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A review of artificial intelligence challenges in surgery

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Abstract

As opportunities for artificial intelligence to augment surgical care expand, the accompanying surge in published literature has generated both substantial enthusiasm and grave concern regarding the safety and efficacy of artificial intelligence in surgery.

Artificial intelligence (AI) is gradually changing the practice of surgery with technological advancements in imaging, navigation, and robotic intervention. Collectively, evidence suggests that artificial intelligence has the potential to augment surgeons via decision-support, technical skill assessment, and the semi-autonomous performance of tasks ranging from resource allocation to patching foregut defects, In this article, we review the challenges of AI in surgery especially for surgeons and intraoperative. Recent progress in using artificial intelligence to achieve performance advantages in surgery suggest that remaining challenges can and will be overcome.

Keywords: Artificial intellegance; AI in mddicine; AI techniques in Surgery; Surgey

1 Introduction

The term artificial intelligence (AI) was first coined by John McCarthy in his Dartmouth Summer Research Project in 1956, but the foundations for the concept date back to the famed Alan Turing(1).AI is the marriage of numerical calculations done with the aid of a computer to create a form of intelligence. Some authors like to think that AI creates simulations, again done on a computer, with three main objectives: to analyze, to understand, and to predict(2).AI involves the use of a computer to interpret a situation and/or help accomplish a task, and in short to make our lives easier and better. Two branches of AI in medicine that are often discussed are machine learning and deep learning (3). Machine learning is a field analyzing how computer algorithms and statistics can be used to autonomously improve through trial and error with pattern recognition. Deep learning, or deep structured learning, is a vaster application of machine learning concepts whose basis is centered-around the formation and utilization of artificial "learning" or "neural" networks (ALNs and ANNs) that are based on the structure of biological brains, such as being multi- layered. Natural language processing deals with pattern recognition of data that comes in unstructured formats (4). Machine learning, deep learning, and natural language processing have enormous potential to improve surgical decision making pre-operatively and post-operatively(5).

In addition to overly inflated expectations, AIS suffers from the fear that surgeons have that robotics are being developed to replace them (6)

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This fear of being replaced in the workforce is enhanced by the growing fear of the technological singularity (TS), or when AI exceeds mankind's intelligence,Although this fear seems to originate from watching one too many science fiction films(7).

2 Intraoperative and technical skill assessment

- Technical errors are a leading cause of preventable harm in surgical patients.
- Intraoperative and technical skill are variable and affect clinical outcomes(8).

AI operating rooms also use machine learning and deep learning to improve the workflow and resource utilization in the operating theatre, pre-operative area and post-anesthesia care unit(9). augmented reality (AR) can superimpose images onto structures during operations either during open or minimally invasive procedures.These AR systems are essentially guidance systems that enable the surgeon to see the tumor and its relationship to major intra-parenchymal vascular structures in real time(10).Solid organs are currently the best intra-cavitary organs to integrate with AR, similarly, the spine has also had good success with AR. Initially surgeons had to use glasses to reap the benefits of AR in spine surgery; however, this practice is cumbersome and has limited AR utilization. Because of this other systems that enhance the intra-operative placement of spinal screws has been developed that projects the image directly onto the patient, thus, eliminating the need to wear special glasses(11).In addition to improving accuracy of screw placement, this technology can reduce fluoroscopy times, which is beneficial to the patient, surgeon, and operating room staff.(12)

Today's operating theaters are characterized by a multitude of information sources. For example, preoperative image and planning data provide information about the positions of tumors and the planned course of the operation, various medical devices (e.g., a suction-irrigation system, operating light, and anesthesia monitor) provide regular status reports and intraoperative imaging devices (endoscope, ultrasound, etc.) provide data about the patient and current processes in the OR. In their entirety, these heterogeneous sensors provide the information necessary to infer the actual course of the operation and to provide proper assistance at the right time. This is subsumed under the term "context-aware assistance" (13), which avoids an information overflow and decreases the cognitive load, in particular in an already stressful and complex environment such as the OR(operative room). A prerequisite for providing such assistance is a SensorOR in which all devices are connected to collect their data.

3 Data annotations

In order for AI to learn from collected data, the original raw data has to be enriched with additional knowledge through annotation. The most common forms of annotation are classification (e.g., which organs are visible in an image), semantic segmentation (e.g., which pixels belong to which organ in an image), and numerical regression (e.g., the size of an object). The process of data annotation is often time-consuming, especially for large data sets. Annotation of surgical data requires expert knowledge, which can be expensive to muster and is often a bottleneck. In addition, only a fraction of the data is digitally available, and there are no standard acquisition and annotation protocols. The data has to be representative of the task to be learned, preferably from multiple centers and accessible in comprehensive open data registries, highlighting questions regarding privacy and confidentiality.

Several approaches to reducing the annotation effort have been proposed, such as active learning(14).A promising pathway for overcoming the lack of annotated data is to generate realistic synthetic images based on a simple simulation by using generative adversarial networks (15),To ensure a consistent vocabulary for annotation, ontologies are used. Ontologies are widely used in the medical domain – for instance, for clinical terms , for modeling surgical knowledge , to identify risks across medical processes , or for surgical processes (16).

