngeal closure (VPC). However, despite the use of multiple, updated surgical techniques, a substantial percentage of children with cleft palates develop velopharyngeal insufficiency (VPI) after palatal repair.<sup>1,2</sup>

A multidisciplinary approach is used to evaluate VPC and determine the surgical indications for VPI. Perceptual speech evaluation by speech-language pathologists is the gold standard for evaluating VPC. Prior to surgical intervention, it is important to evaluate the gap size, location, and pattern of VPC because the velopharyngeal mechanism is three-dimensional (3D) and dynamic. Therefore, direct imaging tests, including cephalometry, videofluoroscopy, and video-nasal endoscopy, have been implemented.<sup>3–9</sup> However, one potential disadvantage of these methods is that the images are either limited to two dimensions or static. Although video-nasal endoscopy provides excellent

anatomical detail of VPCs, it is a distressing procedure that may be difficult to perform in younger children. Incomplete visualization because of the dead angle created by the elevated soft palate is also a concern.<sup>9</sup> Nasometry allows for objective and quantitative measurement of VPC, but it refers to the measurement of air escaping through the nose during phonation and does not provide the necessary anatomical detail required for surgery. To compensate for the limitations and take advantage of the strengths of the currently used methods, a combination of these tests is usually required even though the combination can increase patient stress.

Recent advances in multi-detector-row computed tomography (CT) have dramatically improved its spatial and temporal resolution. Modern CT imaging enables four-dimensional (4D) scanning, wherein dynamic blood flow or movement of an organ can be characterized.<sup>10,11</sup> The purpose of this study was to validate the use of a novel 4D-CT technique for the morphological and kinematic evaluation



**Figure 1** Comparison between cephalometric evaluation and 4D airway CT in patient 4. Note the discrepancy between the cephalometry (c) and 4D airway CT (f) images during phonation [i:]. In the cephalometric evaluation, the soft palate nearly reached the posterior wall (graded as 3); however, in the 4D airway CT evaluation, <50% of the distance from the posterior wall remained (graded as 2). a) cephalometric evaluation at rest, b) cephalometric evaluation during phonation (/a:/), c) cephalometric evaluation during phonation (/i:/), d) 4D airway CT at rest, e) 4D airway CT while phonating (/a:/), f) 4D airway CT while phonating (/i:/).

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