



ChatGPT encounters multiple opportunities and challenges in neurosurgery

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Background: ChatGPT, powered by the GPT model and Transformer architecture, has demonstrated remarkable performance in the domains of medicine and healthcare, providing customized and informative responses. In our study, we investigated the potential of ChatGPT in the field of neurosurgery, focusing on its applications at the patient, neurosurgery student/resident, and neurosurgeon levels.

Method: The authors conducted inquiries with ChatGPT from the viewpoints of patients, neurosurgery students/residents, and neurosurgeons, covering a range of topics, such as disease diagnosis, treatment options, prognosis, rehabilitation, and patient care. The authors also explored concepts related to neurosurgery, including fundamental principles and clinical aspects, as well as tools and techniques to enhance the skills of neurosurgery students/residents. Additionally, the authors examined disease-specific medical interventions and the decision-making processes involved in clinical practice.

Results: The authors received individual responses from ChatGPT, but they tended to be shallow and repetitive, lacking depth and personalization. Furthermore, ChatGPT may struggle to discern a patient's emotional state, hindering the establishment of rapport and the delivery of appropriate care. The language used in the medical field is influenced by technical and cultural factors, and biases in the training data can result in skewed or inaccurate responses. Additionally, ChatGPT's limitations include the inability to conduct physical examinations or interpret diagnostic images, potentially overlooking complex details and individual nuances in each patient's case. Moreover, its absence in the surgical setting limits its practical utility.

Conclusion: Although ChatGPT is a powerful language model, it cannot substitute for the expertise and experience of trained medical professionals. It lacks the capability to perform physical examinations, make diagnoses, administer treatments, establish trust, provide emotional support, and assist in the recovery process. Moreover, the implementation of Artificial Intelligence in healthcare necessitates careful consideration of legal and ethical concerns. While recognizing the potential of ChatGPT, additional training with comprehensive data is necessary to fully maximize its capabilities.

Keywords: artificial intelligence, chatbots, ChatGPT, education, neurosurgeons, neurosurgery

Introduction

Artificial intelligence (AI) is revolutionizing myriad facets of existence, and the recently introduced chatbot “ChatGPT” has garnered substantial attention and user acclaim^[1]. Driven by a natural language processing model called ‘generative pre-trained transfer’ (GPT) and founded upon the transformer architecture, ChatGPT showcases the remarkable capability to generate human-like responses spanning a broad spectrum of inquiries and

subjects^[2]. Endowed with extensive training on an expansive corpus of textual data encompassing ~57 billion words and 175 billion parameters, ChatGPT excels across diverse domains, notably in the realms of medicine and healthcare^[3]. Its prowess stems from its adept exploitation of the wealth of knowledge and intricate language patterns derived from the training data, thereby affording responses that are tailored and enlightening^[4]. The unparalleled efficiency, scalability, and adaptability of

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ChatGPT render it a potent instrument for multifarious contexts, while its sophisticated deep learning algorithm, predicated on the transformer architecture, ensures the delivery of superlative responses to natural language queries and tasks^[5].

