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● *Original Contribution*

PARAFFIN-GEL TISSUE-MIMICKING MATERIAL FOR ULTRASOUND-GUIDED NEEDLE BIOPSY PHANTOM

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Abstract—Paraffin-gel waxes have been investigated as new soft tissue–mimicking materials for ultrasound-guided breast biopsy training. Breast phantoms were produced with a broad range of acoustical properties. The speed of sound for the phantoms ranged from 1425.4 ± 0.6 to 1480.3 ± 1.7 m/s at room temperature. The attenuation coefficients were easily controlled between 0.32 ± 0.27 dB/cm and 2.04 ± 0.65 dB/cm at 7.5 MHz, depending on the amount of carnauba wax added to the base material. The materials do not suffer dehydration and provide adequate needle penetration, with a Young's storage modulus varying between 14.7 ± 0.2 kPa and 34.9 ± 0.3 kPa. The phantom background material possesses long-term stability and can be employed in a supine position without changes in geometry. These results indicate that paraffin-gel waxes may be promising materials for training radiologists in ultrasound biopsy procedures. (E-mail: vieira@if.ufg.br) © **2013 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Paraffin-gel waxes, Carnauba wax, Tissue-mimicking, Breast phantoms, Biopsy training, Ultrasound imaging, Elasticity.**

INTRODUCTION

Tissue-mimicking phantoms are commonly used for training sonographers and residents to improve the accuracy of breast lesion diagnosis. These phantoms have shape, size and acoustic proprieties equivalent to the biological tissue. Some tissue-mimicking materials (TMMs) investigated for ultrasound phantoms are agar based (Blechinger et al. 1988; Browne et al. 2003; Cannon et al. 2011; Culjat et al. 2010; de Korte et al. 1997), gelatin based (Blechinger et al. 1988; Culjat et al. 2010; de Korte et al. 1997; Madsen et al. 1978, 1982), condensed milk–based gel (Browne et al. 2003; Madsen et al. 1998), poly(vinyl alcohol) cryogel (PVA-C) (Culjat et al. 2010; Surry et al. 2004), and urethane rubber (Blechinger et al. 1988; Cannon et al. 2011; Culjat et al. 2010; de Korte et al. 1997; Ma et al. 2004; Madsen et al. 1978, 1982, 1998; Surry et al. 2004). Commercially available tissue-mimicking phantoms are made of urethane rubber (ATS Laboratories, Bridgeport, CT, USA), agarose with water and condensed-milk gel (Gammex-RMI, Middleton, WI, USA), and Zerdine (CIRS Inc., Norfolk, VA, USA).

Ultrasound-guided needle biopsy is a freehand and real-time image guidance technique that is commonly used for visualizing anatomic structures during a biopsy procedure (Harvey et al. 2000; Smith et al. 2001). Because of the complexity evolved in such procedure, a considerable amount of training is needed before performing it on a patient. This training stage is essential to improve the individual's ability to target the correct biopsy site and track the needle during the procedure, and also to remove a sample during the fine-needle aspiration (FNA) of lesions. Needle biopsy training helps reduce the duration of each biopsy, thus causing less trauma to the patient (Harvey et al. 1997; Nicotra et al. 1994) Breast biopsy phantom is a cost-effective training aid for physicians to develop the necessary confidence and skills to perform the biopsy procedure on a patient, with desirable care and tolerability. Therefore, it plays a major role during the ultrasound-guided needle biopsy training period.

This study presented paraffin-gel waxes as a novel tissue-mimicking material for ultrasound-guided biopsy

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training. The paraffin gels are derived from high-molecular-weight saturated aliphatic hydrocarbons obtained from crude petroleum. These gels are a transparent and soft compound composed of 95% mineral oil and 5% polymer resin (Lacerda 2004). Paraffin gels are used in a wide range of daily applications, most notably in the candle industry. Another material investigated was carnauba wax; here, it was used to control the contrast of the lesions in the ultrasound images. Carnauba wax is extracted from the Carnauba palm tree found in the northeast region of Brazil. This wax is used widely in the cosmetics, medicine, electronic component, and capsule industries and serves as a well-known car polish wax. Because of its low solubility in water, carnauba wax is evaporation-resistant, thus resulting in a highly durable material. Carnauba wax's melting point is 86°C, which is higher than the melting point of paraffin waxes, and it has the highest stiffness among the natural waxes (Shellhammer et al. 1997).

Breast phantoms made using gel waxes as the TMMs have several advantages compared with other gels. Paraffin-gel waxes, for example, do not dehydrate, are non-toxic, are not susceptible to bacterial attack, have a good chemical stability and can maintain their form for a long time in a broad range of temperatures.

In this study, paraffin gel was investigated as the base material of breast phantoms to mimic the consistency, form and acoustic texture of the human breast. Measurements of the speed of sound, attenuation coefficients and Young's modulus are reported.

MATERIAL AND METHODS

Breast phantom

The breast tissue phantom was formed from medium-density type (MDT) paraffin-gel wax (Gel Candle, São Paulo, Brazil); 4% w/w of glass microspheres (3M, Campinas, Brazil), ranging from 20 μm to 75 μm in diameter, with an average diameter of 45 μm, were embedded in the paraffin-gel wax. An image of the phantom is shown in Figure 1. The breast phantom was designed to have size and shape similar to the breast of an average patient in the supine position. The phantom has a height of 5 cm and a mean base diameter of 12 cm.

The background material was prepared using MDT paraffin gel with a density of 0.81 g/cm^3 and a melting point of 61.4°C. The TMM background was prepared by melting 610 g of MDT gel wax in a container with a controlled temperature of 80°C. After 20 min, a clear molten solution was obtained. The glass microspheres were then added to the material and continuously stirred to obtain a uniform dispersion. The solution was cooled to 64°C, and the molten material was poured into an aluminum mold in the shape of a hemispheric dome to mimic the mammary gland.

Fig. 1. Photograph of the paraffin-gel breast phantom.

The phantom was prepared in layers. First, a homogeneous layer was prepared in the nipple region, and then solid masses (described later) were placed randomly on this layer. After this, the whole phantom was covered with the same paraffin molten solution. While cooling, the breast mold was attached to a rotation apparatus at two revolutions per minute (2 rpm) to prevent gravitational sedimentation of the solid masses and to keep the glass powder distributed throughout the emulsion.

Abnormal masses

The solid masses were made using high-density type (HDT) gel, with density of 0.84 g/cm^3, which has a melting point of 82.8°C. The material for mimicking abnormal tissues was prepared using a mixture of HDT paraffin-gel wax, carnauba wax and glass microspheres with a diameter of 20–75 μm. The carnauba wax was used to control the level of ultrasound attenuation, and chalk powder was used as scatter medium because of its low gravitational sedimentation. The following ingredients were used to make the abnormal masses similar to cancer, fibroadenoma and cysts:

- Benign mass were prepared with 4% w/w of granular semi-refined paraffin wax (58–60°C) for candle making mixed with the HDT paraffin gel.
- For lobular carcinoma, 17% w/w of carnauba wax was added to the HDT gel.
- Calcified fibroadenomas were made of HDT paraffin gel with 12% weight per weight (w/w) of carnauba wax and 5% w/w of glass microspheres.
- The ductal carcinomas were prepared with 4% w/w of granular semi-refined paraffin wax mixed with the HDT paraffin gel with 0.5% w/w of chalk powder used as scatter.

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