ORIGINAL ARTICLE

Comparative Evaluation of Honey, Aloe Vera, and Olive Oil as Alternative Ultrasound Coupling Agents for Abdominal Imaging

Linati Aina Omar [1], Ummi Farhana Hashim [1,*]

[1]Department of Diagnostic Imaging and Radiotherapy, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, 25200 Kuantan, Pahang, Malaysia

ABSTRACT

Background: Ultrasound imaging requires an effective coupling medium to eliminate air between the transducer and the skin and ensure optimal sound transmission. Commercial ultrasound gel is widely used, but its limited availability in low-resource settings, potential for skin irritation, and risk of contamination highlight the need for accessible natural alternatives. This study aimed to evaluate the image quality produced by aloe vera, honey, and olive oil in comparison with commercial ultrasound gel when imaging the liver, kidney, and aorta using a tissue-mimicking phantom. **Methods:** A comparative experimental design was used to assess four coupling agents: aloe vera, honey, olive oil, and commercial ultrasound gel. All materials were tested under identical imaging conditions using a Kyoto Kagaku ECHOZY Abdominal Set tissue-mimicking phantom and Siemens Acuson X150 system equipped with a 3.5–5 MHz curvilinear transducer. Images of the liver, kidney, and aorta were acquired at fixed ultrasound settings. Quantitative analysis was performed using ImageJ software to measure signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) based on standardised regions of interest. Qualitative image assessment was carried out through a virtual grading analysis (VGA) by three experienced sonographers who independently ranked image sharpness, noise, depth penetration, and overall quality. **Results:** Commercial ultrasound gel produced the highest image quality for the liver, with the highest SNR and CNR values. Aloe vera achieved the best performance for the kidney, producing higher quantitative values compared with the commercial gel. Olive oil demonstrated the highest CNR value for aortic imaging but showed moderate performance in other organs. Honey consistently produced the lowest SNR and CNR values across all organs, indicating limited suitability as a coupling medium. VGA findings aligned with quantitative outcomes, with aloe vera and olive oil performing comparably to commercial gel in selected organs. **Conclusion:** Aloe vera and olive oil demonstrated potential as practical alternatives to commercial ultrasound gel, particularly when standard gel is unavailable. Aloe vera showed the most consistent performance across imaging modalities, while honey was the least effective. These findings support further evaluation of natural products as accessible and cost-effective coupling media, particularly for use in low-resource or mobile ultrasound settings.

Keywords:

SNR; CNR; Aloe vera; honey; olive oil;

INTRODUCTION

Access to commercial ultrasound gel is not always reliable, particularly in rural, low-resource, or mobile healthcare settings where supply shortages, distribution barriers, and cost limitations may restrict its use (Argaw et al., 2022). These constraints can disrupt essential ultrasound services, especially in point-of-care environments. Commercial gels may also contain preservatives such as parabens and phenoxyethanol, which have been linked to skin irritation and allergic reactions in sensitive individuals, and contamination events involving ultrasound gel have been reported (Sherman et al., 2015; Chasset et al., 2015). These challenges underscore the need to identify safe, affordable, and easily obtainable alternatives.

Natural substances such as aloe vera, honey, and olive oil are widely accessible, inexpensive, and commonly used in everyday products. Their favourable biocompatibility (Kaloteraki et al., 2023) and potential acoustic characteristics make them promising candidates for investigation as alternative coupling media, particularly in situations where commercial gel is unsuitable or unavailable).

Although commercial ultrasound gel remains the standard coupling medium (Wray et al., 2023), there is limited empirical evidence evaluating whether natural materials can deliver comparable acoustic performance or diagnostic image quality. Existing studies on natural substances are few, often limited in methodology, and rarely include rigorous quantitative analysis or assessment across multiple abdominal organs under standardised conditions (Paulinus et al., 2022) As a result, there is insufficient evidence to determine whether these alternatives can reliably support diagnostic-quality

* *Corresponding author.*
E-mail address: ummifarahanahashim@iium.edu.my

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imaging. A comprehensive evaluation incorporating both quantitative and qualitative image quality measures is therefore needed to address this gap.

