Introduction

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Artificial Intelligence and the Future of Spine Surgery

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We are currently in the midst of a data explosion unlike any other time period in human history. Continually increasing computational power, advancements in analytical methods, and widespread interest among the populace are driving technology forward at an incredible pace. At the crux of this, is our ability to leverage powerful tools to learn from, and act on the massive availability of digital data. In particular, artificial intelligence (AI) has garnered significant interest from myriad of fields, ranging from medicine and biotech to finance. While popular media often portrays AI as the sentience of machines, in reality AI represents a much broader technological goal, encapsulating numerous disciplines such as natural language processing, robotics, and computer vision. To achieve these goals, data scientists harness the power of extremely sophisticated concepts like artificial neural networks, and techniques such as machine learning. AI seeks to recreate the characteristics of human intelligence – to learn, make decisions, communicate, and adapt to changing circumstances. As humans, we possess the natural ability to subconsciously interact with our environment. We innately synthesize data acquired via different sensory perceptions to make decisions and continue to learn throughout our lives. By striving to replicate human intelligence or natural intelligence, AI attempts to create systems that can dynamically learn, and respond to different situations.

Most commonly when AI is mentioned, it is in reference to machine learning, which is the most popular and widely used technique for implementing AI. Machine learning removes the requirements of hard-coding rules for a program, instead allowing the algorithm to extract patterns within the data to make specific predictions or determinations. The algorithm is iteratively “trained” on large datasets and given free-range to discern mathematical models describing relationships within the data that may not be intuitively apparent. Machine learning is categorized into 3 primary methods: supervised, unsupervised, and reinforcement learning. By implementing such methods, our ability to detect previously undiscoverable patterns in data has the potential to revolutionize predictive analytics, with widespread implications for medical research.

Physicians have been employing similar methodologies throughout the history of medicine. When a patient comes in with a defined set of variables such as demographics, clinical history, lab results, radiographs and more, a physician quickly processes all this information internally and makes decisions based on training and experience. This is in its essence the model of learning AI seeks to recapitulate, but with the ability to analyze extraordinarily large amounts of data in its entirety (investigate all aspects of available data, without ignoring any information that could potentially be relevant). In the past few years, the number of

articles using machine learning principles for clinical research has increased dramatically. These powerful analytics have many potential applications including for medical diagnosis, prognostication and outcomes, and image processing, representing a significant improvement over simpler models such as regression analyses that have historically been used. Recent reviews evaluating the efficacy of machine learning algorithms showed that these models predicted outcomes with a median accuracy of 94.5% and an area under the curve (AUC) of 0.84, with median absolute improvement in accuracy and AUC of 15% and 0.06, respectively over equivalent logistic regression models.¹ Another study comparing the performance of machine learning tools against clinical experts in head-to-head applications remarkably showed that machine learning algorithms used for diagnosis, preoperative planning, and outcome prediction exhibited a median absolute improvement of prediction accuracy and AUC of 13% and 0.14, respectively over the clinical experts.²

One of the biggest benefits of this paradigm shift is that analytic tools can now be tailored more specifically to patients' individual needs, while previous regression models reported results as estimates across entire populations. Because machine learning algorithms are iteratively trained on previously acquired data and then applied prospectively to new data, patient-specific determinations can be made in areas like outcomes research to inform and tailor a physician's clinical practice. This is especially true in spine surgery, where many variables play a role in patient outcomes including pathology, radiographic data, medical history, and perioperative data. Currently, surgeons rely on published literature and clinical experience to discuss informed consent, complication risks, and chances of clinical benefits. This data is usually based on heterogeneous populations and does not accurately reflect a patient's specific profile. The implementation of sophisticated machine learning algorithms for spine surgery has the potential to revolutionize how surgeons approach preoperative clinic visits with patients and guide clinical decisions based on predictive models. More recently, Ames and the International Spine Study Group utilized AI to perform

unsupervised learning via hierarchical clustering to identify unique patient types with distinct risk-benefit profiles for adult spinal deformity (ASD)³, and are currently trialing the prospective use of risk calculators built from predictive models prognosticating postoperative complications.⁴ By catering outcomes analysis to a specific patient, surgeons have the power to supplement years of clinical experience and knowledge with robust mathematical estimates, augmenting their ability to counsel patients and focus more closely on the individual needs of patients.

In this special issue of *Neurospine*, we present a collection of articles highlighting recent technological advances in spine surgery that use AI as a tool to complement decision making in spine surgery. With topics ranging from the use of AI in spinal imaging, to predictive analytics for degenerative disease, spinal cord injury, spinal oncology and ASD, we hope to emphasize the amazing capabilities of advanced analytics. The early adoption of AI in spine surgery will transform our ability to care for patients on an individual level, and guide spine surgeons confidently into the age of data science.

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Title: "Reflections in Venice" 2010

Artist: Christopher Ames

Year: 2010

I was wandering the city late at night and noticed this church reflection opposed to the floating emotional masks of the carnival. Now we should all keep this amazing city close to our hearts as it is eternal beauty recovers from floods of historic proportions. (written by Christopher Ames).