

Double-contrast tongue surface imaging technique in swallowing computed tomography

Kanamori D^{1*}, Fujii N², Inamoto Y³, Aihara K⁴, Kobayashi M⁵, Aoyagi Y⁶, Matsuo K⁷, Kagaya H⁶, Toyama H², Sonoda S⁸ and Saitoh E⁶

¹Department of Dentistry, Nanakuri Memorial Hospital, Fujita Health University, Oodoricho, Tsu, Mie, Japan

²Department of Radiology, School of Medicine, Fujita Health University, Toyoake, Aichi, Japan

³Faculty of Rehabilitation, School of Health Sciences, Fujita Health University, Toyoake, Aichi, Japan

⁴Department of Rehabilitation, Fujita Health University Hospital, Toyoake, Aichi, Japan

⁵Faculty of Radiological Technology, School of Health Sciences, Fujita Health University, Toyoake, Aichi, Japan

⁶Department of Rehabilitation Medicine, School of Medicine, Fujita Health University, Toyoake, Aichi, Japan

⁷Department of Dentistry and Oral-Maxillofacial Surgery, School of Medicine, Fujita Health University, Toyoake, Aichi, Japan

⁸Department of Rehabilitation Medicine II, School of Medicine, Fujita Health University, Oodoricho, Tsu, Mie, Japan

Abstract

We present a method for visualizing tongue motion in the oral stage of swallowing. Conventional computed tomography clearly distinguishes air, swallowing contrast agent, and bone. However, because the tongue contacts the palate, it is difficult to clearly display contours of the tongue. We devised a double-contrast tongue surface imaging technique using sodium alginate, barium (positive contrast), and golden flaxseed oil (negative contrast). This facilitates safe visualization of tongue and soft palate motion during swallowing.

Introduction

Swallowing contrast imaging and swallowing endoscopy are commonly performed to assess clinical status in dysphagia rehabilitation and to evaluate treatment effects. We have successfully used computed tomography (CT) for dynamic analysis during swallowing. For contrast imaging evaluation of swallowing (swallowing CT) using a 320-row area detector computed tomography (320-ADCT) scanner, we typically set a special chair in the semisitting position, and perform serial radiography to coincide with the timing of swallowing of the contrast agent. We then create sequential three-dimensional computed tomographic (3DCT) images. This new technique makes it possible to carry out detailed analysis of the morphological changes of the swallowing organs and the stages that contrast agent passes through.

In conventional CT imaging, air, swallowing contrast agent, and bone are clearly distinguished. The tongue plays an important role during swallowing motion but displaying a clear outline of the tongue is difficult because it contacts the palate (Figure 1). Therefore, we devised a double-contrast technique to image the tongue surface with a liquid mixture of sodium alginate and barium as the positive contrast agent and golden flaxseed oil as the negative contrast agent.

Material and method

Double-contrast technique

We used 90 mL of 5% sodium alginate solution (Alloid G, Kaigen Pharma Co., Ltd., Hiroshima, Japan) mixed with 10 mL of 100% w/v barium as contrast agent for the mucosal surface (1500 HU). To ensure uniform consistency of the mixture, it was agitated for 10 min in a barium shaker (BR-6, Thermal Chemical Industry, Co., Ltd., Tokyo,

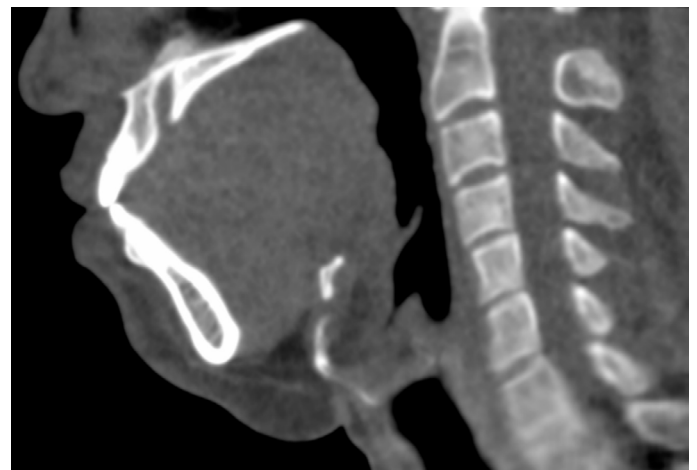


Figure 1. Conventional computed tomography image during swallowing (sagittal plane). The tongue and palate are in contact, so displaying a clear outline of the tongue is difficult

Japan; Figure 2). First, subjects took a sip of 10 mL of the contrast agent for the mucosal surface, rolled it in the mouth for 10 s so that it sticks to the entire surface of the tongue, and then swallowed it. A representative

***Correspondence to:** Daisuke Kanamori, Department of Dentistry, Nanakuri Memorial Hospital, Fujita Health University, Oodoricho, Tsu, Mie, Japan, Tel: +81592523018; Fax: +81592521383; E-mail: dkanamor@fujita-hu.ac.jp

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oral photograph of the contrast agent attached to the tongue and palate is shown in Figure 3. Second, subjects swallowed 10 mL of golden flaxseed oil (Amaniyu, Nippon Flour Mills Co., Ltd., Tokyo, Japan) as a negative contrast agent (-50 HU). CT imaging was performed during swallowing.