The present study sought to identify accessible, cost-effective, and safe options for ultrasound coupling, which was particularly important for low-resource facilities, mobile ultrasound practice, and emergency settings. By evaluating natural materials that were readily available in local markets, the study supported more sustainable and resilient ultrasound services. If certain natural substances were shown to provide image quality comparable to commercial gel, they could have enhanced continuity of care, reduced dependency on manufactured consumables, and expanded the availability of diagnostic imaging in low-resource areas.

This study aimed to evaluate the potential of aloe vera, honey, and olive oil as alternative ultrasound coupling agents by thoroughly comparing them with commercial ultrasound gel. The investigation included a detailed quantitative analysis using SNR and CNR measurements to assess transmission efficiency, as well as a qualitative evaluation through VGA by experienced sonographers.

MATERIALS AND METHODS

This study was conducted at the Diagnostic Imaging Laboratory, Department of Diagnostic Imaging and Radiotherapy, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, Bandar Indera Mahkota, Kuantan, Pahang.

This comparative experimental study was designed to assess the performance of three natural substances which are aloe vera, honey, and olive oil as potential alternatives to commercial ultrasound gel. The commercial gel was used as the reference standard, and all coupling media were evaluated under identical imaging conditions using an abdominal ultrasound phantom. Image quality was assessed through SNR, CNR and VGA to determine their diagnostic suitability.

Coupling Media

Four ultrasound coupling media were selected for this study based on their availability, purity, and suitability for direct application without further preparation. These included a commercial ultrasound gel (Sky Gel Ultrasound Transmission Medical Gel); an aloe vera gel (Fruit of the Earth 100% Aloe Vera Gel); a high-purity natural honey (SIHAT Sidr Yemeni Honey); and a cold-pressed extra virgin olive oil (SIHAT, Syria). These materials were chosen because they are readily obtainable in retail outlets, making them practical options for use in resource-limited or emergency ultrasound settings.

Experimental Setup

Ultrasound imaging was performed using a Siemens Acuson X150 system equipped with a 3.5–5 MHz curvilinear transducer, which is appropriate for abdominal organ evaluation. A Kyoto Kagaku ECHOZY Abdominal Set tissue-mimicking phantom was used to replicate abdominal structures, including the liver, right kidney, and aorta.

Before imaging, the transducer was prepared to ensure consistent acoustic transmission. A thin layer of commercial gel was applied to the probe surface, after which it was tightly wrapped in plastic food wrap to prevent direct contact with the test substances while maintaining adequate echo transmission. The phantom's surface was also wrapped with plastic film to avoid contamination. The transducer was cleaned and rewrapped after every coupling media to maintain experimental integrity.

Ultrasound Scanning Parameters

A frequency of 3.6 MHz was used for all three organs as it provides an optimal balance between image detail and depth penetration, making it suitable for abdominal imaging and ensuring adequate visualisation of the liver, kidney, and aorta.

Gain settings were adjusted according to organ characteristics to optimise image brightness. The liver was imaged at 55 dB to enhance visibility of its relatively homogeneous and moderately echogenic parenchyma. In kidney, the gain was reduced to 52 dB to prevent oversaturation of the mixed echogenic renal cortex and medulla. The aorta required the lowest gain, 45 dB, to clearly differentiate the vessel wall and lumen without over-amplifying echoes.

Dynamic range (DR) values were also tailored for each organ. The liver was imaged with a DR of 55 dB to preserve subtle parenchymal differences. A narrower DR of 50 dB was used for the kidney to increase contrast between the cortex, medulla, and collecting system. In contrast, the aorta was assigned a higher DR of 60 dB to capture the full range of signals from the hyperechoic wall to the anechoic lumen.

A persistence value of 3 was applied uniformly across all organs to reduce speckle noise while preserving fine structural details, and an edge-enhancement setting of 1 was used to provide mild sharpening of organ boundaries.

The resolution/scale parameter was standardised at 3 to maintain consistent image quality across organs. All images were displayed using a grayscale map to ensure uniform contrast for accurate SNR and CNR calculations. A tint value of 1 was applied to prevent any colour bias and maintain a neutral grayscale appearance, supporting reliable quantitative and qualitative image assessment.

