



# A brief history of artificial intelligence and robotic surgery in orthopedics & traumatology and future expectations

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The question of whether robots and computers will eventually replace doctors is a growing debate among physicians. Approximately 90% of knowledge from the beginning of the human history to the current era has been vastly accumulated within the past two years. The half-life of medical knowledge was 50 years in 1950s and seven years in 1980s, while it is estimated to be only 73 days in today's world and only moving downward.<sup>[1]</sup> The speed of production of new information precludes the tracking of the current knowledge in many aspects. With this constant stream of new and updated information, how can a physician provide the most optimal and up-to-date treatment?

At present, each X-ray image, physical examination finding, laboratory test result or patient data, whether normal or abnormal, are processed as data. Big data are defined as datasets which are too large or complex for traditional data process. Accurate analysis and utilization of data is of utmost importance in tailoring

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## ABSTRACT

Recently, the rate of the production and renewal of information makes it almost impossible to be updated. It is quite difficult to process and interpret large amounts of data by human beings. Unlimited memory capacities, learning abilities, artificial intelligence (AI) applications, and robotic surgery techniques cause orthopedic surgeons to be concerned about losing their jobs. The idea of AI, which was first introduced in 1956, has evolved over time by revealing deep learning and evolutionary plexus that can mimic the human neuron cell. Image processing is the leading improvement in developed algorithms. Theoretically, these algorithms appear to be quite successful in interpreting medical images and orthopedic decision support systems for preoperative evaluation. Robotic surgeons have emerged as significant competitors in carrying out the taken decisions. The first robotic applications of orthopedic surgery started in 1992 with the ROBODOC system. Applications started with hip arthroplasty continued with knee arthroplasty. Publications indicate that problems such as blood loss and infection caused by the long operation time in the early stages have been overcome in time with the help of learning systems. Comparative studies conducted with humans indicate that robots are better than humans in providing limb lengthening, patient satisfaction, and cost. As in all new technologies, the developments in both AI applications and robotics surgery indicate that technology is in favor in terms of cost/benefit analyses. Although studies indicate that new technologies are more successful than humans, the replacement of technology with experience and long-term results with traditional methods will not be observed in the near future.

**Keywords:** Artificial intelligence, decision support, robotic surgery.

and applying treatment. However, as it is impossible to process such large datasets in human brain, this interpretation of data is increasingly carried out by faster and faster processors with an increasing speed every day.

Technical developments in the field of orthopedic surgery have resulted in two main contributions: (i) the use of artificial intelligence (AI) in decision support systems for the diagnosis and treatment and (ii) the use of robotic surgery in surgical treatment.

The concept of AI was first introduced in 1956 by Prof. John McCarthy, an American computer and cognitive scientist at Dartmouth College.<sup>[2]</sup> The main principle was based on the following assertion: computers could precisely mimic cognitive functions of human beings such as learning and problem solving. Machine learning, a form of AI using computational algorithms that learn and improve with experience, is becoming popular. The AI concepts, deep learning and artificial neural networks became the cornerstones of significant achievements in image processing. These concepts stimulate neural networks of the human brain and cluster the images.<sup>[3]</sup>

The introduction of image processing through the Convolutional Neural Network (CNN) technique has made a breakthrough in the field of radiology, the most helpful branch for medical decision support mechanisms. Inter- and intra-observer reliability in the classification of fractures has been extensively debated in recent years, and computed tomography images can classify fractures with 98% sensitivity using the latest algorithms.<sup>[4]</sup> Several studies have proven the efficacy of deep learning algorithms for the interpretation of radiological images compared to human experts.<sup>[5,6]</sup> In addition, a study using a novel, fully automatic and interpretable approach to identify the design of total hip replacement from plain radiographs via deep CNN showed that CNN achieved a very high accuracy and reduced healthcare costs.<sup>[7]</sup>

Robotic systems are mainly classified into two categories: haptic and active. Haptic (surgeon-guided) systems consist of user's physical manipulations to increase the success rate of operation. Active or autonomous systems follow a complete preoperative plan and surgery is carried out without the surgeon's intervention.<sup>[8]</sup>

