ORIGINAL ARTICLE

Petroleum Jelly as an Alternative Coupling Agent to Reduce Umbrella Artifacts in Ultrasound Superficial Scans

Muhammad Hanif Hakimi Zainudin[1], Kamarul Amin Abdullah[1,2]

[1] School of Medical Imaging, Faculty of Health Sciences, Universiti Sultan Zainal Abidin, 21300 Kuala Nerus, Terengganu, Malaysia
[2] Cancer, Molecular and Functional Imaging Research (CaMFIRe) Group, Faculty of Health Sciences, Universiti Sultan Zainal Abidin, 21300 Kuala Nerus, Terengganu, Malaysia

ABSTRACT

Introduction: Umbrella artifacts, caused by air bubbles in ultrasound gels, can compromise the diagnostic accuracy especially superficial ultrasound scans. This study investigated whether petroleum jelly, a commonly available alternative, could reduce these artifacts than standard ultrasound gel. **Materials and methods:** A cross-sectional study was conducted from September 2022 to February 2023, including only adult patients (18-40 years old) with normal BMI. Patients were prospectively recruited using a random sampling method and informed consent was obtained. Patients with a history of eczema, surgery, or chronic diseases were excluded. Total scores of overall image quality based on high contrast spatial resolution (HCSR), signal-to-noise ratio (SNR), image contrast, and homogeneity were compared between petroleum-jelly based and ultrasound gel-based images using a paired t-tests. The presence of umbrella artifacts was assessed using McNemar's test. **Results:** A total of 88 patients with 45 males (51.1%) and 43 females (48.9%) participated in this study. Petroleum jelly-based images demonstrated slightly lower image quality compared to ultrasound gel-based images (17.75±1.72 vs. 17.35±1.30; P = 0.018), with an overall mean difference score of 0.40 (95% CI; 0.07, 0.73). However, the umbrella artifacts were significantly reduced with petroleum jelly (n = 2, 2.27%) compared to ultrasound gel (n = 9, 10.23%) (P = 0.039). **Conclusion:** Petroleum jelly shows potential as an alternative coupling agent, significantly reducing umbrella artifacts, despite slightly lower image quality. Its potential application in resource-limited settings needs further investigation and optimisation for broader clinical use.
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Corresponding Author:
Kamarul Amin Abdullah, PhD
Email: kamarulaminab@unisza.edu.my
Tel : (6)03-89472461

INTRODUCTION

Ultrasound has become an indispensable tool in modern diagnostic imaging, offering a non-invasive, rapid, and accurate method for evaluating a wide range of conditions. In dermatology, its utility extends to detailed visualisation of the skin's structure and associated pathologies, providing valuable insights that aid in diagnosis, treatment, and surgical planning (1, 2). For example, ultrasound has demonstrated high sensitivity of 85% and specificity of 88% in detecting conditions such as dermatitis, highlighting its effectiveness in superficial scans (3).

Despite its widespread use, ultrasound imaging is not without limitations, particularly in superficial examinations where artifacts can obscure fine details and compromise diagnostic accuracy. Among these, umbrella artifacts have a unique challenge, often resulting from air bubble entrapment within the coupling medium (4, 5). Addressing such artifacts is critical for improving the quality and reliability of ultrasound imaging, especially in scenarios where precise visualisation of superficial structures is paramount.

This study evaluates the use of petroleum jelly as an alternative coupling agent to standard ultrasound gel, focusing on its impact on overall image quality and the reduction of umbrella artifacts. Other alternatives, such as oil and corn starch, have been explored but were found to be less suitable due to factors including potential skin irritation, limited adhesion to the skin, and suboptimal physical properties (6, 7). By exploring the trade-offs between artifact reduction and overall image quality, this work aims to contribute to the optimisation of coupling agents for improved diagnostic outcomes in superficial scans.

MATERIALS AND METHODS

Study Participants

Participants were recruited using a systematic random sampling method from the hospital's ultrasound

appointment list, with selection guided by a random number generator. The required sample size was calculated using PS: Power and Sample Size Calculation software (version 3.1.6), with parameters set to a 95% confidence interval, 5% significance level, and 90% power. The final sample size of 88 patients included a 15% allowance for potential dropouts.

The study population comprised patients from Kuala Lumpur attending on-site ultrasound appointments. Conducting this study in the Malaysia's most developed region was intended to enhance the generalisability of the findings to the broader Malaysian population.

Inclusion and Exclusion Criteria

The inclusion criteria were adults (18-40 years old) with normal BMI (18.5-24.9 kg/m2) who were available for outpatient appointments during the study period and had no history of chronic skin disease. Participants' medical records were also reviewed to confirm eligibility. Exclusion criteria were patients with missed or delayed appointments, chronic skin conditions to avoid the risk of inflammation, surgical scars, or open wounds in the abdominal area, or those who declined to participate.