4 Machine learning

Machine learning (ML) is a genre of artificial intelligence including algorithms that allow machines to solve problems without specific computer programing. While analyzing big data, machines are enabled to assimilate a large amount of information, applicable for risk stratification, diagnosis, treatment decisions, and survival predictions. Not only can AI models analyze large amounts of data collected over long periods of time, providing predictions for future events on the basis of the statistical weight of past correlations, they can also continuously improve with new data. Through a process called "incremental learning", trainable neural networks improve over time, surpassing unchanging scoring systems and standardized software. Moreover, the human–machine interaction further improves the performance of ML tools. Indeed, the learning process goes far beyond the textbook data, incorporating real-life scenarios and can improve experts' opinions.

Most of the studies conducted on ML tools have focused on machine vision, biomarker discovery, and clinical matching for diagnosis, classification and outcome prediction (17)

Reinforcement learning (RL) is a branch of ML that uses Markov Decision Processes (MDP), which are based on Markov chains, named after Andrey Markov, a Russian mathematician who used this framework to help predict the outcomes of random events (18). In addition to AI in medicine, it has also been applied to autonomous actions in surgery (19). Currently, most research in RL and surgery involves simulations . Due to the vast amount of data that must be analyzed, researchers first used 2-dimensional (2D) models to devise researchable RL applications. One such model involves a 2D model for teaching gynecological surgeons how to do a hysterectomy. The researchers theorized that by defining precise goals or rewards (also known as "models"), and reproducible tasks or movements mimicking a hysterectomy, that they could combine RL with surgery and develop worthwhile algorithms that could be analyzed, studied and improved (20).In a recent study, Kim et al. used reinforcement learning to facilitate accurate manipulation and navigation of surgical tools during eye surgery; in particular, they proposed a method to predict the relative goal position on the retinal surface from the current tool-tip position (21).

5 Natural Language Processing

Natural Language Processing (NLP) is the evolution of the interaction of Artificial Intelligence (AI) and linguistics. Distinct from simple text information retrieval (IR), which indexes and searches a large volume of text based on a statistical technique (22). NLP evolved from basic approaches (word to word), through a complex process of coding words, sentences, meanings and contexts, to its modern structure. Since 1950, NLP and IR converged into what is known today as NLP, namely, a computer-based algorithm that handles and elaborates natural (human) language, making it suitable for computation (23).

When applied to surgery, NPL has been extensively proposed pre-operatively and looking at different post-operative complications such as surgical site infection (SSI). Bucher et al. developed and validated a model of SSI prediction with NLP algorithm by analyzing EHRs(Electronic Health Records) from 21,000 patients entered into the ACS-NSQIP, using only text-based documents regarding history and physical condition, operative, progress and nursing notes, radiology reports and discharge summaries .This predictive model had a sensitivity of 79% and a specificity of 92% on external validation, but its added value was the absolute reliable negative predictive value (NPV), which is a relevant issue for events with a low incidence.(24).

NLP can be used to validate datasets that are the basis of surgical risk predictive models, but the main limit of their widespread use is the non-homogeneity of NLP models and EHRs data entry forms across institutions and countries.Surgeons and their low-level confidence with AI represent another limit to developing a system that is theoretically perfect and promising: it is important for them to understand how AI may impact healthcare and to elaborate strategies of safe interaction to implement this nascent technology, Lastly, ethical issues and privacy rules protecting patients' sensitive data, can limit the large-scale applicability of NLP over EHRs.

6 Conclusion

The complexity of the field of artificial intelligence surgery is highlighted by the finding that only 9.8% of medical devices undergo in-human testing within 10 years, and that involvement with an actual clinician during the development of new devices significantly improved the chances of this (25). ML(Machine learning), Deep Learning (DP), Computer Vision (CV) and possibly Natural Language Processing (NLP) will ultimately be the best path towards more autonomous actions in surgery.Surgeons must understand the basics of AI and learn to better understand its potential benefits instead of insisting on resisting innovation.Robotic surgery in its present form is a form of AIS and a necessary step towards fully autonomous actions in surgery. AIS has the potential to improve surgical outcomes, doctor-patient relationships, and job satisfaction for surgeons in all phases of surgical care.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Kolanska K, Chabbert-Buffet N, Daraï E, Antoine JM. Artificial intelligence in medicine: a matter of joy or concern? J Gynecol Obstet Hum Reprod 2020; 50:101962.

[2] Jean A. [A brief history of artificial intelligence]. Med Sci (Paris) 2020; 36:1059-67.

[3] Loftus TJ, Upchurch GR Jr, Delitto D, Rashidi P, Bihorac A. Mysteries, epistemological modesty, and artificial intelligence in surgery. Front Artif Intell 2020; 2:32.

