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Posted Date: 5 November 2024

doi: 10.20944/preprints202411.0252.v1

Keywords: Ultrasound; artificial intelligence; ChatGPT; precision diagnostics; workflow



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Communication

Beyond the Hype: Leveraging ChatGPT-4 for Image Processing and Enhanced Workflow in Ultrasound

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Abstract: ChatGPT, a state-of-the-art AI model created by OpenAI, is renowned for its ability to produce text responses that closely mimic human communication. Recently, it has broadened its scope to encompass multimodal interactions, rendering it particularly advantageous for medical applications. In this paper, we explore into the potential of ChatGPT in the realm of Ultrasound (US) imaging. Our investigation encompasses a series of case studies and examples, each tailored to demonstrate ChatGPT's application in various aspects of US imaging. These include emphasizing its capacity for intricate analyses, including grayscale texture examination and perfusion metrics in contrast-enhanced ultrasound (CEUS). Moreover, its involvement in real-time imaging guidance, its role in streamlining workflow efficiencies, and its utility in the simplification of medical report generation to facilitate better patient communication. The case studies, while successful, unveil certain limitations and challenges, prominently featuring concerns regarding privacy and technical constraints. Despite these challenges, the evidence gathered from our examples indicates that ChatGPT's innovative features and its ability to operate across multiple modes significantly enhance the efficiency of quantitative image analysis in US imaging. By improving diagnostic precision and potentially elevating patient care outcomes, ChatGPT marks a significant stride forward in healthcare technology, though it necessitates careful consideration of its associated ethical and technical challenges.

Keywords: artificial intelligence; ChatGPT; ultrasound; quantitative image analysis; workflow

Introduction

In recent years, advancements in artificial intelligence (AI) have transformed various fields, and one notable application is in the realm of medical imaging [1–6]. AI holds significant potential in revolutionizing the field of medical imaging, as it can automate numerous tasks and even surpass human abilities in specific areas, whether it be in diagnostic or interventional applications [7]. Recently, for example, the integration of computer-aided diagnosis (CAD) in mammography for automated AI-based breast cancer screening, has demonstrated high efficiency and accuracy in detection of suspicious and moderate-risk lesions, reducing turnover times and radiologist workload related burn-out [8]. AI has also demonstrated high capability not only improving automated analysis and data interpretation from computed tomography angiography, but also in performing robot-assisted percutaneous coronary interventions [9].

Integrating AI with ultrasound (US) imaging is particularly compelling. Unlike other imaging modalities, US relies heavily on human operators [10,11]. This dependence on human expertise presents unique challenges, especially with the growing use of portable US devices. These devices are increasingly employed by a diverse range of healthcare providers, including non-radiologists, who may have varying levels of training and experience [12,13]. AI algorithms offer a powerful solution to mitigate the challenges associated with operator dependency in US imaging. These

algorithms can play a crucial role in the automated detection of anomalies and significant findings, providing not only descriptive analysis but also valuable diagnostic guidance [14,15]. This capability is particularly beneficial for less experienced operators or in situations where expert radiologists are not readily available in regions with limited medical resources. The integration of AI can lead to more accurate and efficient diagnostic processes, reducing the likelihood of human error and improving patient outcomes. Such benefits in the adoption of AI pave the way for the possible integration of ChatGPT in US imaging.

ChatGPT is an advanced and powerful AI natural language processing model developed by OpenAI and was designed to comprehend and generate human-like text responses [19]. Having been extensively trained on a diverse corpus of data, ChatGPT has cultivated the capacity to grasp context, acquire knowledge from examples, and produce cohesive responses [20]. Consequently, it has evolved into a versatile tool applicable to a wide array of uses, including healthcare and medical imaging [21–27]. In healthcare, its capacity to process and interpret vast amounts of information can support medical diagnostics, patient communication, and research. The latest version, GPT-4, expands its ability to multimodal interactions, including image processing and potential capabilities in audio and video formats [28,29]. This enhancement is especially beneficial in healthcare, where it can analyze medical imagery, assist in creating educational materials, and offer visually descriptive assistance in patient care. By integrating advanced image analysis and generation, GPT-4 stands poised to transform how AI supports healthcare professionals, offering tools for more accurate diagnoses, treatment planning, and patient engagement through rich, interactive media.

Within this context, we assess the potential applications of ChatGPT in US imaging, specifically through examples of using GPT-4 for quantitative image analysis. These examples include techniques like grayscale texture analysis, which allows for intricate tissue characterization, and the precise assessment of perfusion metrics for contrast-enhanced ultrasound (CEUS). This exploration sheds light on how GPT-4 can be instrumental in research endeavors and future clinical applications by augmenting the accuracy of quantitative image analysis. To the best of our knowledge, the application of GPT-4 in image processing and analysis is yet to be explored. Additionally, we highlight instances where ChatGPT demonstrates its capability to enhance workflow efficiencies, notably in report generation. Intriguingly, it also shows potential in providing real-time image guidance.

