ARTICLE IN PRESS

Ultrasound in Med. & Biol., Vol. ■, No. ■, pp. 1–12, 2017
© 2017 World Federation for Ultrasound in Medicine & Biology
Printed in the USA. All rights reserved
0301-5629/$ - see front matter

ELSEVIER

http://dx.doi.org/10.1016/j.ultrasmedbio.2017.02.019

● *Original Contribution*

BROADBAND ACOUSTIC MEASUREMENT OF AN AGAR-BASED TISSUE-MIMICKING-MATERIAL: A LONGITUDINAL STUDY

Adela Rabell Montiel,* Jacinta E. Browne,† Stephen D. Pye,‡ Tom A. Anderson,* and Carmel M. Moran*

*Centre for Cardiovascular Science, University of Edinburgh, Edinburgh, UK; †School of Physics & IEO, FOCAS, Dublin Institute of Technology, Dublin, Ireland; and ‡Medical Physics, NHS Lothian, Royal Infirmary of Edinburgh, Edinburgh, UK

(*Received* 19 *September* 2016; *revised* 27 *February* 2017; *in final form* 27 *February* 2017)

Abstract—Commercially available ultrasound quality assurance test phantoms rely on the long-term acoustic stability of the tissue-mimicking-material (TMM). Measurement of the acoustic properties of the TMM can be technically challenging, and it is important to ensure its stability. The standard technique is to film-wrap samples of TMM and to measure the acoustic properties in a water bath. In this study, a modified technique was proposed whereby the samples of TMM are measured in a preserving fluid that is intended to maintain their characteristics. The acoustic properties were evaluated using a broadband pulse-echo substitution technique over the frequency range 4.5–50 MHz at 0, 6 and 12 months using both techniques. For both techniques, the measured mean values for the speed of sound and attenuation were very similar and within the International Electrotechnical Commission-recommended value. However, the results obtained using the proposed modified technique exhibited greater stability over the 1-y period compared with the results acquired using the standard technique. (E-mail: adela.rabell@ed.ac.uk) **© 2017 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Ultrasound, High frequency, Tissue-mimicking material, Speed of sound, Attenuation coefficient, Long term.**

INTRODUCTION

Commercially available quality assurance (QA) test phantoms are widely used to test the performance of clinical ultrasound scanners. These phantoms are manufactured from tissue-mimicking-material (TMM) that is designed to closely match the acoustical properties of the speed of sound (SoS) and the attenuation coefficient of soft tissue. The aim in manufacturing these phantoms is to provide a reproducible method to assess the performance of ultrasound scanners. However, these phantoms are intended for use with clinical ultrasound scanners at frequencies ≤20 MHz. To the best of our knowledge, there are no commercially available test phantoms for assessment of the performance of ultrasound scanners employing ultrasound frequencies >20 MHz.

A variety of TMMs are currently produced both commercially and within laboratories. These include: agar-based TMMs (Teirlinck et al. 1998), condensed milk TMMs (Madsen et al. 1998), gelatin TMMs (Culjat et al. 2010), konjac–carrageenan TMMs (Kenwright et al. 2014; Meagher et al. 2007), urethane rubber TMMs (Culjat et al. 2010), poly (vinyl alcohol) cryogel (PVA-C) TMMs (Cournane et al. 2010; Culjat et al. 2010; King et al. 2011) and Zerdine TMMs (CIRS, Norfolk, VA, USA). The International Electrotechnical Commission (IEC) agar-based TMM has become widely used and popular for clinical and pre-clinical test objects (Brewin et al. 2008; Browne et al. 2003; Cannon et al. 2011; Culjat et al. 2010; Inglis et al. 2006; Moran et al. 2011a, 2011b; Rajagopal et al. 2014; Sun et al. 2012; Yang et al. 2013). The acoustical properties of this agar-based TMM are designed to comply with the ultrasound acoustical parameters provided by the IEC (2001) with the recommended SoS and attenuation over the frequency range 2–10 MHz being 1540 ± 15 m/s and 0.5 ± 0.05 dB/cm, respectively.

Moderately high-frequency ultrasound scanners (≤20 MHz) have been manufactured for many years and have been utilised clinically in assessment of the skin (Machet et al. 2009), vascular structures (Rhee 2007) and in retinal imaging (Foster et al. 2000). In recent

Address correspondence to: Adela Rabell Montiel, 47 Little France Crescent, Queen's Medical Research Institute, Centre for Cardiovascular Science, EH16 4 TJ, Edinburgh, UK. E-mail: adela.rabell@ed.ac.uk

ARTICLE IN PRESS

years, reliable high-frequency (20–50 MHz) and very high frequency (>40 MHz) ultrasound scanners have become mainstream technology for the imaging of superficial structures in clinical imaging and for pre-clinical imaging applications due to improvements in transducer engineering and software technology (Banchhor et al. 2016; Moran et al. 2011a, 2011b; Schmitt et al. 2010; Sundholm et al. 2015; Xu et al. 2012).

