Check for updates

Telemedicine in Neurosurgery and Artificial Intelligence Applications

Mitch R. Paro[2], William Lambert[2], Nathan K. Leclair[2], Petronella Stoltz[3], Jonathan E. Martin[1,3], David S. Hersh[1,3], Markus J. Bookland[1,3]

At the beginning of the coronavirus disease 2019 (COVID-19) pandemic, telemedicine was rapidly adopted as a substitute for in-person clinic visits across medical specialties. Since early 2020, telemedicine has been used in many neurosurgical settings globally and found to be effective,[1] to be accepted as a satisfactory means of health care delivery by patients and providers,[2] and to be cost saving for patients.[3,4] Many patients and neurosurgical providers indicate their intention to continue using telemedicine even after the pandemic subsides.[2]

Broadly speaking, telemedicine is medical care provided when the physician and the patient are physically distant from one another. This is typically done via phone or video conference and is limited only by the availability and quality of electronic devices and internet or phone service. The remote nature of telemedicine encounters calls on physicians to optimize the use of conventional and novel data sources to offset the lack of an in-person examination or the availability of ambulatory diagnostic devices. Promising early telemedicine tools include telehealth stroke triage and machine learning (ML)—augmented prognostics for neurotrauma.[5] As telemedicine becomes incorporated into mainstream neurosurgical care, the specialty will need to identify strategies suited to the unique patient populations that enhance clinical capabilities and support equitable care delivery.

A recent publication by our pediatric neurosurgery team in *Neurosurgery* highlights another example of how neurosurgery might take advantage of modern artificial intelligence (AI), image processing, and big data to deliver high-quality care at ever lower costs and with greater reach.[6] In this study, ML was employed to screen craniosynostosis in an ambulatory pediatric neurosurgery clinic and via telemedicine encounters. Orthogonal, top-down, and facial photographs of the patient's head were obtained by family members or by the clinician, depending on whether the encounter was remote or in person. These digital photographs were processed by a semiautomated image analysis software that

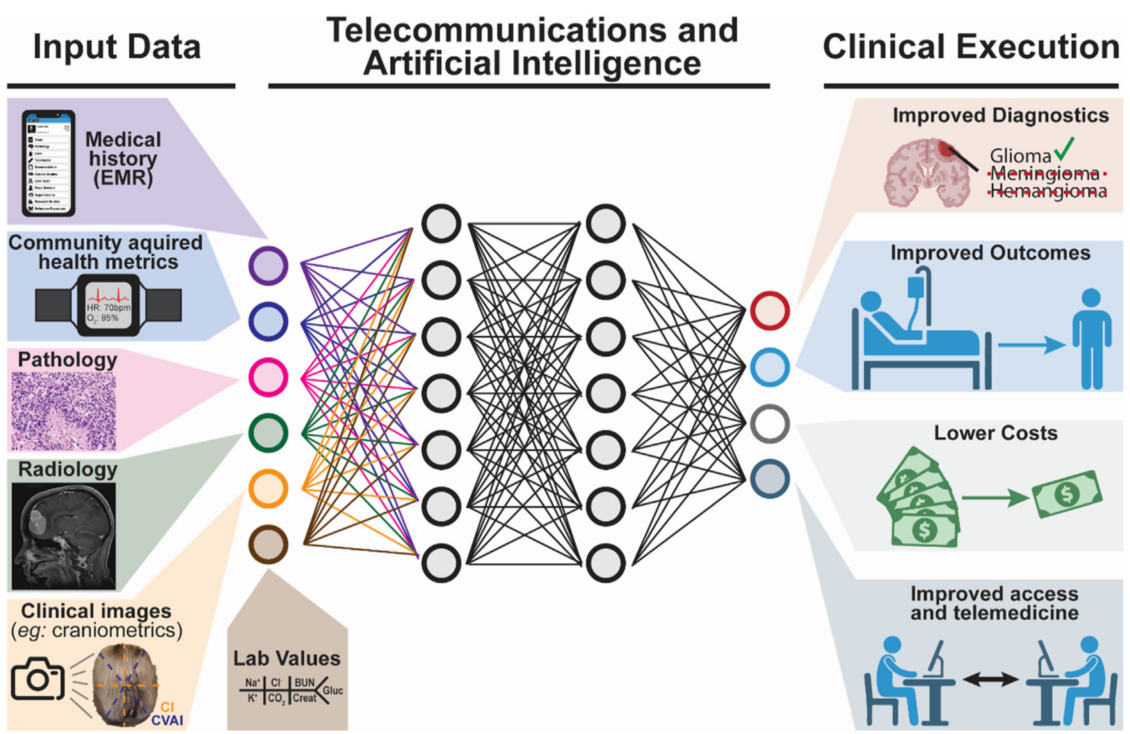

Figure 1. Integration of artificial intelligence and telemedicine can enhance outcomes in neurosurgical practice. EMR, electronic medical record; CI, cephalic index; CVAI, cranial vault asymmetry index. (Created with images adapted from BioRender.com.)