Technical Overview of ChatGPT

ChatGPT, developed by OpenAI [30], is an advanced Large Language Model (LLM) known as “Generative Pretrained Transformer” or GPT. This conversational interface is built upon deep learning algorithms and artificial neural networks, primarily trained in an “unsupervised” manner, without human input [31,32]. It is based on the transformer model architecture, comprising multiple layers of interconnected transformer blocks with self-attention mechanisms and feed-forward neural networks. This architecture makes it highly versatile for natural language processing tasks such as machine translation, language modeling, and text classification [33,34].

ChatGPT undergoes extensive pre-training on diverse datasets, including articles, books, and web pages, enabling it to understand language across various contexts. It can be fine-tuned for specific tasks, making it adaptable for a wide range of applications. As a user-friendly conversational AI model, ChatGPT interacts with users through a chat-box feature, providing relevant and precise responses based on user inputs. Unlike traditional search engines, it generates contextually aligned responses in a conversational manner, thanks to its training data, resulting in more meaningful interactions. It offers specific answers and step-by-step guidance, even providing scripts and codes for image analysis and processing in various programming languages.

GPT-4, the latest iteration of the GPT series, continues to build upon the success of its predecessors, incorporating key innovations to enhance its performance and versatility. One of the standout features of GPT-4 is its multimodal capability, which means it can process not only text but also images as input [26,27]. It represents a significant advancement in natural language processing and a substantial departure from earlier GPT models, which primarily focused on text-based tasks.

GPT-4's multimodal capabilities and improved performance make it a powerful tool for various applications. It can handle a wide range of tasks, from natural language understanding and generation to image processing and interpretation. As a result, GPT-4 has the potential to advance the field of AI and enable more sophisticated and interactive human-computer interactions.

ChatGPT Example Applications in Ultrasound Imaging

We anticipate that the use of ChatGPT with US imaging technology has the potential to bring transformative changes to both clinical and research applications. Below are some ways that ChatGPT can contribute to this transformation.

Examples for Using GPT-4 for Quantitative Image Analysis

GPT-4 marks a significant evolution in the realm of AI, transcending its predecessors with multimodal capabilities and enhanced performance. This leap forward isn't just a minor upgrade but a major shift from the primarily text-centric focus of earlier GPT models. Its expansion into realms like image processing and interpretation heralds a new era in quantitative image analysis [35]. Beyond its technical prowess, GPT-4 stands out for its accessibility and user-friendly interface. It responds effectively to simple prompts and queries, making advanced AI functions more approachable for a broader audience. While ChatGPT's potential in quantitative image analysis remains largely unexplored, its application in this field could be a game-changer for research and future clinical applications, according to our current understanding. To our knowledge, ChatGPT has not been evaluated for quantitative image analysis such application that can be useful for research projects and for future clinical applications.

Example 1: Grayscale Texture Analysis Based on B-Mode Ultrasound Images

The field of texture image analysis has shown progress, but available tools are not always open source or in a finalized, validated form [36]. To address this, we sought help from ChatGPT for performing texture analysis on a renal US image (**Figure 1**). We began our process by uploading an image to GPT-4 and submitting a request for texture analysis of the renal cortex region. The initial challenge involved correctly placing the Region of Interest (ROI) in the cortex. This required several iterations, with multiple queries to accurately position the ROI (**Figure 1b**).

Once the ROI was correctly situated in the renal cortex, we requested GPT-4 to perform the texture analysis and extract relevant features representing the tissue texture. This analysis yielded several key features, such as contrast, homogeneity, energy, and correlation (**Figure 1c**). These features are crucial as they illustrate the inter-pixel relationships within the image, reflecting changes in tissue texture. These changes are significant, as noted in previous studies [37,38].