Neurosurgery is a demanding and intricate medical specialty that focuses on the diagnosis, treatment, and surgical management of disorders affecting the central nervous system, encompassing the brain, spinal cord, and peripheral nerves. It entails performing some of the most arduous and intricate surgical procedures. The treatment approach in neurosurgery is highly personalized, necessitating a patient-centric methodology, interdisciplinary collaboration, tailored preoperative planning, and meticulous execution and design. Within the realm of patient care, individuals can engage with a virtual assistant powered by ChatGPT to acquire comprehensive information pertaining to their condition, available treatment options, and postoperative care. This interactive platform empowers patients to make well-informed decisions regarding their treatment, leading to increased overall satisfaction with their healthcare experience. At an educational level, ChatGPT can contribute to medical education by acting as a virtual assistant for medical students. It serves as a reliable resource to address their inquiries and offer feedback on their comprehension of the fundamental principles underlying neuroanatomy. For neurosurgery residents, ChatGPT provides swift access to a wealth of information encompassing various topics related to neurosurgery, including anatomy, surgical techniques, and postoperative care. This invaluable tool aids medical students and neurosurgery residents in expanding their knowledge base and enhancing their understanding of intricate medical concepts. Furthermore, it facilitates personalized feedback, enriching the learning process. Additionally, it can be utilized to develop interactive quizzes and other educational tools, enabling students to assess their proficiency and skills^[4,6,7]. This interactive approach not only fosters effective learning but also provides immediate feedback on students' progress. Moreover, in the realm of telemedicine interventions and clinical decision-making during treatment, ChatGPT can serve as a valuable resource. It leverages established clinical guidelines and expert opinions, analyzing patient histories, imaging studies, and other pertinent data to provide recommendations. As a result, ChatGPT functions as an aiding tool, assisting neurosurgeons in selecting optimal treatment options for their patients^[8-10].

Despite the numerous merits of ChatGPT, it is imperative to recognize the existence of limitations and ethical implications. The model's propensity to generate responses that are biased or erroneous can be attributed to inherent biases present in the training data. Engaging ChatGPT for purposes such as medical diagnosis or legal counsel raises valid concerns surrounding accountability and responsibility^[9,11,12]. It is crucial to exercise caution and thoroughly contemplate these constraints and ethical considerations when employing ChatGPT in such domains. In this investigation, our objective is to delve into the prospective utilization of ChatGPT across the aforementioned strata within the realm of neurosurgery.

Methods

Ask questions to Chatgpt

Pose inquiries to ChatGPT (<https://chat.openai.com/>) employing English phrases. The inquiries are presented from the perspectives

of a patient, neurosurgery student/resident, and neurosurgeon, encompassing areas such as disease diagnosis, treatment modalities, prognosis, rehabilitation, and patient care. Furthermore, there is a quest for informative concepts, fundamental principles, and clinical knowledge pertaining to neurosurgery. The search extends to tools and methodologies that can enhance the abilities of neurosurgery students/residents, as well as medical interventions and clinical decision-making processes related to a specific ailment. The precise questions are as follows:

- (1) As a patient with acoustic neuroma, I would like to know about the surgical method and process, postoperative symptom recovery and postoperative care precautions.
- (2) Anatomical characteristics, surgical indications and surgical methods of cerebral hemispheric convex cerebral vascular malformations.
- (3) As a neurosurgery student/resident, what tools are there to help me improve and test my abilities.
- (4) For patients with paracentral lumbar disc herniation with vertebral instability, according to expert consensus and treatment guidelines, should neurosurgeons choose minimally invasive surgery or open surgery?

Answers generated by ChatGPT

As a patient with acoustic neuroma, it is important to understand the surgical method and process, as well as the postoperative symptom recovery and care precautions.

The surgical method used for acoustic neuroma is typically called "microsurgical resection." This procedure involves making a small incision behind the ear to access the tumour. Using a microscope and specialized surgical instruments, the surgeon carefully removes the tumour while preserving nearby nerves and structures. The goal of the surgery is to remove the tumour completely or as much as possible while minimizing damage to surrounding tissues.

Postoperative symptom recovery varies from person to person and depends on several factors, including the size and location of the tumour, as well as individual healing capabilities. Common postoperative symptoms may include pain, swelling, dizziness, and temporary hearing loss. It is important to note that these symptoms usually improve over time as the body heals.

Postoperative care precautions are crucial to ensure a smooth recovery. Here are some general guidelines:

Hospital stay: You will typically stay in the hospital for a few days after surgery for close monitoring and management of any potential complications.

Medications: Your doctor will prescribe pain medications and antibiotics to manage pain and prevent infection. It is important to take these medications as directed.

Head elevation: Keeping your head elevated, especially while sleeping, can help reduce swelling and promote healing.