Equipment and Materials

This study utilised the Philips iU22 ultrasound machine equipped with a curvilinear transducer array (model L17-5). An appropriate frequency was selected for all scans, with consistent ultrasound settings applied to ensure standardisation when comparing the two coupling agents.

Six 250-ml bottles or containers of ultrasound gel were retrieved from the ultrasound room, and two kilogrammes of pharmaceutical-grade petroleum jelly were prepared for the study. The petroleum jelly, made from pure petrolatum, high-quality paraffins and the purest white oils, was free from impurities. To maintain consistency in application, the petroleum jelly was decanted into six empty ultrasound gel bottles identical to those containing the ultrasound gel. For identification, the bottles were labelled 'A' (ultrasound gel) and 'B' (petroleum jelly).

As this was an observational study, aseptic techniques were not emphasised. However, care was taken to use identical procedures when handling and applying both coupling agents to ensure consistency in the scanning process.

Scanning Procedure

Although abdominal ultrasound is not typically classified as a superficial scan, the proximity of the transducer to the skin and the soft tissue characteristics of the abdominal region made it suitable for evaluating umbrella artifacts. These artifacts are primarily caused by air bubbles in the coupling medium, making this region an appropriate choice for the study.

To ensure consistency, the epigastric region was selected as the area of investigation. This region was chosen due to its accessibility and uniform soft tissue composition, which minimise variability and provide a controlled environment for artifact evaluation. Prior to the procedure, all surrounding areas near the region of interest were shaved to prevent the formation of artifacts caused by hair.

The scans were performed by a sonographer following standardised protocols to minimise variability in image acquisition. These measures ensured consistency and reliability in evaluating the presence of umbrella artifacts across all participants.

Petroleum jelly and ultrasound gel were applied in separate session to the abdominal skin of each participant. For each session, 10-15 ml of coupling agent was applied by the same sonographer. The petroleum jelly was left on the patient's skin for 30-45 seconds prior to scanning to allow it to warm up (8). This specific timeframe was chosen based on preliminary observations that indicated it was sufficient for the petroleum jelly to warm up to body temperature, reducing its viscosity and allowing smooth transducer movement during scanning. Warming the petroleum jelly enhances its spreadability and ensures even contact with the skin, which is critical for minimising artifacts and obtaining optimal ultrasound image quality. While the timing was not systematically tested for its impact on viscosity or image quality, this approach was standardised across all scans to ensure consistency. The transducer was then gently moved back and forth on the patient's abdomen, and real-time evaluations image quality were conducted. After scanning, the petroleum jelly on the patient's skin and on the surface of the transducer was carefully wiped off. Figure 1 shows the details study workflow to ensure consistency and accuracy in the scanning process while evaluating the effectiveness of two different coupling agents.

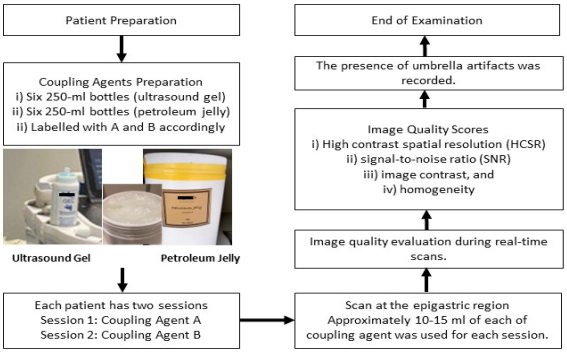

Figure 1: The study workflow during scanning and image evaluation. The workflow involved patient preparation, coupling agents labelled as A and B (ultrasound gel and petroleum jelly), and scanning at the epigastric region with 10–15 ml of each coupling agent used per session. Image quality evaluation was performed during real-time scans, focusing on high contrast spatial resolution (HCSR), signal-to-noise ratio (SNR), image contrast, and homogeneity. The presence of umbrella artifacts was recorded at the end of the examination.

Image Quality Assessment

High contrast spatial resolution (HCSR), signal-to-noise ratio (SNR), image contrast, and homogeneity were visually assessed using defined scoring guidelines adapted from Sassaroli et al (9). Each criterion was rated on a 5-point Likert scale, with scores ranging from poor (1) to excellent (5). The total score for each image was calculated by summing the scores for all four criteria, resulting in a maximum possible score of 20. This total score was used for comparative analysis between the two coupling agents. The presence of umbrella artifacts was recorded as either 'yes' or 'no'. Figure 2 shows the example of the process of image quality assessment during real-time scanning procedures.