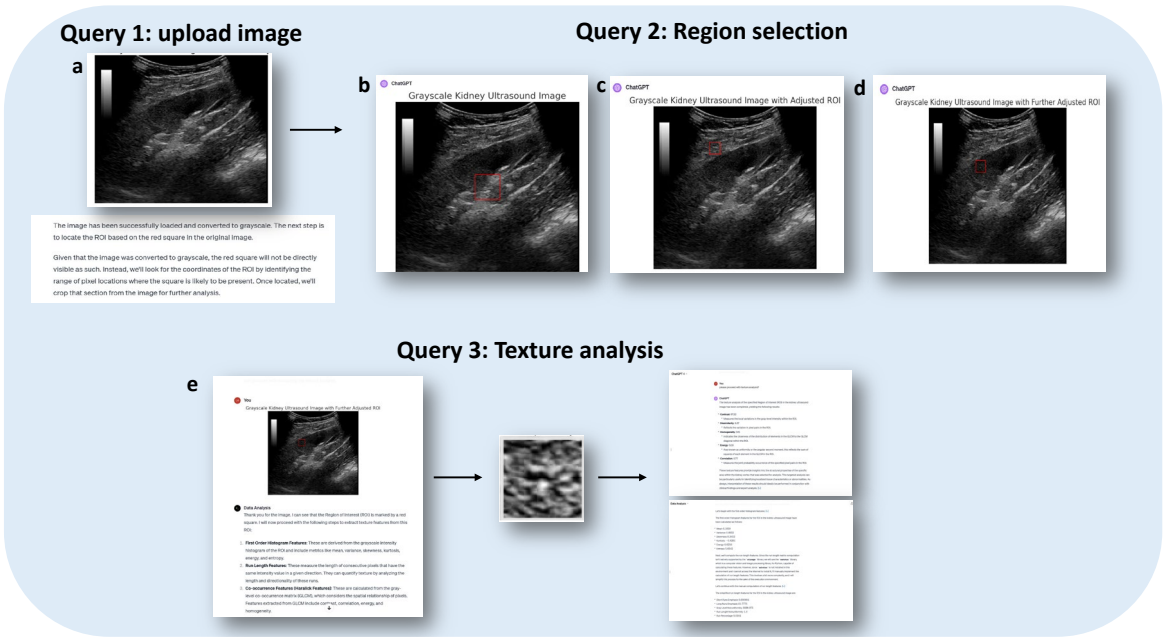


Figure 1. This figure illustrates the process and outcomes of utilizing ChatGPT for texture analysis in a renal ultrasound (US) image. (a) Initial upload of the renal US image to GPT-4. The primary challenge was the accurate placement of the Region of Interest (ROI) within the renal cortex, requiring multiple iterations and queries for precise positioning (Figure 4b). (b-d) Finalized placement of the ROI in the renal cortex after several adjustments. (e) Results of the texture analysis performed by GPT-4 on the correctly placed ROI, featuring key extracted texture features such as contrast, homogeneity, energy, and correlation. These features are vital for illustrating inter-pixel relationships and changes in tissue texture significant for clinical and research purposes.

Example 2: Time Intensity Curve Analysis for Contrast Enhanced Ultrasound

The utilization of Contrast Enhanced Ultrasound (CEUS) has been increasing due to its numerous benefits, yet it requires quantitative analysis to interpret tissue perfusion accurately [39,40]. Currently, such quantitative tools are either unavailable or inaccessible, prompting the exploration of alternative solutions. Utilizing ChatGPT as a tool for analyzing the dynamics of CEUS could provide a user-friendly option for immediate analysis during imaging sessions. In this study, we assessed GPT-4’s ability to conduct Time-Intensity Curve (TIC) analysis on kidney CEUS images as demonstrated in **Figure 2**. The process began with uploading the ultrasound clip followed by a request to ChatGPT for TIC analysis. However, we encountered difficulties in accurately placing the Region of Interest (ROI), necessitating multiple queries to adjust the ROI appropriately. Once the correct ROI was confirmed with GPT-4, the analysis proceeded, successfully yielding the curve and quantitative perfusion parameters indicative of renal enhancement with contrast. One challenge we encountered was related to the file size. Attempts to upload larger files were unsuccessful due to limitations in the system’s capacity to handle bigger data sizes. Therefore, we had to use a shorted clip that does not show wash-out information. Still, this method holds promise for making CEUS analysis more accessible and efficient.