Equipment

We used a 320-row area detector computed tomography scanner (320-ADCT, Aquilon ONE, Toshiba Medical Systems Corporation, Otawara, Japan). A special reclining chair for swallowing CT was inclined at 45 degrees in the semisitting position and placed at the side of the bed opposite to the CT equipment. CT images were taken with the gantry inclined 22 degrees (Figure 4). This chair (co-produced by Tomei Brace Co., Ltd., Seto, Japan, and Aska Corporation, Kariya, Japan) adjusts the angle of the back side and the position of the seat surface in a back and forth direction, making it possible to insert the face into the scan plane.

Scanning conditions and image production

Scanning conditions and positioning for swallowing CT are shown in Table 1. Scanning conditions were 120 kV, 40 mA, and 3.3 s of serial radiography. After scanning, images of 10 frames/s were produced

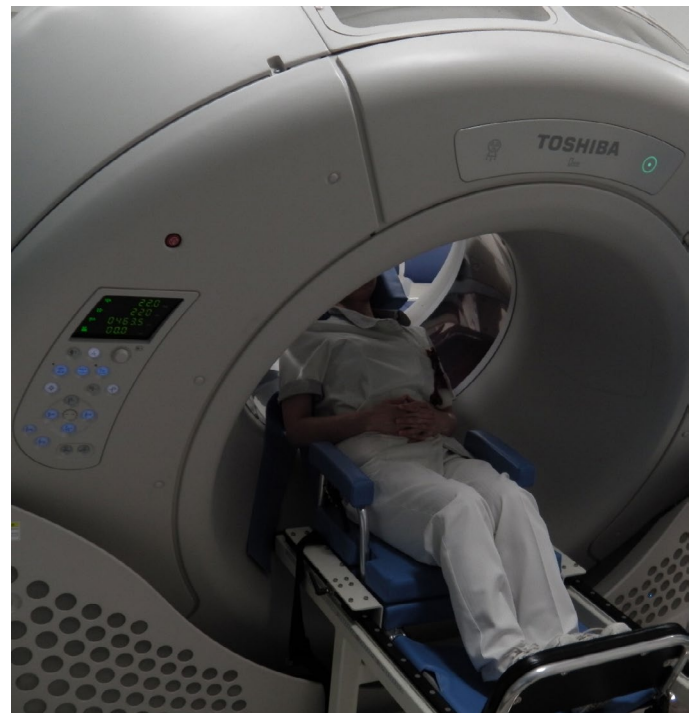


Figure 4. Positioning for 320-row area detector computed tomography imaging. A special chair for swallowing computed tomography (CT) is placed at the side of the bed opposite to the CT equipment and is reclined in a semisitting position inclined at 45 degrees. CT images are taken with the gantry inclined at 22 degrees



Figure 2. Mixture of the double-contrast agent for the mucosal surface. Barium shaker containing 9 mL of sodium alginate solution and 1 mL of 100% w/v barium mixed by stirring for 10 min



Figure 3. Oral photograph. The contrast agent for the mucosal surface is attached to the tongue and palate

Table 1. Exposure parameters for 320-ADCT

	Location selected for CT scan	CT scan
Scan mode	Volume	Dynamic Volume
kV	120	120
mA	10	40
Gantry revolution time [sec/rot]	0.275s/1rot	3.3s /12rot
Detector configuration [mm]	160	160
mAs	2.75	11
FOV [mm]	240(S)	240(S)
CTDIvol [mGy]	0.6	26.2
DLP [mGy·cm]	9.6	419.3

from the data using a reconstruction function (Adaptive Iterative Dose Reduction 3D, Toshiba Medical Systems Corporation, Otawara, Japan) to reduce radiation exposure. Using a workstation for 3D images (Ziostation2, Ziosoft Inc., Tokyo, Japan), the images of air, golden flaxseed oil, bone, and skin surface were reconstructed by the volume rendering (VR) method, and the images of the tongue and soft palate were reconstructed by the surface rendering (SR) method. Following overlaying of each part of the images, we observed the 3D images during swallowing motion along the time sequence.