Wound care: Proper wound care is essential. Follow your surgeon's instructions on how to keep the incision site clean and dry to prevent infection.

Physical activity: It is important to avoid strenuous activities, heavy lifting, and bending over during the initial recovery period. Gradually resume normal activities as directed by your doctor.

Follow-up appointments: Regular follow-up appointments with your surgeon will be scheduled to monitor your progress and address any concerns.

Rehabilitation: In some cases, postoperative rehabilitation, such as physical therapy or hearing rehabilitation, may be recommended to aid in recovery and optimize function.

Remember, every patient is unique, and your surgeon will provide personalized instructions based on your specific case. It is important to follow their guidance and communicate any concerns or changes in symptoms during the recovery process.

Cerebral hemispheric convex cerebral vascular malformations are abnormalities in the blood vessels located on the outer surface (convexity) of the brain hemisphere. These malformations can include arteriovenous malformations (AVMs), cavernous malformations, and dural arteriovenous fistulas. Here is an overview of their anatomical characteristics, surgical indications, and surgical methods:

Anatomical characteristics

AVMs: AVMs are tangles of abnormal blood vessels that bypass the normal capillary system, leading to direct connections between arteries and veins.

Cavernous malformations: Cavernous malformations consist of enlarged and irregularly shaped blood vessels with thin walls, resembling small “caverns.”

Dural arteriovenous fistulas: Dural arteriovenous fistulas involve abnormal connections between arteries and veins within the dura mater, the protective covering of the brain.

Surgical indications

Size and location: The decision for surgical intervention depends on the size, location, and associated symptoms of the vascular malformation. Larger malformations and those situated in critical areas of the brain may have a higher risk of causing symptoms or complications, warranting surgical treatment.

Symptomatic presentation: Surgical intervention is often considered when the malformation causes neurological symptoms, such as seizures, persistent headaches, neurological deficits, or recurrent bleeding.

Haemorrhage: If the malformation has previously bled or there is a significant risk of future bleeding, surgical treatment may be recommended.

Surgical methods

Resection: Surgical resection involves removing the vascular malformation, which may require removing a portion of the affected brain tissue. This approach is commonly used for smaller and well-localized lesions.

Embolization: Embolization is a procedure performed before surgery where a substance, such as glue or tiny particles, is injected into the abnormal blood vessels to block or reduce blood flow. This technique can be used to make the malformation more accessible or reduce bleeding risk during surgery.

Radiosurgery: In some cases, stereotactic radiosurgery may be considered as a treatment option. This non-invasive procedure uses highly focused radiation beams to target and shrink the abnormal blood vessels over time.

The choice of surgical method depends on various factors, including the size, location, and specific characteristics of the vascular malformation, as well as the expertise and preference of the neurosurgeon. It is important for the surgical approach to be tailored to the individual patient’s condition and risks, and the

decision-making process should involve thorough evaluation and discussion between the patient and the medical team.

As a neurosurgery student or resident, there are several tools available to help you improve and test your abilities. Here are some commonly utilized resources:

Medical textbooks: Comprehensive textbooks specific to neurosurgery provide in-depth knowledge and serve as valuable references. They cover a wide range of topics, including anatomy, surgical techniques, and postoperative care. Some popular neurosurgery textbooks include “Greenberg’s Handbook of Neurosurgery” and “Youmans and Winn Neurological Surgery.”

Journals and research articles: Keeping up with the latest research and advancements in neurosurgery is crucial. Subscribing to neurosurgery journals such as “Journal of Neurosurgery,” “Neurosurgery,” and “World Neurosurgery” allows you to access current research, case studies, and surgical techniques.

Surgical simulators: Virtual reality and augmented reality surgical simulators provide a realistic environment to practice surgical procedures. These simulators allow you to develop and refine your skills in a safe and controlled setting, enhancing your surgical abilities and hand-eye coordination.