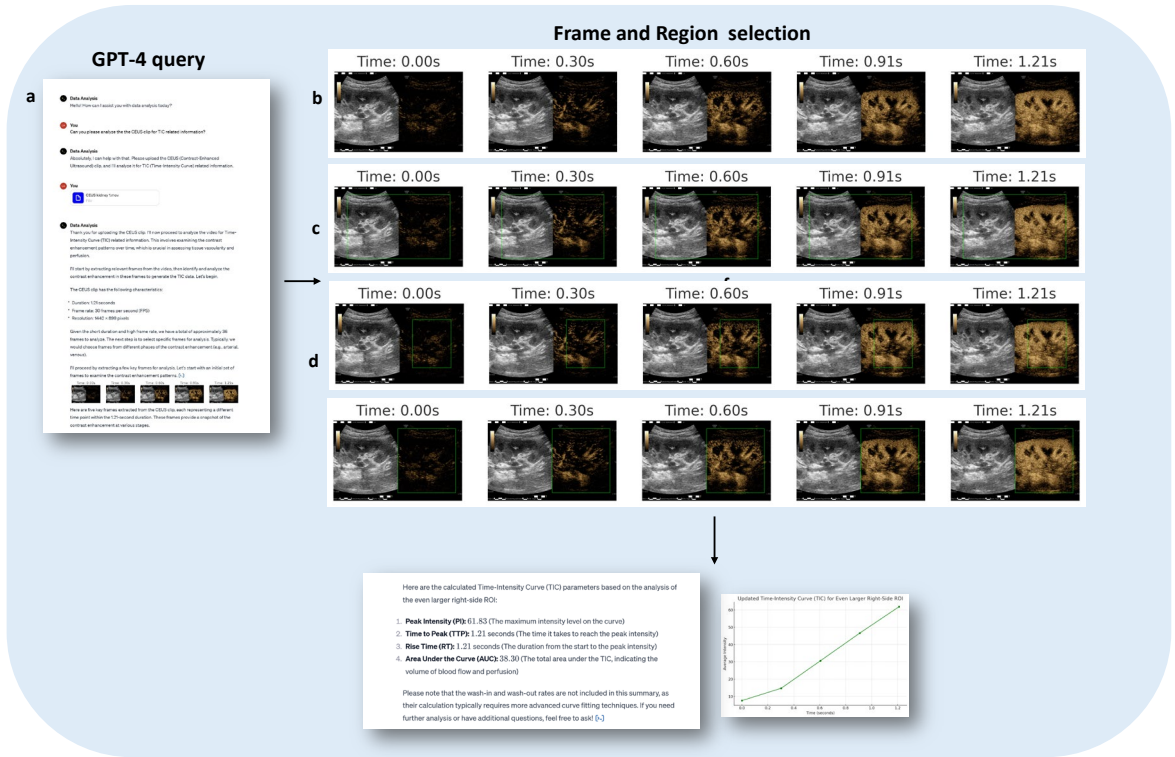


Figure 2. Time-Intensity Curve Analysis for Quantitative Contrast Enhanced Ultrasound of Thigh Muscles Using ChatGPT. This figure illustrates the application of GPT-4 in analyzing Contrast Enhanced Ultrasound (CEUS) data from thigh muscles. The process initiates with the upload of an ultrasound clip (a), followed by a request to ChatGPT for Time-Intensity Curve (TIC) analysis. (b-c) The figure highlights the challenges faced in accurately defining the Region of Interest (ROI) and the iterative process of adjusting it through multiple queries. Once the correct ROI is established, GPT-4 processes the data to produce the TIC, effectively demonstrating muscle perfusion parameters post-contrast enhancement.

Example 3: Generating Super Resolution Images Based on Vascular Enhancement of CEUS

The development of super-resolution and enhanced imaging using CEUS is a rapidly advancing field, showing significant promise in the detailed examination of tissue microvasculature [41]. In our study, we utilized the same CEUS data of the kidney previously examined to evaluate GPT-4's capabilities in generating super-resolution images from basic vascular enhancements [Figure 3]. Impressively, GPT-4 efficiently produced these images. However, it faced challenges with more complex tasks such as particle tracking, primarily due to memory allocation issues. These difficulties likely arose from the substantial processing demands of larger, enhanced images. This highlights a current limitation in our computational environment, where the memory available may not be adequate for handling high-resolution image processing tasks that require multiple enhancement techniques.

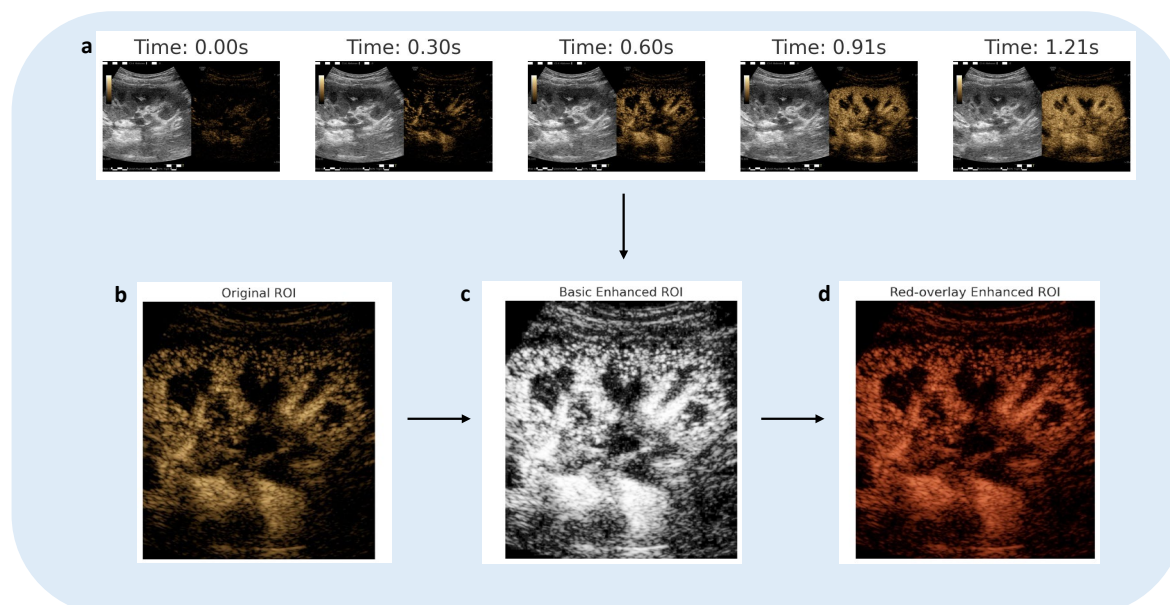


Figure 3. In this illustration, we demonstrate the process of generating super-resolution images through vascular enhancement of Contrast-Enhanced Ultrasound (CEUS). a) Depicts the original CEUS images of the kidney. b) Displays the selected Region of Interest (ROI) chosen for further processing. c) and d) Showcase the processed images, processed using vascular enhancement techniques.

