



Review

Advancing radiology with GPT-4: Innovations in clinical applications, patient engagement, research, and learning

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HIGHLIGHTS

- **GPT-4 in Radiology:** Explores the transformative role of GPT-4 in enhancing diagnostic accuracy and streamlining workflows in radiology.
- **Automated Report Generation:** Demonstrates how GPT-4 can automate the creation and summarization of radiology reports.
- **Patient Engagement:** Highlights GPT-4's ability to convert complex radiological data into understandable language.
- **Educational Impact:** Discusses the potential of GPT-4 to revolutionize radiology education through personalized learning modules and real-time feedback.
- **Ethical and Regulatory Considerations:** Addresses the ethical, privacy, and technical challenges in deploying AI technologies like GPT-4.

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ABSTRACT

The rapid evolution of artificial intelligence (AI) in healthcare, particularly in radiology, underscores a transformative era marked by a potential for enhanced diagnostic precision, increased patient engagement, and streamlined clinical workflows. Amongst the key developments at the heart of this transformation are Large Language Models like the Generative Pre-trained Transformer 4 (GPT-4), whose integration into radiological practices could potentially herald a significant leap by assisting in the generation and summarization of radiology reports, aiding in differential diagnoses, and recommending evidence-based treatments. This review delves into the multifaceted potential applications of Large Language Models within radiology, using GPT-4 as an example, from improving diagnostic accuracy and reporting efficiency to translating complex medical findings into patient-friendly summaries. The review acknowledges the ethical, privacy, and technical challenges inherent in deploying AI technologies, emphasizing the importance of careful oversight, validation, and adherence to regulatory standards. Through a balanced discourse on the potential and pitfalls of GPT-4 in radiology, the article aims to provide a comprehensive overview of how these models have the potential to reshape the future of radiological services, fostering improvements in patient care, educational methodologies, and clinical research.

1. Introduction

As the digital transformation of healthcare accelerates, radiology finds itself at the forefront of adopting artificial intelligence (AI) to enhance diagnostic accuracy, streamline clinical workflows, increase patient engagement and improve outcomes. The emergence of Large Language Models (LLMs) like Generative Pre-trained Transformer 4 (GPT-4) (Open AI, San Francisco, USA) represents a significant milestone in this journey, offering multiple opportunities to reshape the landscape of radiological services. This review article examines how this

powerful AI model has the potential to catalyze innovations across various facets of radiology, including the way reports are structured, patients are engaged, research is conducted, and educational content is delivered.

By leveraging its advanced natural language processing capabilities, GPT-4 has shown a significant potential in automating the generation and summarization of radiology reports, offering informed differential diagnoses, and providing evidence-based treatment recommendations. Such capabilities not only augment the radiologist's role but also promise to reduce diagnostic errors and improve patient care.

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Beyond clinical applications, this article explores GPT-4's impact on patient engagement and education. With its ability to translate complex radiological findings into understandable language, GPT-4 can bridge the communication gap between radiologists and patients, facilitating better-informed healthcare decisions. Moreover, its application in radiology education and research can pave the way for a more interactive and personalized learning experience, fostering the next generation of radiologists and advancing radiological research.

Through a discussion on the ethical implications, data privacy concerns, and the need for human oversight, the article also underscores the importance of navigating the application of AI in radiology with caution and responsibility.

2. GPT-4: origins and development

The genesis of GPT-4 traces back to the foundational work on transformers in 2017, a novel neural network architecture that introduced self-attention mechanisms, allowing for significantly improved performance in language understanding and generation tasks [1]. Building on this, OpenAI introduced the first version of the Generative Pre-trained Transformer (GPT) in 2018, demonstrating the potential of transformers in generating coherent and contextually relevant text based on vast amounts of training data [2].

Subsequent iterations, GPT-2 and GPT-3, marked significant leaps in language model capacity and versatility, with GPT-3, released in 2020, showcasing a substantial ability to perform a wide range of language tasks from a minimal number of examples. These models were pre-trained on diverse internet text, enabling them to generate human-like text, answer questions, summarize passages, and even create content in various formats.

GPT-4 and GPT-4o the latest iterations, represent a further leap in AI capabilities. These new models further refine and expand upon the capabilities of their predecessors, offering better linguistic accuracy, nuanced understanding, and adaptability across languages and contexts. With its enhanced performance, GPT-4 has been shown to have capabilities of AI, particularly in fields requiring high levels of comprehension and synthesis, such as radiology.

