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● *Technical Note*

ULTRASOUND IMAGING FOR ANALYZING LATERAL TONGUE MOVEMENTS DURING MASTICATION IN ADULTS WITH CEREBRAL PALSY COMPARED WITH ADULTS WITHOUT ORAL MOTOR DISABILITIES

Lianne Remijn,*† Gert Weijers,‡ Maria W. G. Nijhuis-van der Sanden,§¶ Brenda E. Groen,† and Chris L. de Korte‡

*Institute of Health Studies, HAN University of Applied Sciences, Nijmegen, The Netherlands; †Sint Maartenskliniek Research, Nijmegen, The Netherlands; ‡Medical Ultrasound Imaging Centre, Department of Radiology, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands; §IQ Healthcare, Radboud University Medical Center, Nijmegen, The Netherlands; and ¶Radboud Institute for Health Sciences, Department of Rehabilitation, Radboud University Medical Center, Nijmegen, The Netherlands

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Abstract—Described here is an ultrasound technique used to study tongue movements, particularly lateral tongue movements, during mastication. A method to analyze spatial and temporal tongue movements was developed, and the feasibility of using this method was evaluated. Biplane ultrasound images of tongue movements of four adults without oral motor disability and two adults with oral motor disability as a result of cerebral palsy, were acquired. Tongue movements were analyzed in the coronal and sagittal planes using B-mode and M-mode ultrasonography. Inter-rater and intra-rater agreement for manual tracing of tongue contours was good (ICC = 0.81 and 0.84, respectively). There were significant differences between the two adult groups in movement frequency in the horizontal direction in both coronal and sagittal planes. In the coronal plane, differences in movement frequency and range of vertical movement were detected. Data obtained from sagittal images, with the exception of vertical frequency, indicated no differences between the groups. The protocol developed in this study (using B-mode and M-mode) proved to be valid and reliable. By using this protocol with individuals with and without oral motor disability, we were able to illustrate the clinical application of our protocol to evaluation of differences in tongue movements during mastication. (E-mail: lianne.remijn@han.nl) © **2015 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Mastication, Tongue movements, Ultrasound, Cerebral palsy.**

INTRODUCTION

Effective mastication is characterized by efficient fragmentation, crushing and mixing of ingested food to form a bolus ready for swallowing (Bilt 2011; Blissett et al. 2007; Engelen et al. 2005; Le Révérend 2013). The tongue is vital for moving and positioning food between the teeth, for selecting food fragments for further mastication, for mixing saliva with the food and for posterior transportation of the bolus into the oropharynx (Blissett et al. 2007; Stone 2005). To perform these actions, the tongue must be able to perform tilting, rotating and pushing movements in different directions at different stages of mastication (Hiiemae and Palmer 2003; Mioche et al. 2002; Ono et al. 2009; Taniguchi et al. 2013). Neuromuscular disorders of the central nervous system (*e.g.* cerebral palsy) may have profound effects on the tongue muscles and, thus, on coordination of mastication, but the exact nature of the disordered movements is difficult to define and measure (Cummings 2008; Thexton 1992). For such individuals, clinical examination of tongue movements during mastication is required to develop an individual intervention plan.

Clinical examination of tongue positioning and tongue movements during mastication is difficult because of the tongue's concealment within the oral cavity and the constant dimensional changes in tongue shape and tongue position (Reilly et al. 1995; Remijn et al. 2014). Ultrasound has been widely used for evaluating intra-oral structures, such as the tongue. Ultrasound is a tolerable, non-invasive procedure and is relatively easy to

Address correspondence to: Lianne Remijn, Health Studies, HAN University of Applied Sciences, Postbox 6960, 6503 GL Nijmegen, The Netherlands. E-mail: lianne.remijn@han.nl

perform (Blissett et al. 2007; Bressmann et al. 2010; Burton et al. 2013; Chi-Fishman 2005; De Wijk et al. 2006; Geddes et al. 2012; McClellan et al. 2010; Peng et al. 2000). Ultrasound has been used to analyze relatively rapid tongue movements associated with articulation, sucking and swallowing. The repetitive tongue movements made during mastication, however, are more complex than the movements of articulation or sucking/swallowing because the tongue contour changes as the consistency of the food changes and the bolus is formed (Liu et al. 2008, 2009).