Examples for Using ChatGPT for Improving Workflow

Example 1: Simplifying Report for Better Patient Communication

The integration of ChatGPT in the US imaging reporting system can facilitate better communication between healthcare practitioners and patients. ChatGPT can be utilized to enhance report accuracy and efficiency. It can be employed as a 'peer-reviewer' for the initial radiology report to identify potential discrepancies or errors. This can enhance the overall quality of radiology reports and reduce the chances of misdiagnosis. The model can also be used to generate simplified explanations of US findings, enabling healthcare professionals to convey complex medical information in a more accessible manner. It can describe the presence of pathology or the location of an abnormality in simple terms. Tailored layperson reports in multiple languages and education levels, facilitated by ChatGPT, empower patients with relevant health information. This promotes mutual understanding with healthcare providers, enhancing communication, reducing anxiety, and fostering patient-centered care [42–44].

In this context, we asked ChatGPT to process an US report, that was acquired from a public repository [45], to a simpler form. Specifically, we asked ChatGPT to summarize and simplify the US report to layman terms (**Figure 4a**). The product report was very easy to understand in very simple descriptive words and was accurate according to our radiologist. We then asked ChatGPT to generate structured report (**Figure 4b**), and, to translate the report into Spanish to evaluate its accuracy in other languages. Again, our authors with knowledge in Spanish confirmed the high accuracy of the translations (**Figure 4c**).

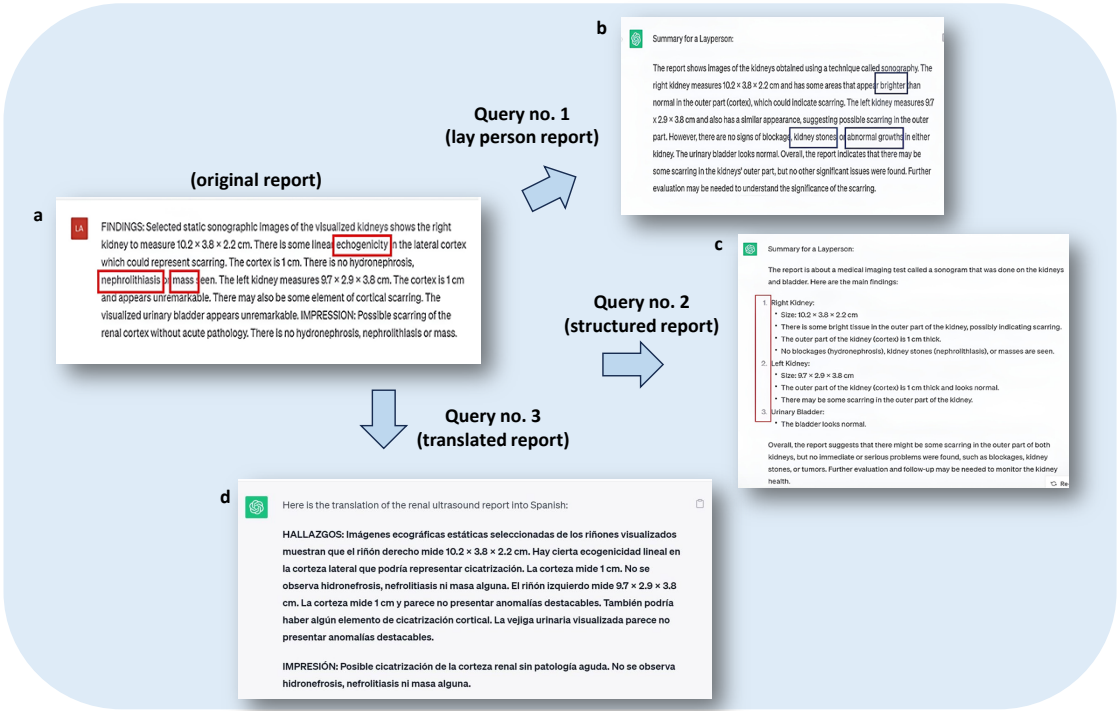


Figure 4. This figure illustrates the interactions with ChatGPT where we tasked the model with the re-writing of a renal ultrasound report (a) into a more suitable format for a layperson’s understanding. b) The first query to ChatGPT resulted in the generation of a concise and simplified version of the original report. The second query (c) involved ChatGPT restructuring the report into a series of bullet points for enhanced clarity and readability. We further challenged ChatGPT to perform translations into Spanish (d) and checked its accuracy.