LLMs have understandably gotten better at standard NLP tasks like text extraction and classification as their size and training data have grown. In addition, they have unexpectedly acquired what are known as emergent abilities—abilities not present in smaller models. To enable specific use cases, for example, classical NLP models needed to be fine-tuned on enormous data sets of labelled instances. Contrarily, LLMs exhibit strong performance upon exposure to a small number of examples—a process known as "few-shot learning." They perform well for some tasks even when given just one example (single-shot learning) or none at all (zero-shot learning). [3]

3. Potential clinical applications in radiology

3.1. Assistance to referring physicians

Ensuring that the patients are referred for the most appropriate imaging investigation is a critical first step in the radiology journey. This will increase diagnostic accuracy and decrease the number of inappropriate and unnecessary investigations, radiation exposure and healthcare costs [4]. Adherence to appropriateness guidelines and recommendations like the American College of Radiology (ACR) Appropriateness Criteria is therefore extremely important. It has been shown that an LLM connected to the ACR appropriateness criteria outperformed radiologists in applying those criteria to certain clinical situations, and at a lower cost [5]

Chat GPT can be of value in providing clinical decision support and provide recommendations regarding the most appropriate investigation for a given clinical setting [6]. The performance of GPT models is shown to be higher when specialist knowledge is incorporated to make them

appropriateness criteria context aware as compared with their generic counterparts [4].

3.2. Automated population of clinical history in a report

Better clinical histories on radiology referrals improve interpretation and diagnosis. But history provided often is incomplete or inadequate [7]. GPT-4 can collate and summarise the relevant information needed by the radiologists to issue accurate reports. It can do this by analysing data from various sources like the referral details, previous imaging reports and the EMR. It can pre-populate the clinical history section of the report with this summary for the radiologists to review prior to reporting, thereby saving a significant amount of time and effort, and potentially improving the accuracy and clinical relevance of the reports [8].

3.3. Automatic determination of the radiological investigation and protocol

GPT-4 is able to use information from the Radiology Referral Form to determine the type of radiology study, the body region to be scanned and whether contrast enhancement should be used. This task is usually undertaken by radiologists or allied health professionals and requires a high degree of knowledge and expertise [9]. Automation at this step would improve speed and efficiency and save time and resources. One study has shown an agreement between GPT-4 and the reference standard (an expert decision made by a board certified radiologist) in 84 out of 100 cases [10].

3.4. Automated structured report generation

Among the potential applications of LLMs in radiology, automated generation of structured radiology reports stands out as an important innovation. This application harnesses the advanced natural language processing (NLP) capabilities of models like GPT-4 to analyze demographic information and key imaging findings and generate reports with good readability, reasonable image findings and differential diagnoses [11]

Structured radiology reports improve understanding of the reports and enhance collaboration between healthcare professionals. They also improve data extraction for research purposes. GPT-4 is shown to be able to effectively convert free text reports into structured reports [12]

This application of LLMs can help alleviate the substantial workload that burdens radiologists. In the current healthcare landscape, radiologists face increasing pressure from growing imaging volumes, which can lead to burnout and potentially affect the quality of diagnostic processes and the accuracy of the reports [13]. By delegating the task of structuring of reports to LLMs, radiologists can focus their expertise on complex cases, interpretive nuances, and direct patient care.

The integration of LLMs into radiology reporting workflows can significantly expedite report turnaround times. The speed and efficiency of LLMs in processing and interpreting vast amounts of data can shorten the time from image acquisition to report completion. This acceleration not only improves patient throughput but also has the potential to enhance patient outcomes by facilitating quicker decision-making in clinical care.

3.5. Provision of differential diagnosis

Providing a differential diagnoses based on imaging patterns is one of the most important aspects of a radiologist's service. This usually requires referring to literature and is time consuming, especially for radiologists in training [14,15]. GPT-4 can generate relevant differential diagnoses when it is given text based imaging patterns as an input. In one study [16] 80 differential diagnoses were generated by an expert panel and GPT-4 respectively across multiple subspecialties. There was

a 68.8 % (55 out of 80) concordance between the differential diagnoses suggested by the expert panel and GPT-4 % and 93.8 % (75 of 80) of diagnoses proposed by GPT-4 were deemed as acceptable alternatives.

Fig. 1 below is an example of an immediate output from GPT-4 for a prompt asking for differential diagnoses for a solitary liver lesion.

3.6. Report summarisation

GPT-4 can be used to distil lengthy and complex radiology reports into succinct comprehensible summaries. This functionality could not only streamline the diagnostic workflow for radiologists by providing immediate access to key findings but also facilitate enhanced interdisciplinary communication, ensuring that critical diagnostic information is promptly and effectively shared among healthcare professionals. GPT-4 could also include information from previous reports or the EMR in its reports to provide better context [8,17].