Neurosurgery conferences and workshops: Attending conferences, seminars, and workshops focused on neurosurgery provides opportunities to learn from experienced neurosurgeons, gain insights into new techniques, and network with professionals in the field. These events often include hands-on workshops and presentations of the latest research.

Online learning platforms: Online learning platforms, such as NEJM Knowledge+, Medscape, and AO Surgery Reference, offer interactive modules, case studies, and quizzes to enhance your understanding of neurosurgical concepts. These platforms provide self-paced learning and may offer certifications or CME (Continuing Medical Education) credits.

Surgical observation and mentorship: Observing experienced neurosurgeons during surgeries and seeking mentorship from senior professionals in the field can be immensely valuable. This hands-on experience allows you to learn surgical techniques, understand decision-making processes, and gain practical insights.

Neurosurgery societies and organizations: Joining neurosurgery societies and organizations, such as the American Association of Neurological Surgeons (AANS) or the Congress of Neurological Surgeons (CNS), provides access to educational resources, networking opportunities, and mentorship programs.

Surgical training programs: Some institutions offer structured surgical training programs for neurosurgery students and residents. These programs combine didactic sessions, surgical simulations, and supervised clinical rotations to enhance surgical skills and knowledge.

Remember, it is important to discuss and coordinate with your program director or supervising faculty to determine the most appropriate resources and tools for your specific learning needs. They can guide you in selecting the resources that align with your training program’s requirements and objectives.

The choice between minimally invasive surgery (MIS) and open surgery for patients with paracentral lumbar disc herniation and vertebral instability depends on several factors, including the specific characteristics of the patient and the expertise of the neurosurgeon. Expert consensus and treatment guidelines can provide general recommendations, but individualized patient

assessment and clinical judgment are essential in making the final decision. It is important for neurosurgeons to carefully evaluate each patient's condition and consider the following factors:

Severity of symptoms: The severity of symptoms, such as pain, neurological deficits, and functional limitations, should be taken into account. In some cases, patients with more severe symptoms or neurological compression may benefit from open surgery, which allows for direct visualization and decompression of the affected nerve roots.

Size and location of the herniation: The size and location of the herniated disc can influence the choice of surgical approach. MIS techniques, such as microdiscectomy or endoscopic discectomy, may be suitable for smaller and more contained herniations, while larger or more complex herniations may require open surgery for better access and decompression.

Vertebral instability: The presence of vertebral instability should be thoroughly evaluated. If significant instability is detected, open surgery with stabilization techniques, such as fusion or instrumentation, may be necessary to address the instability and provide long-term stability to the spine.

Surgeon experience and expertise: The surgeon's experience and expertise in both MIS and open surgical techniques play a crucial role. A highly skilled surgeon may be able to achieve comparable outcomes with MIS while minimizing tissue disruption, reducing postoperative pain, and facilitating faster recovery.

Patient factors: Patient factors, including age, overall health, and preferences, should also be considered. MIS techniques may be favored in certain patient populations, such as elderly or frail individuals, as they are associated with reduced blood loss, shorter hospital stays, and potentially faster recovery.

It is important for neurosurgeons to discuss the available surgical options, including the benefits, risks, and expected outcomes, with their patients. Shared decision-making, based on the patient's specific condition and preferences, is essential to ensure the best possible treatment approach. Ultimately, the choice between MIS and open surgery should be individualized and made through collaborative discussions between the neurosurgeon and the patient.