This study was approved by the ethics committee of Fujita Health University (HM16-135).

Result

We successfully observed the images obtained from 320-ADCT in the axial, coronal, and sagittal planes of multiplanar reconstruction for each organ in the oral cavity and pharynx that is involved in swallowing (Figure 5). In the sagittal plane, the contrast agent attached to the surface of the tongue was detected and the border between

the tongue and palate became clear. In the median sagittal plane, the preparatory, oral, pharyngeal, and esophageal stages and the end of swallowing were all observed along the time sequence. The transfer of the food bolus and the motion of the soft palate and tongue were also confirmed (Figure 6).

In the oral stage, the subject scoops up the food bolus with the tongue and touches the tip of the tongue to the posterior aspect of the upper incisors. Next, the subject pushes down the tongue median and transfers the bolus of food to the pharynx. The pharyngeal stage involves the closure of the upper pharynx by elevation of the soft palate and the closing of the pharynx by elevation of the larynx. In the esophageal stage, the esophageal entrance is dilated, the upper esophageal sphincter is closed after the bolus of food passes through, and the swallowing process ends. The 3D overlay images of VR and SR are shown in Figure 7. The swallowing motion shown in Figure 6 was displayed in 3D. Particularly, the depression that appears on the tongue median during the phase of holding the food bolus on the tongue and the depression that appears on the elevated soft palate and the tongue base during propulsion became distinct.

Discussion

This technical note describes a method for visualizing tongue motion during the oral stage of swallowing. This newly revised swallowing CT imaging technique is carried out using a mixture of sodium alginate and barium as a positive contrast agent, which sticks to the tongue and palate. Golden flaxseed oil is used as a negative contrast agent, as the bolus of food. This double-contrast technique enabled us to depict the motion of the tongue and palate during swallowing.

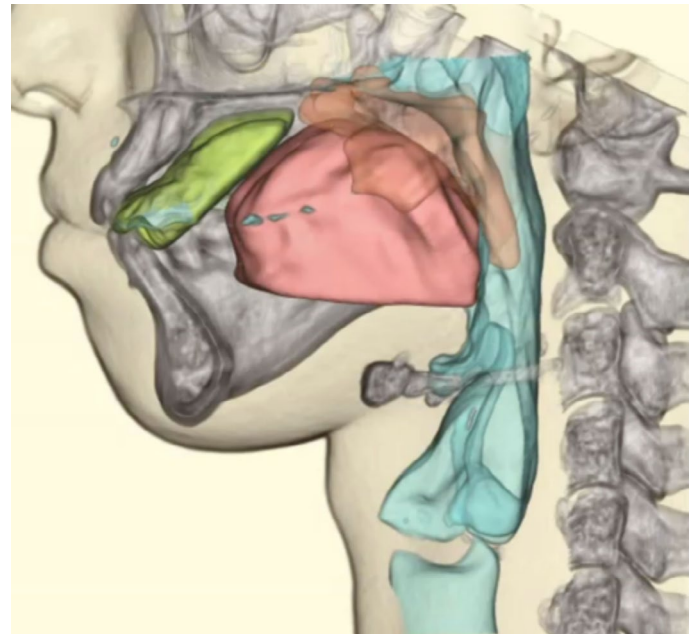


Figure 7. Three-dimensional overlay images of volume rendering and surface rendering. Bone (white), food bolus (yellow), tongue (pink), palate (orange), and respiratory tract (aqua) are seen. The depression seen on the median of the tongue during the holding of the food bolus on the tongue, and the depression that appears on the elevated soft palate and the tongue base during propulsion of the food bolus are clearly depicted. (CT, computed tomography)

Other radiographic tests involving a double-contrast technique include double-contrast upper gastrointestinal examination, double-contrast barium enema, and double-contrast arthrography. CT is used for double-contrast arthrography. In these tests, air is used as a negative contrast agent in addition to barium, a positive contrast agent. We used sodium alginate to facilitate the temporary attachment of barium to the surface of the tongue. Then, the subject swallows the oil as a negative contrast agent. In patients with residual teeth, the border of the buccal mucosa and teeth is clear. Even in edentulous patients, using the double-contrast technique allows the border of the buccal mucosa, alveolar ridge, and tongue to be observed.