returned traditional and novel craniometric values. The measurements were then fed forward into pretrained ML algorithms, which identified common types of plagiocephaly and craniosynostosis. In this pilot study of 174 outpatients, the ability of the ML approach to distinguish craniosynostosis from benign head shape variants was compared with the provider's clinical diagnosis. The ML approach had an accuracy of 94.8% (95% CI 90.4—97.6), sensitivity of 87% (95% CI 66.4—97.2), and specificity of 96% (95% CI 91.6—98.5) in identifying craniosynostosis.

While the excellent performance of the ML model in this work is notable, it is also worth noting that this workflow can be employed at a low cost and is highly scalable in a world saturated with mobile cameras. For telemedicine patients, this approach, combined with the specialist's independent assessment of the photographs, may serve as an alternative to a hands-on physical examination as a screening method. By leveraging mobile technology and modern AI and image processing techniques, pediatric neurosurgery can expand access to screening for head shape abnormalities, facilitate early diagnosis, reduce costs of care, and minimize the burden of ambulatory appointments for families. AI-augmented telemedicine approaches such as this one may also be easily applied by nonspecialists, including primary care providers and others, to identify patients who may need referral to a surgeon. Finally, the photo-based cranial deformity metrics used to inform the ML models in this workflow have the potential to be used by surgeons to gauge response to therapeutic interventions over time, providing a cost-effective stand-in for caliper, optical scan, or radiographic metrics currently in use.[7]

This recent example of telemedicine and AI applications in the care of pediatric neurosurgery patients will not be the last. Telemedicine has become an important part of modern neurosurgery. It has the potential to increase access to neurosurgical care in remote communities, reduce access costs for patients, and extend near—specialist-level interpretation capabilities to nonspecialists (**Figure 1**); it is also limited, however, by the types of data we can gather remotely and the unequal availability of telemedicine-capable devices among different patients. It will be important for neurosurgeons to increase their familiarity with these modern telecommunication and data science tools, while always keeping an eye on equitably improving neurosurgical patient care and honestly accepting the limitations of this technology where it exists.

REFERENCES

1. Eichberg DG, Basil GW, Di L, et al. Telemedicine in neurosurgery: lessons learned from a systematic review of the literature for the COVID-19 era and beyond. *Neurosurgery*. 2020;88:E1-E12.
2. Mohanty A, Srinivasan VM, Burkhardt JK, et al. Ambulatory neurosurgery in the COVID-19 era: patient and provider satisfaction with telemedicine. *Neurosurg Focus*. 2020;49:E13.
3. Hayward K, Han SH, Simko A, James HE, Aldana PR. Socioeconomic patient benefits of a pediatric neurosurgery telemedicine clinic. *J Neurosurg Pediatr*. 2020;25:204-208.
4. Dadlani R, Mani S, A U JG, et al. The impact of telemedicine in the postoperative care of the neurosurgery patient in an outpatient clinic: a unique perspective of this valuable resource in the developing world—an experience of more than 3000 teleconsultations. *World Neurosurg*. 2014;82:270-283.
5. Warman PI, Seas A, Satyadev N, et al. Machine learning for predicting in-hospital mortality after traumatic brain injury in both high-income and low- and middle-income countries. *Neurosurgery*. 2022;90:605-612.
6. Paro M, Lambert WA, Leclair NK, et al. Machine learning-driven clinical image analysis to identify craniosynostosis: a pilot study of telemedicine and clinic patients. *Neurosurgery*. 2022;90:613-618.
7. Leclair NK, Lambert WA, Knopf J, et al. Rate of craniometric change following suture release in patients with metopic and sagittal craniosynostosis. *J Neurosurg Pediatr*. 2021;29:66-73.

From the [1]Department of Surgery, [2]UConn School of Medicine, Farmington; and [3]Division of Neurosurgery, Connecticut Children's, Hartford, Connecticut, USA

https://doi.org/10.1016/j.wneu.2022.04.078