Pakistan Journal of Neurological Sciences (PJNS)

Volume 18 | Issue 4 Article 2

12-2023

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https://doi.org/10.56310/pjns.v18i04.244

ARTIFICIAL INTELLIGENCE AND NEUROSURGERY: A REVOLUTION IN THE FIELD

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Date of submission: *April 30, 2023* ***Date of revision:*** *November 20, 2023* ***Date of acceptance:*** *December 1, 2023*

ABSTRACT

Artificial Intelligence (AI) is being used in the field of neurosurgery for improving patient outcomes, reducing the risk of complications, and increasing the efficiency of surgical procedures. AI algorithms can analyze patient data, plan surgical procedures, guide surgical instruments, monitor brain activity, and improve post-operative care. The benefits of incorporating AI into neurosurgical practice include pre-operative planning, intraoperative navigation, real-time monitoring, and post-operative care. AI is already being used in neurosurgery for image segmentation, surgical planning, intraoperative navigation, real-time monitoring, and predictive analytics. The potential applications of AI in neurosurgery include personalized medicine, virtual reality, robotic surgery, predictive analytics, and medical imaging. However, the challenges of incorporating AI into neurosurgical practice are data quality, data privacy and security, regulatory frameworks, and training and education. In short, AI has the potential to completely transform the discipline of neurosurgery, but there is a need to address the challenges associated with its incorporation into neurosurgical practice.

Keywords: Artificial Intelligence, Machine learning, Deep learning, Neurosurgery

INTRODUCTION

Artificial intelligence (AI) is revolutionizing the way we approach various fields, and healthcare is no exception. In the past few years, AI has been increasingly integrated into the field of neurosurgery for improving patient outcomes and reducing the risk of complications during surgery. Despite all the hoopla around the impending medical AI revolution, there has not been much written about the possible drawbacks of increasing clinical automation. They might include both direct and indirect effects. False results could be produced by algorithms that are weak, faulty, inadequately understood, or poorly taught. Due to over-reliance, a lack of proper comprehension, overconfidence, and a lack of necessary supervision, an increasingly computerized clinical workflow may unintentionally worsen the deskilling of human doctors.[1] Neurosurgery can benefit from AI to give the best possible results for patients. Humans and machines can work together in order to increase the quality of healthcare delivery by acquiring, processing, and interpreting images, choosing patients for the best operations, improving intraoperative work, post-operative follow-up, and making easier access to high-quality healthcare.[2] In this article, we will explore the intersection of AI and neurosurgery, the potential benefits and challenges of incorporating AI into neurosurgical practice, and some of the current as well as future applications of AI in neurosurgery.

DISCUSSION

Neurosurgery is a physically demanding field. In-depth training, endurance, physical dexterity, remarkable hand-eye coordination, an aptitude for good judgement, leadership and organizational abilities, empathy, communication skills, and the capacity for teamwork are all prerequisites for neurosurgeons.[2,3] Kwoh and associates carried out the first robotic brain surgery in 1988 coupled with the guidance of computer tomography.[2,4] Recent technical developments have reduced the gap between humans and machines, allowing computers to replicate and even surpass natural human capacity to produce so-called "artificial intelligence."[2,5]

What is Artificial Intelligence?

The term "artificial intelligence" refers to the creation of computer systems that can do activities that would normally require human intellect, such as, speech recognition, language translation, decision-making and visual perception. AI systems are created to recognise patterns in data, learn from that data, and then make decisions based on that learning.[6-8] Machine learning (ML) is a subset of AI that focuses primarily on the development of algorithms that can learn from data and get better over time without explicit programming.[6,7,9]

AI in Neurosurgery: Potential Benefits

The use of AI in neurosurgery has got the potential for improving patient outcomes, reducing the risk of complications, and increasing the efficiency of surgical procedures.[10] Some of the potential benefits of incorporating AI into neurosurgical practice are:

- **Pre-operative Planning:** AI algorithms can analyze pre-operative imaging data, such as Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans, to create 3D models of the patient's brain.[11] These models can help surgeons visualize the brain and plan the surgery more accurately, reducing the risk of complications during the procedure. Preoperative planning automation in neurosurgical patients has proven useful in detecting the epileptogenic zone and choosing the best candidates for paediatric epilepsy surgery. Preoperative planning automation makes AI usage more trustworthy in the future, since studies suggest that preoperative automation improves outcomes in neuro-oncology patients.[12]

- **Intraoperative Navigation:** During surgery, AI algorithms can be used to guide surgical instruments and help the surgeon navigate through the brain.[11] This can help reduce the risk of damage to critical brain structures and improve the accuracy of the surgery.

- **Real-time Monitoring:** AI algorithms can also be used to monitor brain activity in real-time during the surgery. This enables the surgeon to quickly identify any abnormalities in brain function and take appropriate measures.

- **Post-operative Care:** AI algorithms can analyze post-operative imaging data to track the patient's recovery and identify any complications that may arise. This can help surgeons to provide more targeted post-operative care and improve patient outcomes.[12]

- **Health-care cost:** AI is anticipated to push the boundaries of a greater number of clinical tasks performed by humans, minimise medical mistakes, and cut overall health-care costs.[1,12]

Current Applications of AI in Neurosurgery

AI is already being used in neurosurgery to improve patient outcomes and reduce the risk of complications. Here are some of the current applications of AI in neurosurgery:

- **Image Segmentation:** AI algorithms can be used to segment brain images into different regions, such as white matter and gray matter. This can help surgeons identify the location of tumors and other abnormalities more accurately.