In terms of the formulation, sodium alginate solution is a green, viscous aqueous solution, which is used for mucosal protective and hemostatic effects. This formulation has high adhesiveness. In Japan, it is commonly used as a drug and in the United States, it is used for various purposes in food, drugs, and dental impression materials. In recent years, it has been used as a base for drug delivery systems and film preparation [1]. Extracted from brown seaweed, it has high safety and is used in various industries. It has few side effects including diarrhea and constipation. It mixes readily with barium, and by swirling the mixture in the mouth for 10 s, it can easily coat the entire oral mucosa. Golden flaxseed oil is an edible oil reported to be rich in “α-linolenic acid and is effective for preventing heart disease [2]. When consumed in large amounts, it is known to often cause loose stool and diarrhea. It is easy to consume and does not elute barium, hence it has utility as a negative contrast agent during CT imaging.

Numerous specialized studies exist as the tests for dysphagia. These include modified barium studies, ultrasonography, radionuclide imaging or scintigraphy, and endoscopy. Others are magnetic resonance imaging and ultrafast CT [3]. For swallowing tests, we used the 320-ADCT, which is an ultrafast CT device that has a detector of 0.5 mm×320 rows with a length of 16 cm. The 16-cm length enables

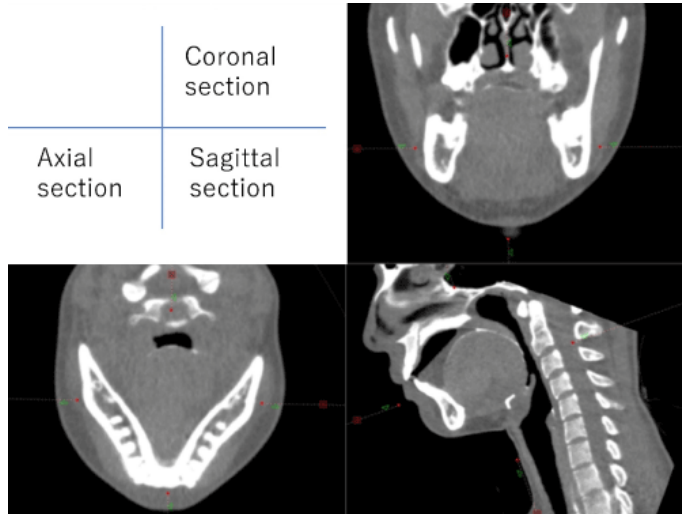


Figure 5. Multiplanar reconstruction images. Contrast agent stuck to the tongue surface, with clear depiction of the border between the tongue and palate

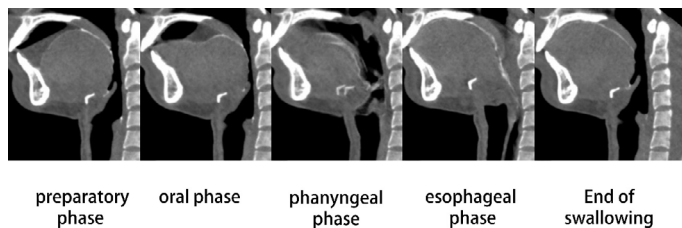


Figure 6. Computed tomography images of tongue median (sagittal plane). Transfer of the food bolus and the motion of the soft palate and tongue are confirmed in the preparatory, oral, pharyngeal, and esophageal stages, and at the end of swallowing

dynamic analysis of swallowing from the pharynx to the cervical esophagus. Swallowing CT has been used not only in research but also in clinical practice, and various studies with the use of cross-sectional and 3D imaging have been reported [4-6].

Reducing radiation exposure is important in performing swallowing CT due to the need for serial radiography. In the first CT imaging protocol reported in 2011 when the swallowing CT test was first introduced, the dose of radiation exposure was a maximum of 3.9 mSv [7,8]. Introducing a reconstruction method for reducing radiation exposure and optimizing the protocol reduced the dose of exposure to 1.9 mSv in the latest protocol [9,10]. Studies using low-radiation-exposure protocols have reported the time and timing [11-15], the square measure and volume of the swallowing organ [16-21], and travel distance of the hyoid bone [14,15,20].

Image assessment during dysphagia rehabilitation is important. Dynamic images are most useful to capture the features and extent of disorders, clarifying the utility of treatments and compensatory techniques.³ This novel imaging technique for tongue motion will enable observation of propulsion of the food bolus by the tongue and the dynamic state during mastication, and will contribute to further development of the use of kinematics and oral devices in rehabilitation.

Authorship and contributorship

DK designed the study and wrote the initial draft of the manuscript. NF contributed to analysis and interpretation of data and assisted in the preparation of the manuscript. All other authors have contributed to data collection and interpretation, and critically reviewed the manuscript. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Competing interest

The authors have no conflicts of interest directly relevant to the content of this article.

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