Fig. 2 below is GPT-4 output when unstructured free text findings from a CT of the pancreas were provided as an input. It was asked to structure the report and provide a summary.

4. Detection of errors in radiology reports

The high radiologist workloads and unreliable speech recognition can result in errors in radiology reports which may go undetected. GPT-4 can be used as a cost-effective solution to detect and highlight these errors. Its performance is shown to be comparable with that of radiologists [18]. The use of assistive technologies such as this in improving radiology report accuracy can help radiologists focus more on clinical interpretation [19]. In a comparative study, GPT-4 showed the highest accuracy in detecting speech recognition errors in radiology errors, compared with the other advanced generative models tested in that

study [20].

4.1. Generation of patient friendly summaries

GPT-4 can interpret and convert radiology reports which contain specialized terminology and complex descriptions, into simpler language. This helps patients understand their medical condition, the findings of radiology reports, and the implications for their health. Access to understandable information empowers patients to take an active role in their healthcare decisions. This empowerment is crucial for shared decision-making. One study [21] has shown that LLMs can improve the readability and ease and decrease the mean reading level of radiology reports across all 4 major diagnostic modalities to the level of the average U.S. adult.

GPT-4 can generate patient friendly summaries in 40 different languages and for patients with different educational levels [8]. This can contribute to reducing health disparities as patients from diverse linguistic and cultural backgrounds will have better access to information.

Fig. 3 is a patient friendly summary generated by GPT-4 for the radiology report example shown in Fig. 3

4.2. Making Treatment Recommendations

GPT-4 is able to generate treatment recommendations from radiology reports. In a pilot study [22] GPT-4 generated largely accurate and clinically useful treatment recommendations for common orthopaedic conditions involving the shoulder and the knee.

4.3. Radiology education and research

GPT-4 can facilitate rapid creation of personalised and customized



ChatGPT

A solitary hypervascular lesion in the right lobe of the liver in a 25-year-old asymptomatic woman can have various differential diagnoses, ranging from benign to potentially malignant conditions. Here are five potential differential diagnoses to consider:

1. **Hepatic Hemangioma:** The most common benign liver tumor, often asymptomatic and discovered incidentally. Hypervascular on imaging, typically showing a characteristic enhancement pattern on contrast-enhanced studies.
2. **Focal Nodular Hyperplasia (FNH):** A benign liver lesion, thought to be a hyperplastic response to a vascular anomaly. It often presents as a hypervascular mass on imaging, with a central scar that may be seen in larger lesions.
3. **Hepatocellular Adenoma:** A benign tumor that can be influenced by hormonal factors and is more common in women. Some subtypes show hypervascularity. The risk of complications like hemorrhage or malignant transformation varies by subtype.
4. **Hepatocellular Carcinoma (HCC):** While less common in a young, asymptomatic woman without known risk factors, HCC can present as a hypervascular lesion. Risk factors include hepatitis B and C infections, cirrhosis, and certain genetic conditions.
5. **Metastases:** Rare in a young, asymptomatic individual without a known primary cancer, but some hypervascular metastases to the liver (e.g., from neuroendocrine tumors) can present similarly on imaging.

It's important to correlate the imaging findings with clinical data and, if necessary, further diagnostic testing, including MRI with hepatic-specific contrast agents, biopsy, or follow-up imaging, to clarify the diagnosis.

Fig. 1. Screenshot of output from GPT-4 for the prompt "Please provide 5 differential diagnoses for a solitary hypervascular lesion in the right lobe of the liver in a 25 year old asymptomatic woman.



ChatGPT

Formal Structured Report

Patient Information: [Confidential]

Clinical Information: The patient presents with acute abdominal pain with a known history of cholelithiasis. Suspected acute pancreatitis.

Examination Type: Contrast-enhanced abdominal CT scan utilizing a helical technique with both oral and IV contrast.

Findings:

- **Pancreas:** There is diffuse enlargement of the pancreas with loss of the normal lobular architecture, indicative of inflammation. There is no evidence of pancreatic necrosis, and the pancreatic duct is not dilated. Mild fluid is noted in the lesser sac and surrounding the pancreas, likely related to pancreatitis.
- **Gallbladder and Bile Ducts:** Multiple gallstones are present within the gallbladder. There is no evidence of choledocholithiasis, and the common bile duct is within normal limits in diameter.
- **Liver:** The liver is normal in size and attenuation with no focal lesions identified.
- **Other Abdominal Organs:** The kidneys, adrenals, spleen, and other abdominal organs are unremarkable without evidence of abnormality.
- **Vascular Structures:** There is no evidence of vascular occlusion or aneurysm.
- **Additional Findings:** No free peritoneal air or significant ascites is seen. Peripancreatic fat stranding is noted, consistent with inflammation. ↓

Conclusion:

The imaging findings are consistent with acute pancreatitis. There are multiple gallstones present in the gallbladder without evidence of choledocholithiasis. No complications such as pancreatic necrosis or bile duct obstruction are identified. Other examined abdominal organs and structures appear normal. ↓

Fig. 2. Screenshots of the GPT-4 output containing a structured report and a summary.

training modules and educational materials tailored to specific learning objectives, thereby enhancing the educational experience for radiologists in training. Through simulations, GPT-4 can provide a safe environment for learners to practice interpretative skills without the risk of patient harm. It can also provide interactive, live mentor like guidance.