[4] Jarvis T, Thornburg D, Rebecca AM, Teven CM. Artificial intelligence in plastic surgery: current applications, future directions, and ethical implications. Plast Reconstr Surg Glob Open 2020;8: e3200.

[5] Agrawal V, Sharma D, Yadav SK. Letter to Editor: “Artificial Intelligence, Machine Learning, Deep Learning and Big Data Analytics for Resource Optimization in Surgery”. Indian J Surg 2020; 21:1-2.

[6] Shuaib A, Arian H, Shuaib A. The increasing role of artificial intelligence in health care: will robots replace doctors in the future? Int J Gen Med 2020; 3:891-96.

[7] Technologies, E.G.o.E.i.S.a.N., Artificial Intelligence, Robotics and ‘Autonomous’ Systems. European Commission Directorate-General for Research and Innovation Unit RTD.01 - Scientific Advice Mechanism, 2018: 1-24. Available from: https://ec.europa.eu/research/ege/ pdf/ege_ai_statement_2018.pdf [Last accessed on 29 Jan 2021]

[8] GUMBS, Andrew A., et al. What is artificial intelligence surgery. Art Int Surg, 2021, 1: 1-10.

[9] Bellini V, Guzzon M, Bigliardi B, Mordonini M, Filippelli S, Bignami E. Artificial intelligence: a new tool in operating room management. Role of machine learning models in operating room optimization. J Med Syst 2019; 44:20.

[10] Phutane P, Buc E, Poirot K, et al. Preliminary trial of augmented reality performed on a laparoscopic left hepatectomy. Surg Endosc 2018; 32:514-5.

[11] Xu B, Yang Z, Jiang S, Zhou Z, Jiang B, Yin S. Design and validation of a spinal surgical navigation system based on spatial augmented reality. Spine (Phila Pa 1976) 2020;45:E1627-33.

[12] Fan N, Yuan S, Du P, et al. Design of a robot-assisted system for transforaminal percutaneous endoscopic lumbar surgeries: study protocol. J Orthop Surg Res 2020;5:479.

[13] Vercauteren T, Unberath M, Padoy N, Navab N. CAI4CAI: The Rise of Contextual Artificial Intelligence in Computer Assisted Interventions. Proc IEEE Inst Electr Electron Eng. 2020 Jan;108(1):198–214.

[14] Lecuyer G, Ragot M, Martin N, Launay L, Jannin P. Assisted phase and step annotation for surgical videos. Int J CARS. 2020 Apr;15(4):673–80.

[15] Pfeiffer M, Funke I, Robu MR, Bodenstedt S, Strenger L, Engelhardt S, et al (2019, October). Generating large labeled data sets for laparoscopic image processing tasks using unpaired image-to-image translation. In International Conference on Medical Image Computing and Computer-Assisted Intervention (pp. 119-127). Springer, Cham.

[16] Ngiam, K.Y.; Khor, I.W. Big data and machine learning algorithms for health-care delivery. Lancet Oncol. 2019, 20, e262–e273.

[17] Zhang, T.; Mo, H. Reinforcement learning for robot research: A comprehensive review and open issues. Int. J. Adv. Robot. Syst. 2021, 18, 17298814211007305. [Google Scholar] [CrossRef]

[18] Datta, S.; Li, Y.; Ruppert, M.M.; Ren, Y.; Shickel, B.; Ozrazgat-Baslanti, T.; Rashidi, P.; Bihorac, A. Reinforcement learning in surgery. Surgery 2021, 170, 329–332.

[19] Sato, M.; Koga, K.; Fujii, T.; Osuga, Y. Can Reinforcement Learning Be Applied to Surgery. In Artificial Intelligence—Emerging Trends and Applications; IntechOpen: London, UK, 2018.

[20] Kim, J.W.; Zhang, P.; Gehlbach, P.; Iordachita, I.; Kobilarov, M. Towards Autonomous Eye Surgery by Combining Deep Imitation Learning with Optimal Control. arXiv

[21] Nadkarni, P.M.; Ohno-Machado, L.; Chapman, W. Natural language processing: An introduction. J. Am. Med. Inform. Assoc. 2011, 18, 544–551.

[22] Yim, W.W.; Yetisgen, M.; Harris, W.P.; Kwan, S.W. Natural Language Processing in Oncology: A Review. JAMA Oncol. 2016, 2, 797–804.

[23] Bucher, B.T.; Shi, J.; Ferraro, J.P.; Skarda, D.E.; Samore, M.H.; Hurdle, J.F.; Gundlapalli, A.V.; Chapman, W.W.; Finlayson, S.R.G. Portable Automated Surveillance of Surgical Site Infections Using Natural Language Processing: Development and Validation. Ann. Surg. 2020, 272, 629–636.

[24] Marcus, H.J.; Payne, C.J.; Hughes-Hallett, A.; Gras, G.; Leibrandt, K.; Nandi, D.; Yang, G.Z. Making the Leap: The Translation of Innovative Surgical Devices from the Laboratory to the Operating Room. Ann. Surg. 2016, 263, 1077–1078.