Overall assessment of answers

The responses exhibited a superficial nature and displayed regenerated answers for identical questions. Additionally, ChatGPT may lack the capability to discern a patient's emotional state, a crucial aspect in establishing rapport and delivering suitable care. The language employed in the medical field is often laden with technicality and can be influenced by cultural and social factors. Should the training data employed for ChatGPT manifest bias, this could result in biased or erroneous responses. Moreover, ChatGPT's capacities are limited by its incapability to conduct physical examinations or interpret diagnostic imagery^[13,14]. Another potential constraint lies in ChatGPT's inability to capture the intricate subtleties and nuances of individual patient cases. Neuroendoscopy constitutes a profoundly specialized domain, and the intricacy and surgical approach may significantly vary across individual patient cases. While ChatGPT can offer general guidance and recommendations, it may not consistently encapsulate the distinctive aspects of each patient's case. ChatGPT's physical absence in the surgical environment constrains its utility. While it can proffer recommendations and guidance based on provided data and

information, it lacks the ability to physically manipulate or adjust implants or surgical instruments. Consequently, the surgical team must continue to rely on their own expertise and experience to effect adjustments and execute the procedure. Finally, concerns pertaining to the ethical and legal implications of employing ChatGPT in neurosurgery abound. For instance, if ChatGPT dispenses inaccurate or misleading information that leads to adverse outcomes, liability concerns may arise.

Discussion

Certainly, ChatGPT holds immense potential in the field of neurosurgery, particularly in preoperative planning, intraoperative management, and postoperative rehabilitation. However, it is crucial to exercise caution regarding the training dataset utilized by ChatGPT, its ability to comprehend technical terminology, and the ethical and legal ramifications associated with its implementation. Hence, the use of ChatGPT should be complemented by other medical tools and resources to ensure optimal surgical outcomes for patients. As a language model, ChatGPT generates responses by leveraging acquired patterns and associations from a vast corpus of text. Although ChatGPT aims to provide valuable suggestions and recommendations, it is not infallible and may occasionally furnish incorrect or misleading information. The accuracy of ChatGPT's responses hinges on several factors, including the quality and relevance of the user's input and the accuracy of the data deployed for model training. ChatGPT functions by generating responses based on learned patterns and associations, and its accuracy is contingent upon the quality of the training data it has been exposed to.

Hence, it is imperative for users to engage in a critical appraisal of the information presented by ChatGPT, substantiating its accuracy through independent research and validation from reputable sources. It is crucial to recognize that ChatGPT cannot serve as a substitute for professional medical advice or prescriptions^[8,9,11]. The scientific validation of ChatGPT's information necessitates a meticulous and systematic approach to assess its accuracy and reliability. The following measures can be undertaken to scientifically validate the information provided by ChatGPT:

- (1) **Source identification:** It is paramount to ascertain the origin of the information furnished by ChatGPT. This aids in evaluating the credibility and dependability of the information.
- (2) **Accuracy verification:** Compare the information provided by ChatGPT with other reputable sources to corroborate its accuracy. Independent research and analysis should be conducted to validate the information.
- (3) **Bias assessment:** Determine if any biases exist in the information disseminated by ChatGPT. This encompasses biases within the training data, biased language or terminology employed by ChatGPT, or any other biases that may influence the accuracy of the information.
- (4) **Evidence evaluation:** Evaluate the presence of substantial evidence supporting the information provided by ChatGPT. This assessment entails examining the quality, significance, authenticity, and consistency of the evidence.
- (5) **Expert consultation:** Seek the guidance of domain experts to verify the information furnished by ChatGPT. This

collaborative approach ensures the accuracy and reliability of the information.

By adhering to these steps, users can engage in a scientific validation process to appraise and authenticate the information presented by ChatGPT. Moreover, it is crucial to acknowledge that, at the present stage, ChatGPT responses cannot substitute human expertise and discernment. While ChatGPT can offer valuable suggestions and guidance, the surgical team must ultimately rely on their own knowledge, wisdom, experience, and judgment to make optimal decisions for their patients. The scientific validation of ChatGPT information demands a methodical and comprehensive approach to evaluating its accuracy, reliability, and credibility. By adhering to these steps, users can ascertain the accuracy and reliability of the information provided by ChatGPT.