Submental transducer placement is generally used to obtain real-time images of the oral cavity. These images are displayed in two modes (B-mode and M-mode) to quantify differences in duration, range and speed of tongue movements. B-Mode images allow visualization of the changing tongue surface contours (*i.e.*, tongue shape) (De Wijk et al. 2006; McClellan et al. 2010). M-Mode images allow visualization of the tongue surface movements along the scan line over time (Fig. 1). Blissett et al. (2007) and Bressmann et al. (2010) completed a quantitative analysis of four coronal tongue images (B-mode and M-mode) taken during chewing and speech tasks. Both studies analyzed four anterior-to-posterior images. Unlike the standard B-mode transducer used in Blissett et al. (2007) and Bressmann et al. (2010), Burton et al. (2013) used a matrix-array transducer to create 3-D tongue images to track tongue movements made during breastfeeding.

The studies mentioned in the previous paragraph differ in several methodologic aspects, namely, the locations for measuring tongue movements, the measurement parameters and the parameter calculations. Because the tongue movements of mastication are complex, we used a semi-3-D approach involving biplane imaging. Analysis of data from biplane imaging requires an updated protocol and analysis tool. The previously mentioned studies had limited data as they included only 12 measurement points (4 points on the sagittal view and 3 points on the coronal view). The primary aim of the present study was to develop a method using ultrasound to explore spatial and temporal tongue movements and to establish parameters to quantify lateral tongue movement during mastication (part 1). The secondary aim was to investigate differences in tongue movements during mastication between individuals with and without oral motor disability (part 2). We hypothesized that individuals with oral motor disability will make less frequent lateral tongue movements and have a lower lateral movement rate and range than individuals without an oral motor disability.

METHODS

Part 1. Developing the method of data analysis

Ultrasound recording procedure. We simultaneously recorded coronal and sagittal images to allow visualization of a movement in two planes. This is termed *biplane imaging*. We used an iE33 real-time 3-D ultrasound scanner equipped with an X7-2 matrix-array transducer (Philips Ultrasound, Andover, MA, USA). Ultrasound images were stored as DICOM (Digital Imaging and Communications in Medicine) files for further data processing.

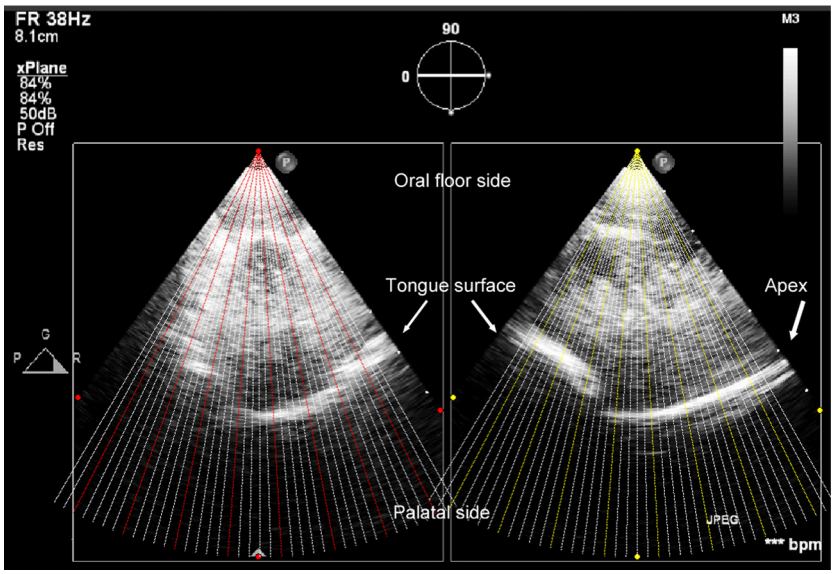

Fig. 1. Original DICOM biplane sectors with marked sector calibrations (*red dots*: coronal plane, *yellow dots*: sagittal plane) and estimated M-line positions for back-scan conversion.