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How will technology shape spinal surgery during the next decade?

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The last decade proved to be a turning point in the use of advanced technologies in spinal surgery, with developments in areas such as robotics for screw placement, computer-assisted navigation and new techniques for minimally invasive surgery all moving forward at pace. Many believe that further technological development across areas such as augmented and virtual reality, endoscopic surgery and 3D printed implants will continue to change approaches to spinal surgery throughout the course of the next 10 years. *Spinal News International* spoke to four surgeons who have led research into new technologies to ask their view on the developments that will shape the field of spinal surgery over the coming decade.

"If you look historically, 10 years ago there was this underlying sense within the spine community that was very depressed," says Isador Lieberman (Texas Back Institute, Plano, USA), who has been a pioneer in robotic-assisted spinal surgery, having helped to develop SpineAssist (Mazor) the first robotic guidance system to have been employed in spinal surgery. "We had been using pedicle screws for a long time and the biggest technological advance that we saw was the different pitch thread on the pedicle screw, or a different tool configuration. We just didn't have the excitement. Over the last five years, with the advance and the acceptance of navigation and robotics, all of a sudden, this excitement came back into the spine community."

Isador Lieberman

Lieberman comments that the spinal surgery field is currently at an "inflection point" regarding the use of automation within the operating theatre. "That is going to continue to grow and continue to be a very important component of what we do surgically," he says, looking to the near future. He sees augmented reality as the next area for major development. "That is coming and is going to be a huge advantage—a real change in what we are doing," he told *Spinal News International*. "When we marry the augmented reality to the navigation and robotics I can plan an operation, I can execute the operation, I can validate the operation, all before the patient even gets to the operating room."

Elsewhere, Lieberman says advances in implants and tool design, bone cutting equipment and soft tissue removal will also lead to improvements in patient outcomes. "There are a lot of implants and new tools that are coming out. We are getting much better with bone cutting and soft tissue removal tools, whether it is high energy lasers or ultrasound, or ultrasonic devices. When you couple that with augmented reality, with guidance and robotics, it just makes more sense. I can remove bone more precisely, less tissue damage, and it protects the collateral tissue, the nerves and blood vessels. All of those things are really, really important," he says.

Minimally invasive surgery

"If I had to say what major technological developments will have the biggest impact on spinal surgery throughout the 2020s," Avelino Parajon, head of section at neurosurgery at Hospital Universitario Ramón y Cajal (Madrid, Spain) comments, "in order of significance, I believe it will be: endoscopy; expandable technology (interbody cages); robotics and augmented reality; and big data."

Parajon, who specialises in minimally invasive surgery (MIS), says that endoscopic spinal surgery, although not new in concept, has only recently become more common practice among surgeons in Europe and the USA. "It looks like MIS surgery is moving quickly into endoscopy and this, in the very near future, will be one of the standard approaches for the spine across the world. Reasons for that are mainly the increasing interest from patients, doctors and companies in minimising the impact of the surgical approach, the great improvements in visualisation, optics and image resolution, and the development of curriculum and teaching activities for endoscopy."

Avelino Parajon

Expandable technologies, in particular interbody cages, are another area where Parajon believes advances are being made. "They have been in the market for a long time," he says, "but in recent years the improvement in their design and biomechanical properties, and the increasing interest in minimising complications and improving sagittal balance outcomes, has made them more interesting. In my opinion, the use of expandable interbody cages will be a very common practice in the next few years."

3D navigation

Parajon comments that 3D navigation has become the "standard of care" in many major healthcare centres, because of its capacity to increase accuracy of implant placements, decreased exposure to radiation, as well as advantages including better tumour resection and implant selection. "Robots seem to be the next step in this evolution," he adds. "They can improve accuracy even more and give the opportunity to explore easier positioning of patients—for example, placing screws in LLIF surgeries in a lateral position. Robotics combine 'normal' 3D navigation with robotic placement of screws." Parajon believes that the potential to integrate augmented reality systems into spinal procedures will "definitely be the next step in our spine ORs".

Finally, and "by no means least", says Parajon, the use of big data analytics is likely to have a profound impact on spinal surgery in the 2020s. "This will take a little more time to be relevant in our daily clinical practice, but probably will have more impact.

"Nowadays, surgeons are able to put screws and other implants with very high accuracy and morbidity in big spine surgeries has decreased significantly with the aid of less invasive approaches. But, our biggest challenge is still knowing the best indication for each pathology and each single patient case. Being able to study big collections of data outcomes from different groups of patients with their own characteristics treated by different approaches will probably give us the solution to some of these relevant questions."

