Aloe vera (L.) Burm.f.-based gel as an alternative to commercially available ultrasound gel on diagnostic ultrasound imaging: a phantom study

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Abstract – *Ultrasound has gained widespread attention in diagnostic radiology. The procedure utilizes a coupling gel that serves as a conductive medium for the soundwaves generated by the transducer to produce images. Commercially available ultrasound gels contain chemicals which can be potentially harmful to the body. Natural products are known to be sources of less or nonharmful alternatives. In this study, 4% w/v Aloe vera-based gel was prepared which was used as a coupling medium during ultrasound. Two sets of ultrasound images were taken on the gelatin-based phantom design containing pellet balls and seedless grapes, using Aloe vera- based gel and commercial ultrasound gel (control). The image produced was compared in terms of geometric properties and spatial resolution. As to geometric properties, results show that the images produced using Aloe vera-based gel have no significant difference with the control and the actual size of the pellet in terms of length (p= .989), depth (p= .954) and size (p=.998). It can be inferred from the obtained ultrasound images that spatial resolution is acceptable. Therefore, Aloe vera-based gel can be used as an alternative coupling gel to commercially available ultrasound gel.*

Keywords – *Aloe vera, ultrasound, coupling gel, diagnostic ultrasound imaging.*

INTRODUCTION

Ultrasound is gaining widespread attention in diagnostic radiology because it can display the anatomy of bones, muscles, joints, tendons and internal body organs for suspected pathology or lesions using non-ionizing radiation [1]. Ultrasonography offers numerous advantages compared to other imaging modalities in terms of safety, cost, and effectiveness. Diagnostic ultrasound is noninvasive and offers real-time imaging that allows examinations of both structures at rest and in motion. This ability to capture the movements makes ultrasound distinct against other imaging modalities and can permit more accurate diagnoses. For a variety of reasons, healthcare providers are relying on more expensive imaging modalities over time. The utilization of such imaging modalities as computed tomography and magnetic resonance imaging, instead of lower-cost alternatives, such as ultrasound, may not ascertain better outcomes on some diagnoses and it adds cost to the healthcare system and patients [2].

Anatomical imaging with ultrasound is accomplished with a pulse-echo technique. The transducer generates pulses of echoes and sent into the patient, where echoes are produced within the organ boundaries. These echoes travel back to the transducer where they are detected and then presented on display [3].

The transducer uses a coupling gel that serves as a conductive medium for the transmission of soundwaves. The coupling gel must be free of air bubbles to secure optimum transmission of sound waves to the skin surface. Skin tissues are chiefly made up of physiologic saline solution. Sound wave transmission is kept to a maximum when the high acoustic impedance mismatch to the skin is minimized. This effect results in the amplification of signal strength; therefore, image quality is enhanced [4]. The coupling gel must have a matching acoustic impedance to the structure it connects and permits the transmission of ultrasound waves with minimal absorption, attenuation or disturbance [5].

Aqueous substances such as alcohol and water are suitable mediums but are deemed inappropriate due to their viscous and volatile properties. These substances require successive application and cleaning. Liquids are converted into semi-solid gels by ultrasonic gel manufacturers to induce spreadability [5].

The image quality of an ultrasound is dependent upon different number of factors, and some of the most important factors are geometric distortion and spatial resolution. Geometric distortion is the inherent malformation in the size and shape of the ultrasound image. It is due to variations in speed of sound produced in different areas of the body which in turn, degrades the axial and lateral resolution of the images [6]. Spatial

resolution refers the ability to distinguish anatomical structures that are lying close to each other. It displays the depth and width of a cross section of an anatomical part, which is termed as axial resolution and lateral resolution, respectively and collectively represent the spatial resolution [3]. Good contact between the transducer and body surface is necessary for resolution. Ultrasound gels are applied to the transducer where it improves contact to the body surface [7].