With the increase in high-frequency ultrasound imaging applications, there is a need to develop and acoustically characterise TMMs suitable for high-frequency ultrasound quality assurance and training phantoms. It has been reported that above 10 MHz, the TMMs in the commercial test phantoms do not have optimum acoustic properties, as the attenuation starts to exhibit a non-linear response with increasing frequency (Browne et al. 2003), whereas the IEC guidelines for TMM properties recommend a linear relationship between attenuation and frequency up to 10 MHz.

The agar-based TMM developed under the IEC guidelines and used in this study has previously been found to have a non-linear response when acoustically investigated at frequencies ≤23 MHz by Brewin et al. (2008) and in our own laboratory and in the National Physical Laboratory (Teddington, UK) at frequencies up to 47 MHz (Sun et al. 2012) and 60 MHz (Rajagopal et al. 2014), respectively. In these studies, test cells or TMM samples wrapped with film material (Saran Wrap or Mylar) were employed to preserve the samples during acoustic characterisation when degassed, de-ionised water was used as the reference medium. Moreover, thin slices of TMM ranging in thickness from 2.5 to 30 mm were used, enabling higher ultrasound frequencies to propagate through the TMM slices (Brewin et al. 2008; Rajagopal et al. 2014; Sun et al. 2012). The encasing of the TMM in film is important as, without the film, the TMM will degrade rapidly. This degradation is due to leaching of the glycerol from the TMM into the water reference medium, thus altering the acoustic properties of the TMM (Brewin et al. 2008). A reference water test cell, also encapsulated in Saran Wrap or Mylar film, was used in the reference measurement to account for the effect of the film on measurements (Rajagopal et al. 2014; Sun et al. 2012). However, the production of both the TMM slices wrapped in film and water test cells is time consuming and technically challenging, especially for thin TMM samples. Therefore, the aim of this study was to compare this well-established technique for the measurement and preservation of an IEC agar TMM to a technique in which TMM is characterised and preserved in a preserving fluid. Furthermore, this method was evaluated over a 1-y period to determine the longitudinal stability of the acoustic properties.

METHODS

Acoustical measurements

Data were captured using two different acoustical systems, described briefly here and elsewhere (Sun et al. 2012). First, a Vevo 770 pre-clinical ultrasound scanner (Visualsonics, Toronto, ON, Canada) was used at the University of Edinburgh, and second, a scanning acoustic macroscope (SAM) system developed in-house was used at the Dublin Institute of Technology (Cannon et al. 2011). The SAM system was used to provide additional acoustic data and to extend the lower limit of the bandwidth of the measurements to 4.5 MHz.

Manufacture of FTMM and UTMM samples

A batch of the IEC agar-based TMM was manufactured according to a widely used standard recipe and method (Brewin et al. 2008; Browne et al. 2003; Cannon et al. 2011; Ramnarine et al. 2001; Teirlinck et al. 1998). This mixture was poured at 42°C onto a pre-warmed metal plate. The plate was pre-warmed to ensure that the mixture spread uniformly. The TMM mixture was then left to cool to room temperature. From this batch of TMM, 22 cylindrical slices of TMM

Table 1. Characteristics of Vevo 770 and SAM system transducers*

Transducer model and measurement system	Central frequency (MHz)	Focal length (mm)	Measured 3-dB bandwidth (MHz)	Peak negative pressure (MPa)
Vevo 770				
RMV 704	40	6	18–40	0.52
RMV 707 B	30	12.7	12–32	1.05
RMV 710 B	25	15	12–28	1.06
RMV 711	55	6	25–50	0.23
SAM system				
V320	7.5	95	4.5–9	0.05
V317	20	65	14–25	0.021
V390	50	12	20–40	0.022

SAM = scanning acoustic macroscope.
* The central frequency and focal length are parameters provided by the manufacturer: Vevo 770 (VisualSonics, Toronto, ON, Canada) and SAM system (Olympus Panametrics NDT, Waltham, MA, USA), The 3-dB bandwidth is from measurements, and the peak pressure is from Sun (2012).

Download English Version:

https://daneshyari.com/en/article/5485654

Download Persian Version:

https://daneshyari.com/article/5485654

Daneshyari.com