Scanning Technique

The Kyoto Kagaku ECHOZY Abdominal Set tissue-mimicking phantom was scanned several times for each organ and each coupling medium to ensure consistency in image acquisition, with the transducer maintained at the same location and imaging plane for every scan. The most representative image, defined as the clearest and most stable image obtained under fixed parameters, was then selected for both quantitative SNR and CNR analysis and qualitative VGA assessment.

Quantitative Analysis: Signal-to-Noise Ratio and Contrast-to-Noise Ratio

Quantitative assessment of image quality was performed using ImageJ software to calculate the SNR and CNR for all images obtained with each coupling medium. SNR and CNR provide measurements of image clarity, tissue contrast, and background noise which are the key determinants of diagnostic usefulness in ultrasound imaging.

All ultrasound images were exported in high-resolution format and analysed using a standardised region-of-interest (ROI) approach. Consistency in ROI placement was maintained across all images to ensure accurate comparisons. ROI placement was standardised by using fixed anatomical reference points within the phantom, and ImageJ software enabled the same ROI shapes and sizes to be replicated across all images. The evaluator applied identical ROI templates to corresponding anatomical regions for every coupling medium, ensuring that all SNR and CNR measurements were derived from comparable and reproducible locations.

Descriptive Analysis of SNR and CNR

Data were presented as mean values with their corresponding standard deviations. Due to the limited number of repeated scans, inferential statistical testing was not conducted. As a result, comparisons across coupling media are descriptive in nature and should be interpreted carefully.

Liver region-of-interest placement

In liver, three rectangular ROIs were placed within the liver parenchyma to assess tissue uniformity, while three circular ROIs were positioned along the diaphragm (Figure 1). The diaphragm serves as a crucial reference point due to its strong echogenic contrast against the liver tissue, allowing for a clearer evaluation of boundary definition and sound wave penetration. These ROI placements enable a comprehensive assessment of liver echogenicity by capturing variations between soft tissue structures and high-contrast interfaces (Theodotou et al., 2019).

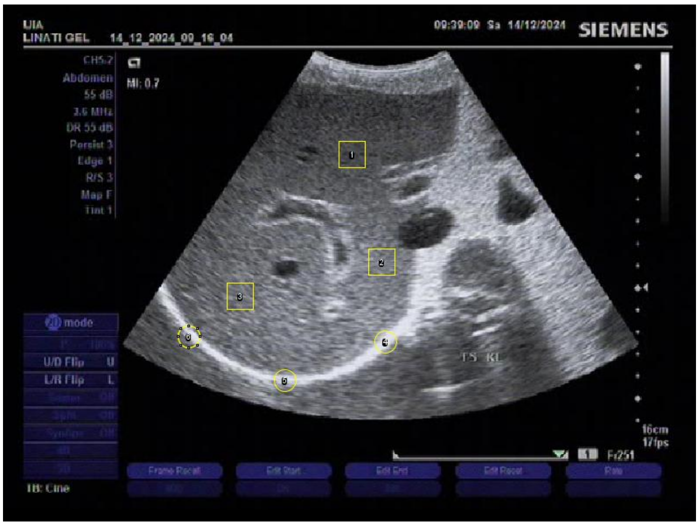

Figure 1: Ultrasound Image of the Liver with ROI Markings

Kidney region-of-interest placement

In right kidney, three ROIs were placed over the renal cortex, medulla, and sinus to represent its key anatomical structures (Figure 2). The cortex and medulla help evaluate tissue contrast and homogeneity, while the sinus, which contains fat and vascular elements, reflects the acoustic penetration and signal (Beutler et al., 2024).