- **Surgical Planning:** Pre-operative imaging data may be analyzed by AI algorithms to generate 3D models of the patient's brain. These models can aid surgeons in making more precise surgical plans and lowering the possibility of problems.

- **Intraoperative Navigation:** AI algorithms can be used to guide surgical instruments during the surgery. This can help reduce the risk of damage to critical brain structures and improve the accuracy of the surgery.

- **Real-time Monitoring:** AI algorithms can monitor brain activity in real-time during the surgery. This can help the surgeon detect any changes in brain function and take corrective action immediately.

- **Predictive Analytics:** AI algorithms can use patient data to foresee potential problems and identify those who could be more vulnerable to them. This can assist surgeons in providing more individualized treatment and enhancing patient outcomes.

Challenges of Incorporating AI into Neurosurgical Practice

While the potential benefits of incorporating AI into neurosurgical practice are significant, there are also several challenges that need to be addressed. Some of the challenges of incorporating AI into neurosurgical practice are:

- **Data Quality:** AI algorithms require a significant amount of high-quality data to learn from. In the case of neurosurgery, this means having access to high-quality imaging data that accurately represents the patient's brain. The more clean data the AI algorithms acquire, the more likely they are to produce clinically relevant outcomes; yet, proper data implementation is essential to train the AI algorithms.[12]

- **Data Privacy and Security:** The use of AI in healthcare raises concerns about data privacy and security. Patient data must be protected to ensure patient confidentiality and prevent data breaches. Large volumes of data are required to train AI systems and generate sequences. The patient privacy policy does not make data collection practicable, thus impeding the long-term growth of AI in neurosurgical disease management. As a result, overprotection of patient privacy might lead to less development in the long run.[12,13]

- **Regulatory Framework:** There is currently no regulatory framework in place to govern the use of AI in healthcare. This implies that precise guidelines or rules and regulations are required to guarantee the ethical

and secure application of AI.

- **Training and Education:** The use of AI in neurosurgery requires specialized training and education for surgeons and other healthcare professionals. This means that there is a need for ongoing training and education to ensure that healthcare professionals are equipped to use AI safely and effectively.[12]

- **Over-reliance:** Another issue about the use of AI in neurosurgery is that neurosurgeons may become overly reliant on the technology, preventing them from learning surgical skills and mastering methods.[5]

- Technology malfunction: Hardware and software faults are unavoidable and pose the danger of misdiagnosis if not addressed promptly.[5]

- **Transparency of data:** Transparency is another issue, since the health-care practitioner should understand the mechanics of how the machine created the data so that they can determine whether the logic is sound enough to believe. If health-care practitioners do not understand how the computer generated the result, they are less likely to incorporate it into clinical practice.[14]

- **Patient's concern:** One of the worries about the usage of AI in any industry is that it may eventually replace humans. While in neurosurgery, the outcomes should be patient-centred, and the use of AI should be balanced against the advantages and risks it might give to patients. It is difficult for a patient to trust a robot with their procedure, and it is frequently stated that a neurosurgeon has final control in the end.[15]

Future Applications of AI in Neurosurgery:
The potential applications of AI in neurosurgery are vast and continue to evolve.16 Here are some of the future applications of AI in neurosurgery:

- **Personalized Medicine:** On the basis of the patient's unique traits, personalized treatment regimens may be created using AI algorithms that analyze patient data.

- **Virtual Reality and Augmented Reality:** AI algorithms can be used to create virtual reality simulations of the patient's brain. This can help surgeons in practicing surgical procedures and developing novel techniques in a safe and controlled setting.[17,18] Virtual reality helps people understand spatial relationships and allows them to practise skills, whilst augmented reality may make operations safer and more efficient.[19,20]

- **Robotic Surgery:** AI algorithms can be integrated with robotic surgical systems to create more precise and efficient surgical procedures.[21,22] Robots can provide virtual data, greater spatial resolution and geometric precision, superior dexterity, quicker manoeuvring, and non-fatigability with consistent motion.[23,24]

- **Predictive Analytics:** Analyzing patient data using AI algorithms can help identify potential issues and predict negative outcomes. This can assist surgeons in providing more individualised treatment and enhancing patient outcomes.

- **Medical Imaging:** Medical image analysis using AI algorithms can increase the precision of medical diagnosis and treatment planning.[25,26]

- **Rehabilitation:** Dynamic implantable technology in the form of brain control interfaces (BCIs) has the potential to significantly improve rehabilitation through automated monitoring and response mechanisms. BCIs work by directly engaging with neural circuitry, algorithmically interpreting real-time cortical inputs, and allowing for increased regulated brain and spinal cord stimulation.[27,28]

CONCLUSION
The application of AI to neurosurgery has the potential to transform the discipline and enhance patient outcomes. AI algorithms may be applied to patient data analysis, surgery planning, instrument guidance, brain activity monitoring, and improved post-operative care. But there are also a number of issues that need to be resolved, including data security and privacy, regulatory frameworks, and training and education programmes. As AI continues to evolve, the potential applications in neurosurgery are vast and continue to expand. The future of neurosurgery is likely to be shaped by the integration of AI with traditional surgical techniques, resulting in safer, more efficient, and more effective surgical procedures.

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Conflict of interest: Author declares no conflict of interest.
Funding disclosure: Nil

Author's contribution:
Ahtesham Khizar; concept, literature search, manuscript writing

The author has approved the final version of the article, and agrees to be accountable for all aspects of the work.