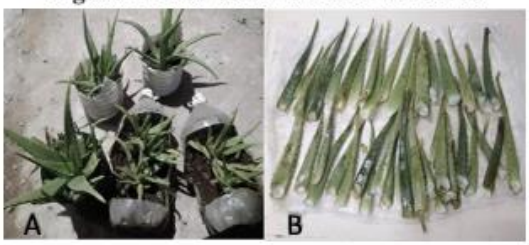
One major concerns of many consumers and doctors with medical-grade ultrasound gels is the cost, which is why they resort to using alternatives. The need for relatively cost-effective, naturally produced, occupationally safe and available material for routine ultrasound gel in diagnostics is very essential in resource disadvantage setting [8].

There is a case report where a patient warned the sonographer that he had severe painful erythematous rash with pruritis, due to the allergic reaction caused by his previous ultrasound examination using a commercially available ultrasound gel. Due to the severity of the allergic reaction, the patient consented to an ultrasound examination only if an alternative gel could be used [4].

Commercially available ultrasound gels contain chemicals like propylene glycol, methyldibromoglutaronitrile [4]. carbapol R 940 polymer, and phenoxyethanol which can be potentially harmful to the body. Use of natural alternative based gels such as Aloe vera can lessen the allergic effect because of its anti- inflammatory actions [9].

Aloe vera is a succulent plant that grows abundantly in tropical regions. The scientific name of Aloe vera is Aloe vera (L.) Burm.f. and it belongs to Xanthorrhoeaceae family. Aloe vera plant has many different synonyms. Some of the synonyms are Aloe abyssinica Lam., A. barbadensis Mill., and A. chinensis Baker. It has been used for centuries and has been popular for its beauty and therapeutic properties [10]-[11].

Figure 1. Aloe vera A. Plant B. Leaves



According to a study conducted by Sekar et al. [9], Aloe vera can be used in ultrasound physiotherapy and is recommended to be used in diagnostic imaging. However, there are no studies conducted regarding the effectivity of Aloe vera in diagnostic ultrasonography. Aloe vera is known for its anti-inflammatory and wound healing properties.

Aloe vera is known for its cooling effect, which is widely used as a soothing agent in most skin care products [9]. It is used in the treatment of burns, skin erythema, genital herpes, and seborrheic dermatitis [13]. Moreover, it has antioxidants, elastin formation and matrix agents, anti- inflammatory agents and fatty acids that prevent the formation of stretch marks. Aloe vera is also known for its anti-aging and moisturizing properties which makes it safe in skin contact. Aloe vera has 99% water content. It is easy to find as an organic substance and it contains a semi- solid gel that makes it a consistent and suitable lubricant for the transducer and transmitter of ultrasound waves [12].

This study is limited to the preparation and testing of the experimental gel. Stability testing is not included in this study.

This study aims to compare the image quality produced of Aloe vera-based gel against the control, commercially available gel, in terms of geometric properties and spatial resolution. If proven that the resulting image quality obtained using Aloe vera-based gel is comparable with the control, then a natural product that is locally available can be used as an alternative coupling gel for diagnostic ultrasound imaging.

MATERIALS AND METHODS

Collection, identification and authentication of the plant Fresh 1-year-old, home-grown Aloe vera was harvested at Cabataña's Residence, Lipa City and was authenticated at the Museum of Natural History, University of the Philippines-Los Baños. The Aloe vera leaves used in this study are shown in Figure 1B.

Preparation of the Aloe vera-based gel

Aloe vera-based gel was extracted from ten Aloe vera leaves using a knife and was placed in a mixer grinder for blending. The resulting extract was filtered to remove any remaining particles in the liquid form. Four percent weight over volume of Aloe vera gel was formulated and used in this study. Fifty grams of cornstarch was dissolved into 500 ml of boiling water and was stirred with a magnetic stirrer at a consistent rate to avoid clumping. The solution was boiled until it became a solid gel. Upon completion of boiling, 0.5g of methylparaben, 10g of salt and 20g of Aloe vera were poured into the solution and it was stirred continuously using the magnetic stirrer to produce a homogenous gel. The mixture was left for about 1 hour to cool down. The resulting gel was transferred into a squeeze-type bottle and was stored in a refrigerator to

avoid contamination before the experimentation. The composition of formulated ultrasound gel is based on Sekar et al., [9].

Table 1 Composition of Formulated Gel.