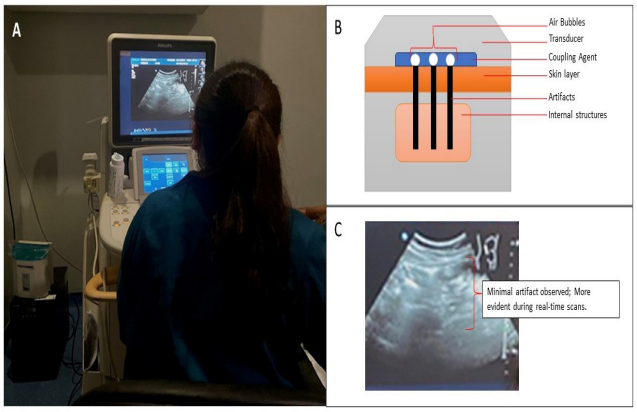

Figure 2: Real-time scanning setup and evaluation of potential artifacts. (A) Real-time scanning setup highlights the evaluation process with a typical ultrasound machine. (B) Schematic diagram shows potential artifacts, including air bubbles and coupling agent interference, observed between the transducer and the skin. (C) Static ultrasound image reveals minimal artifacts, which were more evident during real-time scans, emphasizing the need for real-time observation for accurate evaluation.

Image evaluations were conducted by a sonographer with more than four years of experience in interpreting ultrasound images. To minimise bias during the evaluation of artifacts and image quality, the coupling agents (A and B) were prepared in identical, unlabelled containers. While the sonographer was blinded to the specific coupling agents used, it is acknowledged that differences in texture or viscosity might have allowed some level of differentiation during the application process. Every effort was made to ensure consistency in the application process and scanning technique. Due to logistical constraints, including limited storage space for video recordings, image evaluations were performed in real-time during the scans. This approach ensured immediate artifact assessment and reduced the potential for errors or misinterpretations associated with retrospective analysis. The evaluations followed a standardised protocol to maintain consistency across all scans.

Statistical Analysis

Data analysis was conducted using IBM SPSS Statistics software version 21. The paired t-test was utilised to analyse the quantitative differences in image quality between the two coupling agents. For categorical data, specifically the presence of umbrella artifacts with each coupling agent, McNemar's test was employed.

Ethical Clearance

This study was approved by the ethics committee of the tertiary hospital (Ref: UniSZA/UHREC/2022/432) prior to commencement. Informed consent was obtained from all participants. The research followed a cross-sectional diagnostic-analytical study design and was conducted at a tertiary hospital from September 2022 to February 2023.

RESULTS

Demographic Details

The study included a total of 88 adult patients with a mean age of 29 ± 6 years old and a mean BMI of 20.91 ± 0.51 kg/m (see Table I). The gender distribution was nearly equal, with 51.1% (n = 45) of participants being male and 48.9% (n = 43) being female.

Table I: Demographic details of the participants

	Mean ± SD*
Age	29 ± 6
Body Mass Index (BMI)	20.91 ± 0.51
	Frequency, n (%)**
Male	45 (51.1%)
Female	43 (48.9%)

*SD = standard deviation, **n = total number

Overall Image Quality and Umbrella Artifacts Occurrences

The analysis of overall image quality revealed a statistically significant difference in the total scores between the ultrasound gel-based images and petroleum jelly-based images ($P < 0.05$) (see Table II). Although statistically significant, the difference in scores was considered minimal, amounting to less than 5%.

Table II: Summary of overall image quality scores between ultrasound gel-based and petroleum jelly based images

	Mean ± SD	**Mean Difference (95% CI)**	***P*-value**
Ultrasound gel	17.75 ± 1.72	0.40 (0.07, 0.73)	<0.05* (0.018)
Petroleum jelly	17.35 ± 1.30		

*$P < 0.05$ indicates statistical significance.

Table III shows a statistically significant reduction in the presence of umbrella artifacts when petroleum jelly was used compared to ultrasound gel with a P value of 0.039.

Out of all included patients, only 2 (2.27%) patients recorded the presence of umbrella artifacts on the scans with petroleum jelly, while 9 patients (10.23%) had the artifacts on the scans with ultrasound gel.

Table III: A comparison of the count of presence of umbrella artifacts between both coupling agents

Presence of Umbrella Artifacts		Petroleum Jelly		*P*-value
		No	Yes	
Ultrasound Gel	No	78	1	<0.05* (0.039)
	Yes	8	1	
Total Participants		86	2	

*$P < 0.05$ indicates statistical significance.

DISCUSSION

This study found that while petroleum jelly-based images provide slightly lower overall image quality compared to ultrasound gel-based images, it results in significantly less occurrence of umbrella artifacts. The slightly reduced image quality observed with petroleum jelly could be attributed to its higher viscosity, which may dampen the transmission of ultrasound waves and result in a minor loss of resolution. Additionally, petroleum jelly lacks the acoustic coupling properties of commercially formulated ultrasound gels, which are specifically designed to optimise impedance matching between the transducer and the skin surface. This difference in material composition might also explain the observed discrepancy in the overall image quality.