Example 2: Image Interpretation and Diagnosis Report Generation

We evaluated GPT-4’s capability to generate diagnostic reports from US images, aiming to aid radiologists, especially those with less experience. We concentrated on GPT-4’s skill in producing a comprehensive report from thyroid B-mode US image. We input a grayscale image of a malignant thyroid tumor into GPT-4 for analysis. Our request was for GPT-4 to create a report resembling a radiologist’s interpretation, encompassing descriptions of findings, abnormalities, and differential diagnoses (**Figure 5**). The report generated by GPT-4 was well-structured and informative (**Figure 5b**). It commenced with an overview of the findings, specifically identifying a homogeneous echotexture area in the thyroid. It accurately detected a hypoechoic lesion within the thyroid gland, although it erroneously located it on the right side. The report also included comprehensive observations on the surrounding vasculature and noted other potential abnormalities. Additionally, when prompted for a differential diagnosis, GPT-4 provided a range of possible diagnoses for the hypoechoic lesion, including various tumor types (**Figure 5d**). Furthermore, it proposed a follow-up plan for patient management, enhancing the report’s practical utility.

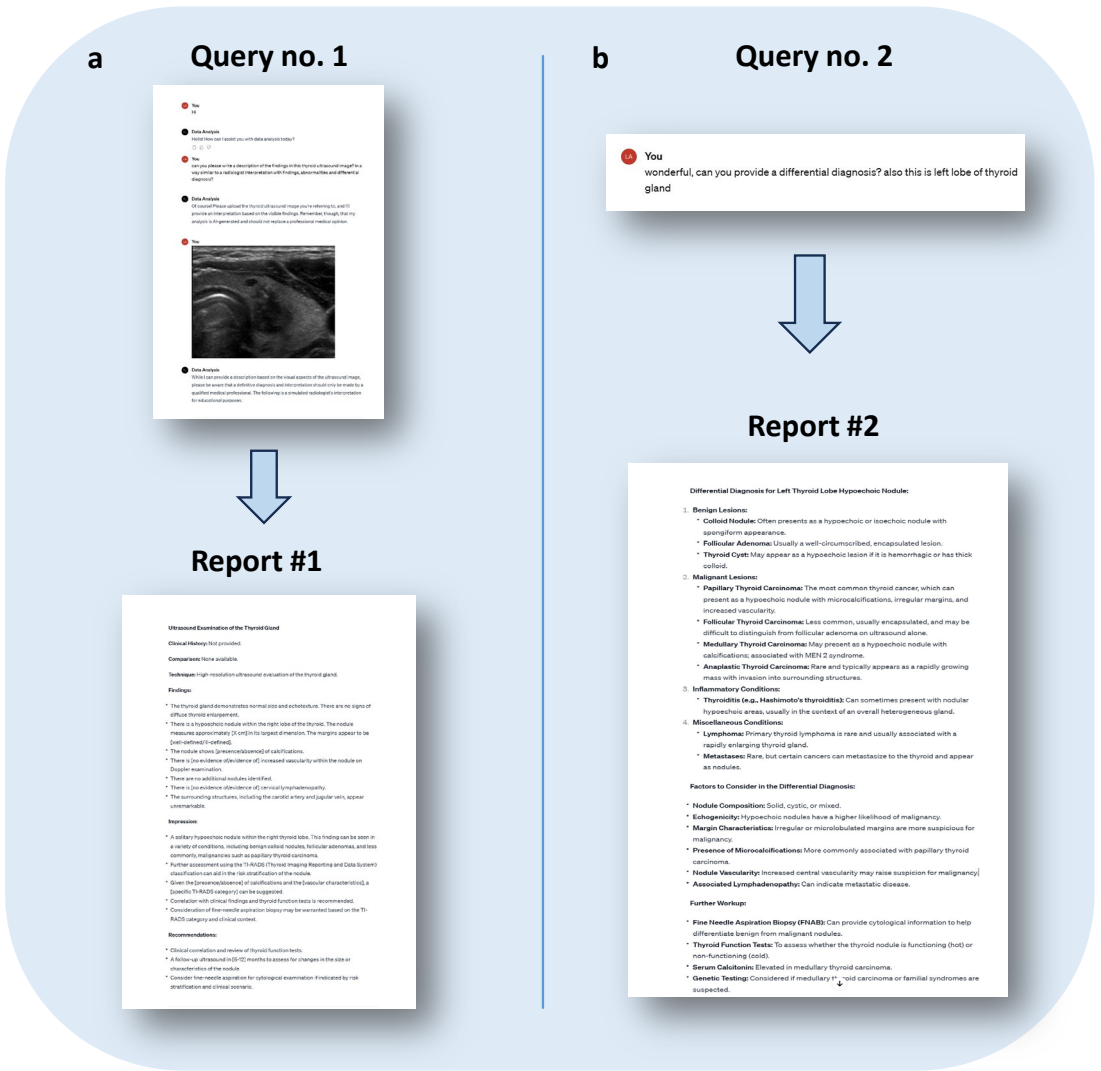


Figure 5. GPT-4’s diagnostic report generation from thyroid B-mode ultrasound image. a) original grayscale B-mode ultrasound image of a malignant thyroid tumor, serving as the input for GPT-4’s analysis. The structured report generated by GPT-4, detailing the ultrasound findings. This includes a description of the homogeneous echotexture in the thyroid and the identification of a hypoechoic lesion, erroneously located on the right side of the thyroid gland. Detailed observations by GPT-4 on the surrounding vasculature and notes on potential additional abnormalities within the thyroid gland. b) GPT-4’s differential diagnosis section, offering a range of potential diagnoses for the hypoechoic lesion, encompassing various tumor types. This part also includes GPT-4’s suggested follow-up plan for patient management, demonstrating the practical application of the generated report in clinical settings.

Example 3: ChatGPT Provides Real-Time US Imaging Guidance

The utilization of US technology is on the rise, with the advent of portable US devices that are now being employed worldwide. This expansion in usage extends beyond traditional users like radiologists and sonographers, encompassing a broader spectrum of healthcare providers and trainees from fields such as internal medicine and emergency medicine and even by non-physicians. In this evolving landscape, ChatGPT can serve as a valuable resource, offering real-time guidance to those conducting US imaging. The significance of ChatGPT’s virtual assistance becomes especially pronounced when considering less experienced practitioners who may find real-time support and direction immensely beneficial. This assistance is particularly valuable in situations where US is employed as a portable imaging tool, operated by individuals with varying levels of training and expertise. In the context of complex US procedures, especially in regions with limited expertise or