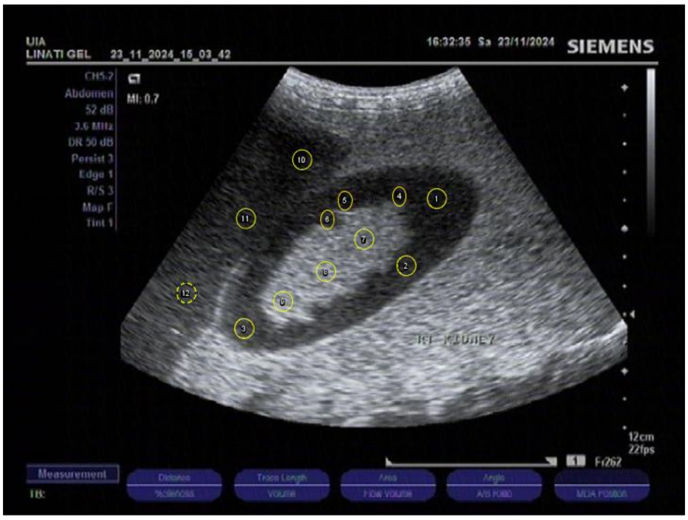

Figure 2: Ultrasound Image of the Kidney with ROI Markings

Aorta region-of-interest placement

In aorta, a rectangular region of interest was placed within the lumen, while the mean wall intensity was derived from several point measurements taken along the delineated vessel wall (Figure 3). Three narrow rectangular background ROIs were positioned adjacent to the aorta to represent surrounding vascular tissue and to calculate the standard deviation (SD) of the background noise.

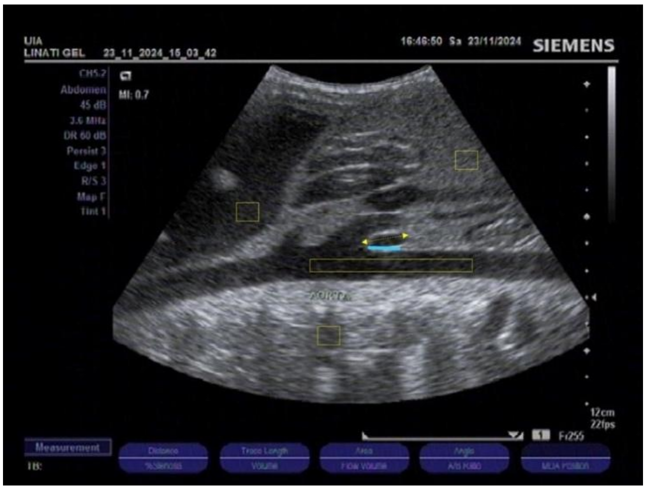

Figure 3: Ultrasound Image of the aorta with ROI Markings

Signal-to-Noise Ratio Calculation

The SNR was calculated to determine the relationship between the signal intensity of the target tissue and the degree of noise in the surrounding background. Higher SNR values indicate clearer images with reduced noise interference. SNR was computed for each ROI using the formula:

$$\mathrm{SNR} = \frac{\mu_{\mathrm{ROI}}}{\sigma_{\mathrm{BG}}} \quad (1)$$

where, μ_{ROI} = mean pixel intensity of the tissue of interest
σ_{BG} = SD of pixel intensities within the background ROIs

Contrast-to-Noise Ratio Calculation

The CNR was calculated to evaluate how effectively each coupling medium allowed differentiation between adjacent anatomical structures. The general formula used was:

$$\mathrm{CNR} = \frac{\mu_{\mathrm{ROI}} - \mu_{\mathrm{BG}}}{\sigma_{\mathrm{BG}}} \quad (2)$$

where, μ_{ROI} = mean pixel intensity of the tissue of interest
μ_{BG} = mean pixel intensity of the background
σ_{BG} = SD of pixel intensities within the background ROIs

Qualitative analysis: Virtual Grading Analysis

Qualitative image quality was assessed using a VGA approach, with the evaluation criteria adapted from Smit and Breedt (2022). Three sonographers with more than ten years of diagnostic ultrasound experience independently reviewed the images.

Images of the liver, right kidney, and aorta obtained using using different coupling medium were exported in digital format and organised into organ-specific sets. Each set contained four images, one representing each coupling medium. To minimise observer bias, the images were anonymised and relabelled as Image A, B, C, and D, without disclosing the coupling agent used.

