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Commentary

Quantum Computing and Artificial Intelligence: Disruptive Technology with Potential Applications in Surgical Practice

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Abbreviations: AI: Artificial Intelligence; ML: Machine Learning; NNs: Neural Networks

Humans are intelligent and creative beings who are capable of generating useful tools. Among the best examples of this innate capacity are recent advances in computer technology and the development of robotic automation, and Artificial Intelligence (AI). The Oxford English Dictionary defines AI as "The capacity of computers or other machines to exhibit or simulate intelligent behaviour" [1]. This is achieved largely by Machine Learning (ML) algorithms that can identify patterns in large datasets and create instructional programs that permit computers to learn from experience.

Surgical practice has benefitted greatly from these developments. AI-based decision-support algorithms have already been incorporated into routine patient care practice. Among the most effective of these are applications that interpret visualized pattern-based information (e.g, radiographs, computed tomography and magnetic resonance images, and surgical/robotic procedures [2]). Ultimately, advanced AI will be used to identify and disentangle more complex patterns and will lead to improvements in patient diagnosis, disease prognosis, and therapeutic optimization [3,4]. However, while computers can be programmed to simulate human intelligence, they are not intuitive or innately innovative. As discussed by Sarris [5], AI is essentially the output of Neural Networks (NNs) and deep learning programs that facilitate the progressive extraction of high-level features from raw input data [6] and is not inherently different from other disruptive innovations.

Quantum computing is an emerging technology that harnesses the laws of quantum mechanics to solve problems that are too time-consuming and/or complex for classical computers. While practical large-scale quantum computers remain primarily experimental at this time, these devices will ultimately be used to solve critical problems and improve surgical outcomes. The term "quantum" refers to the behaviors of atoms and molecules and a state in which the laws of physics that we experience on a daily basis are replaced by a different and somewhat counterintuitive set of principles. The power of quantum ML algorithms relies on the properties of their unique data elements (i.e, qubits) as well as concepts that include superposition, interference, and entanglement [7-9]. While traditional bits are binary (i.e, confined to values of 0 or 1) qubits can occupy multiple states at the same time. Thus, the act of adding qubits will result in an exponential increase in the number of states that can be represented at a single moment in time. Interference patterns are used to amplify correct solutions and nullify those that are erroneous and entanglement generates connections between qubits so that their states become intrinsically intertwined with one another regardless of their spatial separation. Collectively, these properties provide quantum computers with the power to surpass their classical counterparts and permit quantum computing algorithms to accelerate ML tasks such as data clustering, feature selection, and recommendation systems. For example, quantum NNs which have applications in materials science, chemistry, drug discovery, and the development of precision surgical robotics [10,11] may enable AI to address problems that are currently difficult if not impossible to solve using classical computers.

In 2023, the Cleveland Clinic and IBM announced the installation of an onsite quantum computer that will be fully dedicated to healthcare research. Among the first projects to be addressed, researchers plan to explore ways to improve quantum-enhanced prediction models for cardiovascular risks in patients undergoing non-cardiac surgery [12]. Future surgical advances that might be accelerated by quantum computing include precision diagnostics for complex neurosurgical and orthopedic procedures, complex implantable devices, and robotics-driven surgical tools and procedures [13-16]. Of note, quantum computing poses a significant threat to classical cryptography and data security. Because they are capable of factoring large numbers at rates that are exponentially faster than those achieved by their traditional counterparts, quantum algorithms will become capable of deciphering even the most complex codes. Healthcare systems often rely on secure communication and data encryption to maintain patient privacy, among other concerns. As quantum computing becomes more prevalent, these systems will need to develop and adopt quantum-resistant cryptographic techniques to make certain that patient data remains secure.

In conclusion, while practical, large-scale quantum computers are still in the early stages of development, this technology will likely have a substantial impact on surgical practice. Several technical challenges need to be overcome, such as improving quantum error correction and increasing the number of qubits available for use. Nevertheless, researchers are actively exploring the use of quantum computing in medical research [17]. The results of these efforts are likely to have a transformative impact in many fields of medicine, notably on the tools and methods used to predict patient outcomes and perform precision surgery.

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