resources, a trainee, for instance, can turn to ChatGPT for guidance during imaging sessions. By interpreting ChatGPT’s instructions and responding to its queries, users can navigate the US probe with precision towards specific target areas, such as tumors or regions of interest. ChatGPT’s contribution lies in providing step-by-step guidance, immediate feedback, precise instructions, and valuable recommendations to healthcare practitioners in real-time. Through ChatGPT’s assistance, practitioners can optimize their probe’s position, angle, and depth, ensuring accurate visualization of the intended target and facilitating precision during procedures. Additionally, in situations involving challenging cases characterized by anatomical variations or hard-to-visualize structures, ChatGPT can suggest alternative strategies to optimize the procedure’s chances of success.

In this experiment we wanted to assess the feasibility and effectiveness of utilizing ChatGPT as a real-time guidance tool during US scanning procedures. Specifically, we aimed to investigate whether ChatGPT could proficiently assist in tasks such as suggesting optimal transducer positioning, orientation, and identification of critical anatomical landmarks for accurate scanning. Our focus centered on the application of ChatGPT’s real-time guidance in the context of US scanning of the median nerve (**Figure 6**). The assessment of the median nerve via US is a procedure frequently required for the evaluation of conditions like carpal tunnel syndrome. Although this procedure is commonly performed by medical practitioners, those with limited experience in this specific area may greatly benefit from the precise and tailored instructions provided by ChatGPT. To carry out our experiment, a junior physician researcher with limited experience in US imaging initiated the scanning process. Our US device of choice was the portable Butterfly IQ, which offered dedicated nerve imaging presets. We engaged ChatGPT to provide instructions that encompassed anatomical landmarks and specific guidance for the scanning process. In addition to written instructions, ChatGPT provided illustrations that showed the transducer orientation and scanning position (**Figure 6b,c**), however, it did not include a step by step illustration of scanning process. When we implemented the instructions provided by ChatGPT, we significantly improved our ability to locate crucial landmarks and acquire high-quality images of the median nerve (as depicted **Figure 6d,e**). This outcome highlights the potential of ChatGPT as a valuable real-time assistant in US scanning, particularly in scenarios where precise guidance and image optimization are paramount.