The VGA utilised a structured scoring form comprising four criteria: (1) detail and sharpness, (2) image noise, (3) depth and penetration, and (4) overall image quality. The sonographers ranked the four images on a scale from 1 to 4 for every organ and criterion, where 1 indicated the highest quality and 4 the lowest. This ranking process resulted in 12 rank values for each image (4 criteria × 3 reviewers), derived from four criteria assessed by three reviewers using a forced-ranking format. The mean rank was calculated by summing all 12 assigned ranks and dividing the total by 12, following the formula:

$$\text{Mean Rank} = \frac{Sum\ of\ all\ assigned\ ranks\ for\ that\ image}{12} \quad (3)$$

RESULTS

Quantitative Analysis: Signal-to-Noise Ratio and Contrast-to-Noise Ratio

Liver imaging results (Table 1) show that commercial ultrasound gel produced the best image quality, with the highest SNR (2.78) and CNR (1.93), indicating superior signal clarity and structure definition. Olive oil performed closely behind (SNR 2.72; CNR 1.68), suggesting it could serve as a practical alternative when commercial gel is not available. Aloe vera showed slightly lower image clarity (SNR 2.63), and honey produced the poorest results (SNR 1.36; CNR 1.55), reflecting weak contrast and limited visualisation of liver structures.

In kidney imaging, aloe vera outperformed all other coupling agents, with the highest CNR (3.37) and SNR (5.82). These values exceeded those of commercial gel (CNR 2.27; SNR 4.71), indicating that aloe vera may be a strong alternative for renal assessment. Olive oil produced moderate-quality images (SNR 3.19; CNR 1.37), while honey again delivered the lowest values (SNR 2.19; CNR 0.61), showing poor structural detail and signal quality.

Aortic imaging showed a different trend, with olive oil producing the highest CNR (6.82), providing the best contrast between the aortic wall and lumen. However, its SNR (1.21) was slightly lower than the commercial gel (1.78), meaning it had weaker overall signal clarity. Aloe vera yielded moderate performance (SNR 1.12; CNR 3.76), and honey again produced the lowest values (SNR 0.21; CNR 2.86), indicating visibly poor contrast and unsuitable image quality for aortic evaluation.

Table 1: SNR and CNR for different coupling medium and organ

Part	Coupling Medium	SNR	CNR
Liver	**Aloe Vera**	2.63	1.59
	Honey	1.36	1.55
	Olive Oil	2.72	1.68
	Ultrasoud Gel	2.78	1.93
Kidney	**Aloe Vera**	5.82	3.37
	Honey	2.19	0.61
	Olive Oil	3.19	1.37
	Ultrasoud Gel	4.71	2.27
Aorta	**Aloe Vera**	1.12	3.76
	Honey	0.21	2.86
	Olive Oil	1.21	6.82
	Ultrasoud Gel	1.78	5.12

Qualitative analysis: Virtual Grading Analysis

Based on Table 2, honey produced the best perceived image quality for the liver, with average rank of 2.17. This means the sonographers consistently judged honey to provide sharper images with less noise and good penetration. Commercial ultrasound gel followed closely with a score of 2.25, indicating strong and clinically acceptable performance. Aloe vera received an average rank of 2.58, suggesting moderate but acceptable image quality, while olive oil ranked lowest at 3.00, indicating reduced sharpness, more noise, and poorer depth penetration for liver imaging.

While for the kidney, aloe vera achieved the highest-quality images with an average rank of 1.83 as it provides the clearest visibility of renal structures, including the cortex, medulla, and sinus. Commercial ultrasound gel was the second-best performer with an average rank of 2.00, producing high-quality images. Olive oil showed moderate performance with a ranking of 2.83, while honey performed the worst with a rank of 3.33, indicating noticeably higher noise and reduced contrast, making it the least effective medium for kidney imaging.

Evaluation of the aorta showed that aloe vera again produced the best perceptual image quality, ranking first with an average score of 1.67. Aloe vera provided clear vessel wall definition, good lumen visibility, and overall balanced contrast. Honey ranked second with an average score of 2.17, indicating that while its performance was acceptable. Olive oil received a score of 3.00, reflecting moderate clarity with some limitations in contrast and noise. Commercial ultrasound gel ranked last with 3.17, suggesting that the sonographers judged its aortic images to be the least sharp and least distinct compared with the natural alternatives.

Table 2: VGA for different coupling medium and organ

Part	Average Rank			
	Aloe Vera	Honey	Olive Oil	Ultrasoud Gel
Liver	2.58	2.17	3.00	2.25
Kidney	1.83	3.33	2.83	2.00
Aorta	1.67	2.17	3.00	3.17

DISCUSSION

The quantitative analysis indicates that although commercial ultrasound gel performed strongly overall, it did not consistently produce the highest SNR and CNR values across all organs assessed. While it remains the clinical standard and delivered excellent image quality for liver imaging, its performance was exceeded by aloe vera in kidney evaluation and by olive oil in aortic contrast assessment. These outcomes suggest that commercial gel continues to provide reliable acoustic transmission, as reported in previous studies (Williams et al., 2019), but its advantage is not uniform across all anatomical regions.