This study evaluated umbrella artifacts in the epigastric region using a curvilinear transducer. Although abdominal ultrasound is not traditionally classified as a superficial scan, the relatively shallow imaging depth in the epigastric area, combined with soft tissue characteristics, provided a suitable setting for assessing umbrella artifacts caused by air bubbles in the coupling medium. This approach highlights the versatility of abdominal ultrasound in studying artifacts typically associated with superficial imaging.

Previous studies have reported mixed findings on the effectiveness of petroleum jelly as a coupling agent. Ras et al (10) found that ultrasound gel produced higher mean image quality scores than petroleum jelly in renal ultrasound examinations, supporting our findings regarding the limitations of petroleum jelly in achieving optimal image resolution. However, Smit and Breedt (11) found no significant difference between petroleum jelly and ultrasound gel in echocardiography examinations. The disparity maybe attributed to differences in imaging depth and the context of application. Umbrella artifacts, which are influenced by the trapping of air bubbles within the coupling medium, are more prominent in imaging scenarios with closer transducer-to-skin proximity. In contrast, deeper imaging applications, such as echocardiography, are less affected by these artifacts due to greater tissue depth overcoming their impact.

Petroleum jelly exhibits distinct thermal and acoustic properties compared to ultrasound gel, which may influence its performance as a coupling agent (12). Although these properties were not specifically analysed in this study, the slight difference in mean image quality scores (less than 5%) could reflect the unique characteristics of petroleum jelly. Its thermal stability and semi-solid composition minimise the formation of air bubbles during application, a critical factor in reducing umbrella artifacts. The absence of air bubbles within its structure ensures a smoother interface between the transducer and the skin, reducing one of the primary causes of artifact formation (13). However, the high viscosity of petroleum jelly, while beneficial for artifact reduction, can also interrupt the propagation of ultrasound waves, potentially leading to reverberation artifacts. These artifacts, characterised by repeating lines in the ultrasound image, occur when the viscosity impedes wave transmission and reflection (14). This interplay of properties highlights a trade-off between artifact reduction and overall image quality.

The reduction of umbrella artifacts observed with petroleum jelly has significant clinical implications in scenarios where artifact-free imaging is critical. For example, in superficial scans such as vascular imaging, skin lesion evaluation, or certain musculoskeletal examination, the minimisation of artifacts is essential for accurate diagnosis (15). Umbrella artifacts can obscure fine anatomical details, leading to diagnostic uncertainty or misinterpretation. The findings of this study suggest that petroleum jelly could be a viable alternative to ultrasound gel in such cases, particularly when artifact reduction takes precedence over minor differences in image quality. Additionally, its stability and lower likelihood of trapping air bubbles could make it particularly useful in resource-limited settings, where high-quality ultrasound gel may not be readily available. However, its higher viscosity and the slight reduction in overall image quality warrant further investigation to optimise its formulation for broader clinical use.

This study has several limitations that should be acknowledged. First, while patient comfort regarding the greasiness of petroleum jelly was not explored, future research should consider assessing patient tolerance to enhance the practical applicability of the findings. Additionally, broadening the demographic to include individuals with varying ages and BMI classifications would improve the inclusivity and generalisability of future studies. Data collection in this study was conducted prospectively, ensuring patient privacy and standardisation in image assessment. However, the study lacked interobserver reliability testing, as image evaluations were conducted by a single senior sonographer. Although adherence to standardised scanning protocols and multiple evaluations by the sonographer helped reduce bias and improve data reliability, the absence of multiple observers introduces

the potential for subjective variability. Future research should incorporate multiple evaluators and conduct interobserver reliability assessments to further validate findings and minimise individual variability in interpretation.

Last, there was a limited exploration of the thermal and acoustic properties of petroleum jelly. Investigating these properties in greater detail could provide a deeper understanding of its performance compared to ultrasound gel. Such research could lead to optimised formulations that reduce artifact presence while enhancing overall image quality. Nevertheless, despite these limitations, the methodological rigour of this study, including the use of standardised protocols and consistent artifact evaluation, provides a reliable foundation for further investigation. Future studies should aim to address these limitations to strengthen the robustness and applicability of findings.

CONCLUSION

This study highlights the potential of petroleum jelly as an alternative coupling agent to ultrasound gel for superficial ultrasound scans. The results show that petroleum jelly significantly reduces the occurrences of umbrella artifacts, which can distort ultrasound images and hinder diagnostic accuracy. However, the results also show that petroleum jelly-based images have slightly lower overall image quality compared to ultrasound gel-based images. Despite this limitation, the reduction in artifacts achieved by petroleum jelly presents an opportunity to enhance diagnostic accuracy in specific applications. Future research should focus on optimising the formulation of petroleum jelly to improve its acoustic properties and balance artifact reduction with overall image quality, enabling broader clinical applicability.

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