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Neurosurgical skills analysis by machine learning models: systematic review

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Abstract

Machine learning (ML) models are being actively used in modern medicine, including neurosurgery. This study aimed to summarize the current applications of ML in the analysis and assessment of neurosurgical skills. We conducted this systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. We searched the PubMed and Google Scholar databases for eligible studies published until November 15, 2022, and used the Medical Education Research Study Quality Instrument (MERSQI) to assess the quality of the included articles. Of the 261 studies identified, we included 17 in the final analysis. Studies were most commonly related to oncological, spinal, and vascular neurosurgery using microsurgical and endoscopic techniques. Machine learning-evaluated tasks included subpial brain tumor resection, anterior cervical discectomy and fusion, hemostasis of the lacerated internal carotid artery, brain vessel dissection and suturing, glove microsuturing, lumbar hemilaminectomy, and bone drilling. The data sources included files extracted from VR simulators and microscopic and endoscopic videos. The ML application was aimed at classifying participants into several expertise levels, analysis of differences between experts and novices, surgical instrument recognition, division of operation into phases, and prediction of blood loss. In two articles, ML models were compared with those of human experts. The machines outperformed humans in all tasks. The most popular algorithms used to classify surgeons by skill level were the support vector machine and k-nearest neighbors, and their accuracy exceeded 90%. The "you only look once" detector and RetinaNet usually solved the problem of detecting surgical instruments - their accuracy was approximately 70%. The experts differed by more confident contact with tissues, higher bimanuality, smaller distance between the instrument tips, and relaxed and focused state of the mind. The average MERSQI score was 13.9 (from 18). There is growing interest in the use of ML in neurosurgical training. Most studies have focused on the evaluation of microsurgical skills in oncological neurosurgery and on the use of virtual simulators; however, other subspecialties, skills, and simulators are being investigated. Machine learning models effectively solve different neurosurgical tasks related to skill classification, object detection, and outcome prediction. Properly trained ML models outperform human efficacy. Further research on ML application in neurosurgery is needed.

Keywords: Artificial intelligence; Deep learning; Machine learning; Neurosurgery; Neurosurgical skills; Neurosurgical training.