Among the alternative materials tested, olive oil showed notable potential, particularly in vascular imaging. Its exceptionally high CNR for the aorta indicates enhanced differentiation between the vessel wall and lumen, which is crucial for accurate assessment of vascular structures. Olive oil also demonstrated competitive performance for liver imaging, ranking close to the commercial gel. The improved contrast observed in this study suggests that olive oil may offer diagnostic advantages in settings where commercial gel is unavailable.

Aloe vera showed its strongest performance in kidney imaging, surpassing the commercial gel in both SNR and CNR. This finding indicates that aloe vera's acoustic behaviour may align particularly well with the tissue composition of the kidney, enabling clearer structural differentiation. The superior performance in renal imaging suggests that aloe vera may be a viable natural alternative for specific organ applications.

In contrast, honey delivered consistently poor results for all organs, showing the lowest SNR and CNR values across the dataset. Its high viscosity likely impairs efficient sound transmission, resulting in reduced signal quality and weak structural contrast. The consistently suboptimal performance suggests that honey is unsuitable as a general-purpose ultrasound coupling agent.

Qualitative assessment using VGA provided additional insight into the perceptual quality of images produced by each coupling medium. Aloe vera ranked highly for both the right kidney and aorta, reflecting strong performance across multiple evaluators. Its favourable viscosity and acoustic behaviour appear to reduce image noise while improving boundary clarity, leading to consistently high-quality visualisation. The highlight its potential as a practical substitute when commercial gel is not available.

Honey exhibited mixed qualitative performance. Although it scored well for the liver, its ranking for the kidney was substantially poorer. This pattern suggests that honey may interact differently depending on organ type or tissue echogenicity. While certain physical properties might have temporarily enhanced liver image appearance, its consistently low SNR and CNR across the quantitative analysis indicate that honey does not reliably support diagnostic-quality imaging. These inconsistent outcomes align with previous findings that highlight the need to consider anatomical variation when evaluating unconventional coupling agents (Okere, 2019).

Olive oil showed moderate performance across most organs, receiving intermediate rankings that reflect acceptable but not superior image quality. While its strong quantitative contrast performance for the aorta was promising, the qualitative results suggest that olive oil may not provide uniform clarity across all anatomical regions.

Commercial ultrasound gel, despite being the reference standard, showed varied rankings in the VGA. Its strong performance for the right kidney contrasted with its lower rank for aortic imaging. This inconsistency suggests that while commercial gel is generally reliable, perceptual image quality may still vary according to specific anatomical or operator-related factors.

CONCLUSION

This study demonstrates that while commercial ultrasound gel remains a reliable reference standard, its performance was not consistently superior across all organs. Quantitative assessment showed that commercial gel produced the best liver image quality but was outperformed by aloe vera in kidney imaging and by olive oil in aortic contrast evaluation. These findings indicate that certain natural materials may offer organ-specific advantages in acoustic transmission.

Among the alternatives, olive oil showed strong potential, producing the highest aortic CNR and competitive liver imaging quality, suggesting suitability for vascular and soft-tissue applications when commercial gel is unavailable. Aloe vera delivered the clearest kidney images in SNR, CNR and ranked highly in qualitative assessments, demonstrating favourable acoustic behaviour and consistent visual clarity across evaluators.

Honey performed poorly across most measurements, with the lowest SNR and CNR values and weak qualitative rankings, indicating limited suitability as a coupling medium.

Taken together, the findings suggest that aloe vera and olive oil may be considered as provisional alternatives in specific clinical scenarios, particularly in resource-limited settings. Their reliable performance highlights the potential value of natural coupling agents in expanding ultrasound accessibility when commercial gel is restricted or unavailable. However, as this was a phantom-based study, the results may not fully replicate in clinical environments, and further in vivo studies are required before these natural media can be recommended for routine clinical use.

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