Concentrationof formulated gel (%)	Components	Amount
	Corn starch	50 g
4 % w/v	*Aloe vera* extract	20 g
	Methylparaben	0.5 g
	Salt	10 g
	Distilled Water	500 ml

Commercially Available Ultrasound Gel

The commercial gel that was used in this study is a 300 ml Zelec Ultrasound gel. It is a clear aqueous coupling agent that is used for ultrasound and electromedical procedures. It is manufactured by Kohl Industries Corporation. The commercial gel was procured at Batangas Medical Center.

Phantom Design

A box (26cm x 25cm x 13cm) made up of plastic served as a container for the gelatin-based phantom. The phantom was based on the previous work of Khera and Keshava [14]. The two seedless grapes were placed at the center of the container that simulated a cyst-like structure. Two pellet balls were also placed at the center of the grape that simulated microcalcification.

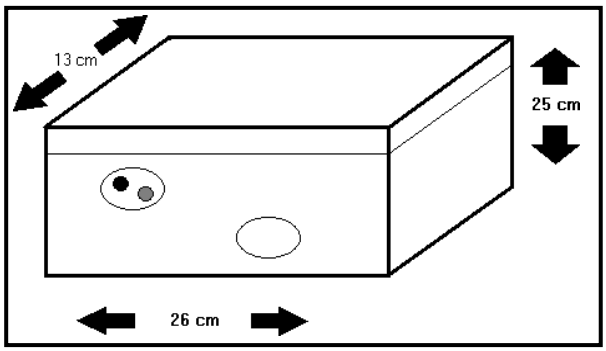


Figure 2. Phantom Design

Ultrasound Procedure

Aloe vera-based gel and commercially available ultrasound gel were tested on a gelatin-based phantom. The equipment used in this study was a Medison X4 Samsung using a linear-type transducer which is best in producing 2D images. The procedure for ultrasound was based on the protocol used at Batangas Medical Center since it is where the procedure was done. The procedure was done under the supervision of a registered Radiologic Technologist.

A set of images were taken using Aloe vera-based gel and the commercially available ultrasound gel. These images were evaluated and compared to the actual size and measurements of the phantom. The images were evaluated by a radiologist. Through these, geometric properties and spatial resolution were evaluated based on the results.

Statistical Analysis

The mean and standard deviation was used to describe the images' length, size, and depth produced using the commercially available ultrasound gel and Aloe vera-based gel. Independent T-test was used to determine the significant difference between the actual dimensions of the object, dimensions acquired using the Aloe vera- based gel and dimensions acquired using the commercially available ultrasound gel.

RESULTS AND DISCUSSION

Physical properties of the Aloe vera- based gel

The formulated Aloe vera-based gel has a semisolid appearance. It was non- greasy, viscous, and cool to the touch. It was free of air bubbles and was also odorless. The physical appearance is comparable with the commercially available ultrasound gel. However, they vary in color, the commercially available gel is transparent while the prepared Aloe vera-based gel was white. The color of Aloe vera-based gel is due to the cornstarch which served as a thickening agent. Mueller and Theoharis [4] stated that the coupling gel must be free of air bubbles to secure transmission of ultrasound waves to the skin surface.

Figure 3. Aloe vera-based gel

According to Lautenschlager [5], aqueous substances such as alcohol and water are suitable mediums but are deemed inappropriate due to their viscous and volatile properties. These substances require successive application and cleaning.

Liquids are converted into semi-solid gels by ultrasonic gel manufacturers to induce spreadability.

Image Quality

I. Geometric Properties

Table 2 shows the geometric properties of the grapes and pellet balls used in this study. As to length, the resulting measurements for Grape 1 were 2.71 cm and 2.75 cm, using commercially available ultrasound gel and Aloe vera-based gel, respectively. For Grape 2, the measurements were 3.47 cm and 3.43 cm, using commercially available ultrasound gel and Aloe vera-based gel, respectively. As to depth, the obtained measurements for Grape 1 were 0.741 cm and 0.742 cm, using commercially available ultrasound gel and Aloe vera-based gel, respectively: while 2.24 cm and 2.21 cm for Grape 2, using commercially available ultrasound gel and Aloe vera-based gel. As to size, Pellet 1 was measured 0.602 cm and 0.609 cm, using commercially available ultrasound gel and Aloe vera-based gel, respectively, and 0.456 cm for Pellet 2 for both gels.