Limitation of ChatGPT

ChatGPT possesses the potential to revolutionize the dynamics of medical information dissemination and patient communication in neurosurgery. Nevertheless, like any technological advancement, it is imperative to address the inherent limitations of ChatGPT to ensure its safe and effective integration in the field. An essential limitation lies in the accuracy and reliability of the information generated by ChatGPT. Despite its capability to mimic human speech, ChatGPT often struggles to comprehend contextual nuances or accurately interpret intricate medical details. Consequently, the information generated by ChatGPT may prove misleading or erroneous, potentially leading to misconceptions or misinterpretations of surgical procedures, techniques, and outcomes. Furthermore, the lack of transparency regarding the mechanisms by which ChatGPT generates responses exacerbates these concerns. The intricate algorithms employed by ChatGPT present challenges in comprehending and evaluating the quality and accuracy of the information generated, fostering an environment of mistrust between healthcare providers and patients. Another limitation stems from ChatGPT's restricted capacity to comprehend subtle language nuances. For instance, it may fail to discern sarcasm or irony, thereby hindering effective communication and contributing to misunderstandings. Moreover, ChatGPT's responses are based on patterns and associations derived from its training data, which encompasses a vast volume of online information^[2,15]. Consequently, the responses provided by the chatbot may lack the comprehensiveness and accuracy of those offered by qualified medical professionals. It is crucial to recognize that ChatGPT's responses are intended to offer general information and should not be utilized as a substitute for expert medical advice or diagnosis.

Consequently, the excessive enthusiasm generated through various media outlets fails to yield tangible benefits for users, including both patients and healthcare professionals. It is imperative, therefore, to meticulously assess the limitations of ChatGPT before capitalizing on its potential. Notably, post-June 2021 developments and research have not been incorporated into the ChatGPT responses, as acknowledged by OpenAI, which indicates that the model possesses "limited knowledge of the world and events after 2021." Regrettably, users lack the means to verify the information's sources as the responses lack proper citations, thus leaving room for potentially biased or popularized

representations to influence the chatbot's responses. However, ongoing updates to this chatbot and comprehensive training efforts hold promise for improved outcomes. According to several articles, ChatGPT can offer guidance and recommendations based on medical history, symptoms, and other clinical data^[15,16], thus assisting healthcare providers in formulating more accurate diagnoses and making well-informed treatment decisions.

Conclusion

ChatGPT, as a formidable language model, possesses the ability to generate responses across a wide spectrum of inquiries and subjects. While it can offer valuable suggestions and recommendations, it must be understood that it cannot supplant the invaluable experience, knowledge, and expertise of a trained physician. It is not equipped to conduct physical examinations, make diagnoses, or administer medical treatments. Consequently, medical decisions ought to be made in collaboration with qualified surgeons or physicians who can deliver personalized care and treatment tailored to an individual's unique needs and circumstances. The utilization of artificial intelligence in medical decision-making necessitates careful consideration of legal and ethical concerns, encompassing issues such as privacy, patient confidentiality, and liability in instances of errors or inaccuracies. Surgical procedures demand a broad array of skills that extend beyond the mere transmission of information. These skills entail comprehending patients' conditions and lifestyles, discerning individual requirements, establishing rapport and trust, offering motivation and solace, as well as facilitating recovery and rehabilitation. They require empathy, emotional intelligence, and interpersonal communication—attributes that currently elude ChatGPT or any other artificial intelligence technology. While we acknowledge the remarkable potential of ChatGPT, we assert that further training, incorporating comprehensive data relevant to surgery, is necessary to fully unlock its capabilities.

Ethics approval

The study protocol was approved by the Institutional Review Board.

Consent

Not applicable.

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Authorship

B.W.Z., H.Q.N., B.Y.Z., Y.R.K., and M.X.Z. contributed to the conception and design of the study. M.X.Z. and B.W.Z. contributed to drafting and revision of the manuscript. All authors read and approved the final manuscript.

Conflicts of interest disclosure

The authors declare that they have no competing interests.

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This manuscript is an editorial and does not contain any original data. Further inquiries can be directed to the corresponding author to the report results derived from research data.

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