GPT-4 offers multiple forms of assistance to radiologists in research, particularly in organizing and composing their research articles. It can provide guidance on structuring the article coherently, advise on the arrangement of sections such as the introduction, methodology, results, and discussion. In addition, it can aid in refining the article's language and presentation by recommending suitable words, grammatical constructs, and sentence formations. ChatGPT further contributes to the research article's formatting by offering advice on incorporating references, citations, and essential details. [23]. However, the integration of LLMs into the research landscape has raised serious ethical considerations. However a prudent, cautious and transparent use of LLMs in assisting manuscript creation and review process may have benefits [24]

5. Pitfalls, drawbacks, limitations and ethical considerations

As discussed in this article Large Language Models like GPT-4 have a lot of promise in transforming radiology for the better. However, none of these models are currently approved as regulated medical devices. Their

use will need close oversight, review and validation by radiologists for every use case.

A significant technical limitation for GPT-4 is the phenomenon of "hallucinations," where it generates convincing but inaccurate or fabricated information. One of the causes of hallucinations could be intrinsic bias or deficiencies in the data used for training these models [25]. The plausible sounding but inaccurate information generated by hallucinations may lead to inappropriate clinical decisions with serious adverse implications for the patients [26]

Data privacy emerges as another paramount concern, especially given the sensitive nature of medical records; ensuring GPT-4's compliance with stringent data protection regulations like HIPAA is essential to safeguard patient confidentiality. Ethical issues also abound, particularly in the realm of patient consent and the transparency of AI-driven decisions. Patients must be adequately informed about the role of AI in their care, including the potential for errors and the measures taken to mitigate such risks.

6. Conclusion

Large Language Models like GPT-4 and its successors hold promise and potential for having a significant positive impact on radiology services at almost every step, offering benefits such as improved accuracy,

What the CT Scan Shows:

- **Your Pancreas:** The scan found that your pancreas is a bit swollen and not looking as it usually does, which matches up with having pancreatitis (inflammation of the pancreas). This is what's likely causing the pain you've been feeling. Good news, though—there's no sign of serious damage to the pancreas itself.
- **Gallstones:** We spotted multiple gallstones in your gallbladder. These are small, hard deposits that can form in your gallbladder and are likely the reason behind the pancreas issue. However, none of these stones have moved into a place where they could cause a blockage.
- **Other Organs:** Everything else in your abdomen, like your liver, kidneys, and spleen, looks normal. There are no signs of any problems with your blood vessels either.
- **Fluid Around the Pancreas:** There's a bit of fluid around your pancreas, which is common when it's inflamed like this. But there's no worrying buildup of fluid or air in your abdomen.

In Simple Terms:

Your CT scan suggests that you have a condition called acute pancreatitis, mostly due to gallstones in your gallbladder. Thankfully, there are no signs of severe complications. All your other abdominal organs are looking good, which is great news.

Fig. 3. A screenshot of a patient friendly summary generated by GPT-4 for the CT scan report shown previously that showed acute pancreatitis with gall stones.

efficiency, consistency, and decision support. They could help ease the huge workload burden faced by radiologists across many parts of the world and also allow radiologists to focus more on complex interpretation tasks. However, realizing their full potential requires overcoming significant challenges related to data privacy, model bias, and clinical integration.

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Ethical statement

This review article does not involve any new studies with human or animal subjects performed by any of the authors. Therefore, no ethics committee approval was required for the preparation of this manuscript.

CRedit authorship contribution statement

Janani Baradwaj: Writing – review & editing, Validation. **Sadhana**

Kalidindi: Methodology, Conceptualization.

Declaration of Competing Interest

I, Dr. Sadhana Kalidindi, declare that I have no financial or personal relationships with other people or organizations that could inappropriately influence my work. There are no professional or other personal interests of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled "Advancing Radiology with GPT-4: Innovations in Clinical Applications, Patient Engagement, Research, and Learning." This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. All data generated or analyzed during this study are included in this published article.

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