Table 2, The actual size of the objects, and the size of the image produced using Aloe vera-based gel and commercially available ultrasound gel

Subject	Actual Size	Commercially available ultrasound gel	*Aloe vera*-based gel
Length			
Grape 1	2.9 cm	2.71 cm	2.75 cm
Grape 2	3.9 cm	3.47 cm	3.43 cm
Depth			
Grape 1	0.8 cm	0.741 cm	0.742 cm
Grape 2	2.8 cm	2.24 cm	2.21 cm
Size (Grape 1)			
Pellet 1	0.61 cm	0.602 cm	0.609 cm
Pellet 2	0.46 cm	0.456 cm	0.456 cm

It is noticeable that there is a minimal difference in the actual length, depth of grapes and size of pellets to the measurements produced using the Aloe vera-based gel and commercially available ultrasound gel. It can be deduced that the acquired dimensions and images from the ultrasound gels revealed no remarkable foreshortening, elongation and magnification of the grapes and pellets.

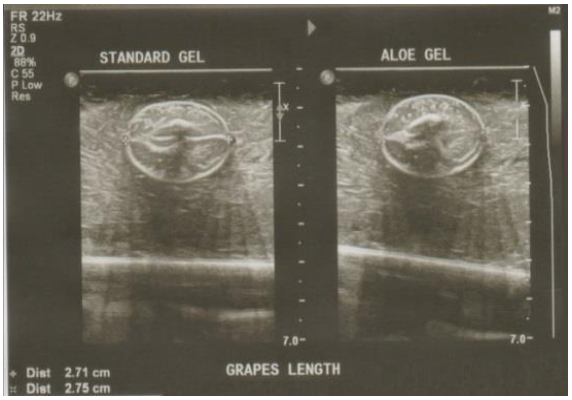
This is more likely due to their similar physical properties, in terms of viscosity, greasiness and absence of air bubbles, which permitted uniform transmission of the ultrasound waves to the phantom.

Mueller and Theoharis [4] stated that the coupling gel must be free of air bubbles to secure transmission of ultrasound waves to the skin surface. According to Lautenschlager [5], aqueous substances such as alcohol and water are suitable mediums but are deemed inappropriate due to their viscous and volatile properties. These substances require successive application and cleaning. Liquids are converted into semi-solid gels by ultrasonic gel manufacturers to induce spreadability.

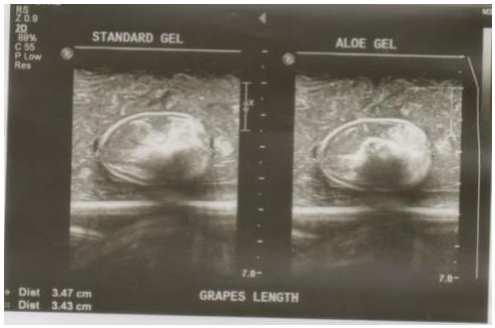
Statistical comparison of the values in Table 2 is shown in Table 3. The p-values obtained for the grape length, depth and pellet sizes were 0.989, 0.954 and 0.998 respectively, all of which were higher than the computed t-values.

Table 3. The difference in the dimensions produced using the Aloe vera-based gel and commercially available ultrasound gel compared to the actual dimensions of the object

Parame-ters	p-values	Compute d t-values	Decision on Ho	Verbal Interpretation
Grape Length	0.989	0.011	Failed to Reject	Not Significant
Grape Depth	0.954	0.048	Failed to Reject	Not Significant
Pellet Size	0.998	0.002	Failed to Reject	Not Significant



A



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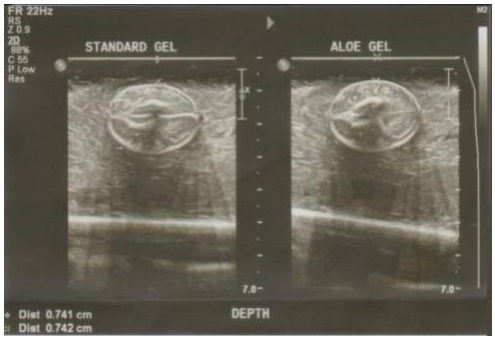