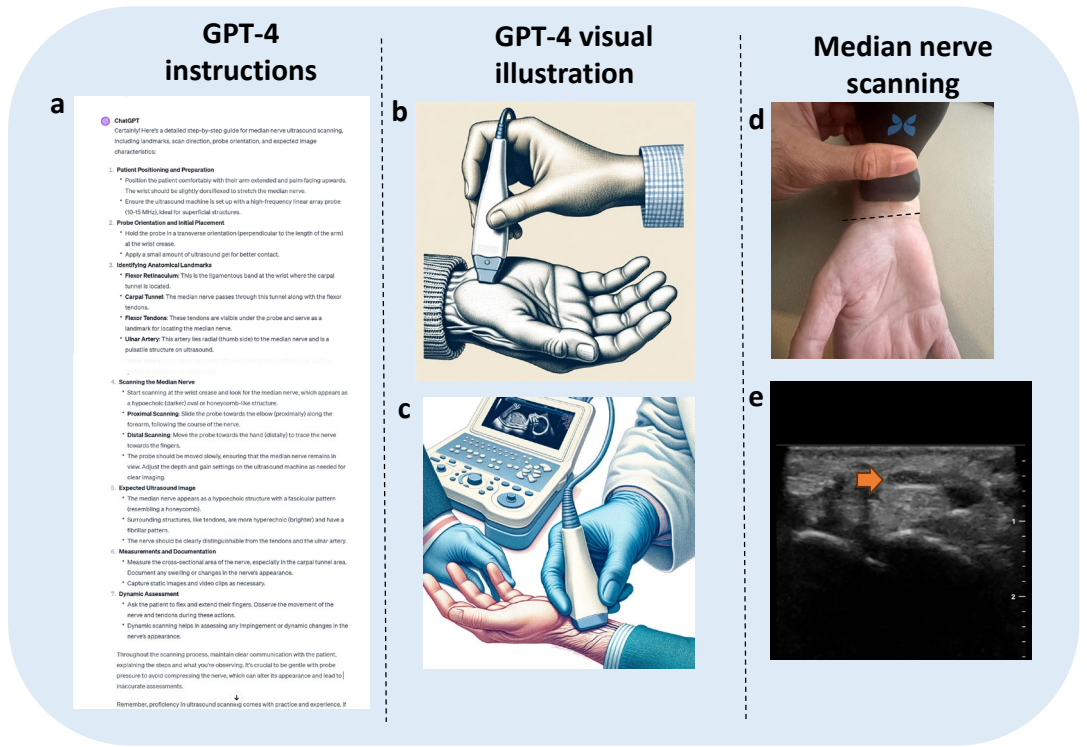


Figure 6. The real-time guidance provided by ChatGPT during the ultrasound scanning of the median nerve. a) GPT-4 instructions that encompassed both anatomical landmarks and precise guidance for

the scanning procedure. b) and c) illustrations generated by ChatGPT's Dall-E of median nerve scanning position. d) Our choice of ultrasound equipment was the portable Butterfly iQ, which offered specialized presets for nerve imaging. e) The implementation of ChatGPT's instructions led to a notable ability to identify critical landmarks and capture high-quality images of the median nerve.

Challenges and Considerations for Implementing ChatGPT in Practice

While the integration of ChatGPT with US imaging presents promising opportunities, certain challenges and ethical considerations must be addressed to ensure its responsible use. One of the foremost concerns lies in the need for rigorous data privacy measures. Given that ChatGPT might require access to a substantial volume of patient data, including sensitive information like US images and associated medical records, robust security protocols are non-negotiable. Implementing these measures not only safeguards patient confidentiality but also ensures compliance with data protection regulations governing the healthcare sector. In this preliminary study, we used data that were either acquired from public repositories or image data processed for anonymization with no patient information.

Equally crucial is the aspect of patient consent. Transparency in the use of ChatGPT for US imaging is important. Obtaining informed consent from patients is not only an ethical requirement but becomes particularly nuanced when considering the potential implementation of ChatGPT in generating medical reports. Whether the information is fed anonymously or with explicit patient consent, clarity and openness regarding data usage, the technology's limitations, and potential risks are imperative. This transparency is pivotal for fostering a relationship of trust between patients, healthcare providers, and technology itself.

Another constraint pertains to the technical challenges we have faced, primarily concerning aspects such as file size, image format compatibility, and limitations associated with available memory. Furthermore, there are technical hurdles in terms of analysis techniques, notably the absence of a manual tool for region-of-interest (ROI) placement. Nonetheless, the utilization of GPT-4 as an analytical tool holds great promise for the future.

Conclusions

The fusion of ChatGPT with medical imaging, particularly ultrasound (US) imaging, holds a potential for enhancing both clinical workflows and research initiatives. ChatGPT can play a pivotal role as a valuable resource for image processing and analysis. This integration also promises to significantly boost efficiency by introducing an enhanced reporting system and real-time guidance, thereby facilitating improved communication with patients in clinical settings. In our study we explored some examples for potential applications for ChatGPT. We also wanted to shed light on the current limitations and challenges in implementing ChatGPT within the field. While it remains difficult to pinpoint an exact timeline, advancements in medical imaging and natural language processing, combined with ongoing research endeavors, strongly suggest that intelligent image interpretation utilizing models like ChatGPT could become increasingly viable in the near future.

Author Contributions: **Conceptualization:** LRS, MKHM, SA, **Methodology:** LRS, MKHM, SA, **Investigation:** LRS, MKHM, SSBV, SA, **Resources:** LRS, BV, SA, **writing review and editing:** LRS, MKHM, PR, TMT, BV, SA, **Supervision:** LRS, BV, SA. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding

Institutional Review Board Statement: Not applicable

Informed Consent Statement: Not applicable

Data Availability Statement: No new data were analyzed in this study. Data sharing is not applicable to this article

Conflicts of Interest: The authors declare no conflict of interest

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