The ROBODOC system (Curexo Technology, Fremont, CA, USA) was the first robotic system used in orthopedic surgery in 1992. It was originally an active-autonomous, image-based, robotic system which allowed the surgeon to plan the femoral side for component implantation and to assist surgery in cementless total hip arthroplasty (THA).<sup>[9]</sup> However, the incorporation of this technology was limited due to its technical complexity, increased operative time, and insufficient versatility.<sup>[10]</sup> The CASPAR (OrthoMaquet/URS, Schwerin, Germany) was another early autonomous system. It was an image-guided, active robot used for THA and total knee arthroplasty similar to ROBODOC.<sup>[11]</sup> Operating time for these first 70 cases averaged 135 min, but decreased to approximately 90 min at the end of the study, which

was approximately equal to the control group. No major adverse events related to the CASPAR system were reported.<sup>[12]</sup>

The RIO<sup>®</sup> Robotic Arm Interactive Orthopedic System (MAKO Surgical Corp., Lauderdale, FL, USA) is a haptic robotic system that requires active participation of the surgeon and assists the surgeon in knee arthroplasty. It creates a three-dimensional model of the patient's anatomy, enabling the surgeon to develop a preoperative plan. These systems provide navigation during surgery thanks to the pins placed in the femur and tibia. The rotating burr allows the RIO robotic arm to resect bone.

On the other hand, similar to all new technologies, the initial investment cost is the leading major issue of robotic surgery. The costs of a robotic system ranges from US\$ 400,000 for a NAVIO surgical system (Smith and Nephew, Pittsburgh, PA, United States) to US\$ 700,000 for a MAKO RIO system and, for advanced da Vinci robotic surgery system (Intuitive Surgical Inc., Sunnyvale, CA, USA), costs may be as high as US\$ 2.8 million. In addition, for each procedure, the cost of consumables increases up to US\$ 2,000 and the annual maintenance fees for robots may cost US\$ 173,000.<sup>[13,14]</sup> Although these numbers appear high, it should be kept in mind that an average of 11 years of education costing a minimum of US\$ 208,000 is required for a doctor in USA.<sup>[15]</sup> In addition, robotic surgery eliminates logistic costs such as transport, re-sterilization, and storage of eight to 12 trays to be used in the operating room during conventional joint arthroplasty. As robotic surgery increases workflow and work productivity, it is cost-effective for centers practicing unicompartamental knee arthroplasty with a volume of  $\geq 94$  cases per year.<sup>[16]</sup>

As with all new techniques, serious complications were reported with the early use of robotic surgery including patellar tendon rupture, peroneal nerve injury, an increased amount of bleeding, and prolonged operation duration.<sup>[17]</sup> In recent years, infections related to prolonged operation duration have been dramatically reduced. Robotic joint arthroplasty has been shown to be associated with increased success rates, shorter preoperative plan and operation duration, more accurate alignment, correct positioning of components, shorter hospital stays, less bleeding, lower complication rates, and improved patient satisfaction than conventional methods.<sup>[18,19]</sup>

The data on the long-term results of these systems, which are reported to be quite successful in the literature recently, are rather limited. In addition, the rate of surgical robot malfunctions during surgery

has been reported to range from 0.4 to 4.6%.<sup>[20,21]</sup> For such unexpected situations, both the surgeon and traditional instruments are kept available in the operating room. Therefore, the issue of cost is still controversial. In addition, it has not been possible to respond to problems such as long preoperative preparation time, exposure of the patient to higher amounts of radiation compared to conventional radiology, and problems related to pins used to provide alignment.

Is every new technique, whether conservative or surgical, good?<sup>[22]</sup> It is not possible to say “yes” to this question. The history of medicine is full of bad experiences in this regard. Although, theoretically, AI and robots seem quite successful in performing routine works, their helplessness in the face of complications and their legal non-liability are an indication that surgeons will remain an indispensable staff in the operating theater.

The familiarity of the new-generation surgeons with technology and the increasing data flow to machine learning systems are an indication that the share of these systems in the planning and implementation of the treatment will increase in the long term, if not earlier. Artificial intelligence is expected to be used more efficiently in the surgical decision-making mechanism and to be able to eliminate risk factors and human-driven errors. It should be kept in mind that more successful results may be obtained when technological applications are used with the doctor, not against the doctor.

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