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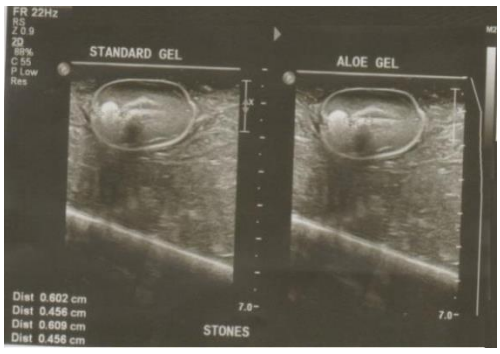

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Figure 4. Ultrasound Images A. Length of Grape 1 B. Length of Grape 2 C. Depth of Grape 1 D. Depth of Grape 2 E. Size of Pellets on Grape 1

This shows that there was no significant difference between the measurements acquired using the Aloe vera-based gel and commercially available ultrasound gel. The Aloe vera-based gel was not able to produce excessive geometric distortion to misrepresent the true size and shape of the structures in the phantom. According to Nesbitt-Hawes et al. [15], true ultrasound accuracy should be taken to be the correlation between an ultrasound measurement and the actual structure being measured. Their study has shown that this measurement is indeed reliable in the term singleton pregnancy.

II. Spatial Resolution

Spatial resolution refers the ability to distinguish anatomical structures that are lying close to each other. It displays the depth and width of a cross section of an anatomical part, which is termed as axial resolution and lateral resolution respectively and collective represent the spatial resolution [3].

As shown in Figure 5, the pellets were displayed inside the middle portion of the Grape 1, situated close to each other. The outlines of the objects in the phantom were sharp and well defined, producing images of the pellets and grapes that can be distinguished from each other. It also produced enough number of horizontal scan lines that filled the display and there were no gaps between the lines. This made the structures in the image visible. The Aloe vera- based gel similarly permitted the transmission of soundwaves as the commercially available ultrasound gel did. Since there was no presence of bubbles in the Aloe vera-based gel, there was no artifact that may interfere with the structures in the phantom. The spatial resolution was enhanced due to the composition of the Aloe vera-based gel, which allowed contact between the body tissue that permitted the transmission of ultrasound waves.

Good contact between the transducer and body surface is necessary for resolution. Ultrasound gels are applied to the transducer where it improves contact to the body surface [7].

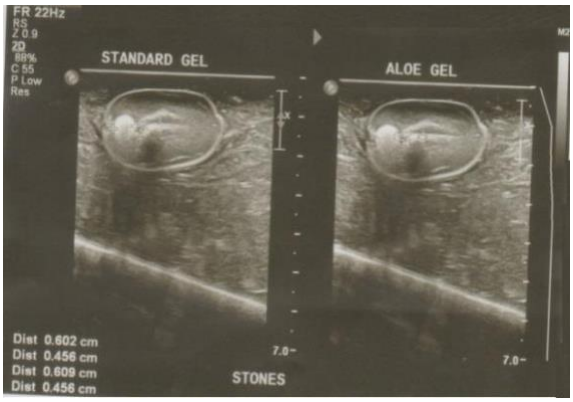

Figure 5. Size of Pellets on Grape 1

CONCLUSION AND RECOMMENDATION

Ultrasound is gaining widespread attention in diagnostic radiology and the need for a cost-effective, naturally produced, occupationally safe and available material for ultrasound gel is essential in resource disadvantage setting. *Aloe vera*-based gel has exhibited

similar physical properties and imaging capabilities on ultrasonography. It produced similar image quality compared to the control in terms of geometrical properties and spatial resolution. Thus, *Aloe vera*- based gel is a feasible alternative to commercially available ultrasound gel on diagnostic ultrasound imaging

The researchers recommend the inclusion of testing Aloe vera-based gel's chemical properties in terms of stability, spreadability, pH, and homogeneity. Its formulations can be optimized and in vivo testing can also be carried out to check its utility using actual subjects.

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