Enrico Tessitore, deputy chairman of the Neurosurgical Unit at Geneva University Hospitals (Geneva, Switzerland), and president-elect of the Swiss Spine Society told *Spinal News International* that the continued development of robotics within the spinal field will be a hallmark of the 2020s. Further evidence of their efficacy will be crucial in advancing this push, Tessitore said. Consequently Geneva University Hospitals is one of a number of European centres to participate in the European Robotic Spinal Instrumentation (EUROSPINE) study, involving patients receiving thoracolumbar pedicle screw placement

for degenerative disease, infections or tumours. The three arms of study will consist of robot-guided (RG), navigated (NV), or freehand (FH) screw insertion to assess the performance of each. "The primary outcome is not the accuracy of the screws but the number of screws that are revised. This may have a clinical impact on patient outcome," Tessitore said. "We have already started to recruit subjects, and we are pretty convinced that we will find no revised screws in the navigation and robotics cohorts."

Enrico Tessitore

Furthermore, Tessitore comments that he sees the range of surgical applications for which robotic technologies can be employed moving beyond screw placement and into more complex procedures during the course of the next decade. He says: "I am convinced that screw insertion was the first and most common procedure addressed by companies developing robotics, but they have now successfully. Having the radiation exposure and the screw misplacement drop down to zero, this is a clear success of the technology. Nevertheless, I am not convinced that good technology should be limited to the screw insertion. Putting a screw in the lumbar pedicle, which is 10mm width is not a big problem—you probably don't need a ₹1 million device to put such a screw in.

"I would expect further developments in terms of some other steps of the spinal procedures. For example, decompression. We are not that far from having robots that will be able to drill or remove bone in the way the surgeon has planned."

3D printing

With regards to spinal implants, Tessitore describes the continued development of 3D printing as showing "great promise" particularly in promoting bone fusion. "Titanium 3D printed cages provide a peculiar geometry which optimises bone ingrowth profile, but this needs to be confirmed by further studies." He adds that his institution is taking part in a randomised study involving 3D printed interbody cages from the Swiss manufacturer Spinea. "We perform a very early SPECT-CT scan in order to see if there is an early integration of these cages. Compared to PEEK cages, for example, 3D printing technology seems to promote fusion by facilitating ingrowth of bony cells from the endplates into the cage."

Tessitore also pointed to developments in endoscopic surgery as another area for growth. He said: "There have been big developments in terms of endoscopic devices. Joimax and Richard Wolfe (RWD) are investing a lot in new endoscopes. I have been really impressed with the improvements in optics and image resolution, amelioration of working channels, and creation of dedicated instruments, like rongeurs and drills, which was not the case with the earlier generation of endoscopes."

For Nicholas Theodore, professor of neurosurgery at the Johns Hopkins University School of Medicine, and director of the Neurosurgical Spine Center of Johns Hopkins Medicine (Baltimore, USA), "the intersection of engineering and spinal surgery" is the trend he expects to see in the coming decade. Theodore is himself a pioneer in robotics in spinal surgery, having invented the Excelsius (Globus Medical) spinal surgery robot.

"Spinal surgery meets engineering"

He sees the further integration of image guidance technology, alongside robotics as having a major impact in future. "When we look at the data, it is quite clear. If you utilise screws in just freehand, your accuracy rate is about 70%. That increases to the low nineties when you start using X-ray, and the high nineties when you start utilising image guidance. We have this data, so why aren't people using it? The majority of screws that are not perfectly placed are usually harmless. If it doesn't cause harm to the patient, then we are not jumping up and down about that. Then you add robotics in and that has changed everything now," he comments. "The whole concept of utilising robotics with image guidance is that we can reliably and quickly get to a point where the robot can take us to any trajectory that would be impossible with X-ray in a very rapid and precise fashion."

Nicholas Theodore

Despite being a pioneer in the field, Theodore does not see robots replacing the role of the surgeon entirely, although he does concur that increasing applications of the technology will create a further demand for robotics in the OR. The robot is not going to replace the surgeon," he says. "It is also not going to take a bad surgeon and make them good. But, it certainly could take a good surgeon or an adequate surgeon and make them much better." On future applications for the technology, he adds: "When we start introducing drills to be able to cut bone and jig bone, that will be the next step. I will go out on a limb and say that will also be able to be planned. In other words, the robot can pick the best site to do the osteotomy, for instance for scoliosis cases. It will take you to that position, you put the drill in, or the license guided and you remove the bone yourself to do that. But in the fraction of the time that we are taking to do it freehand, for instance."

Patient safety and improving outcomes from robotic-assisted surgery

Although cost is recognised as a barrier to wider adoption of robotics in spinal surgery, Theodore argues that this should be offset by potential benefits in patient safety and outcomes. "First and foremost," he says, "it is about patient safety. Can we improve our outcomes by the use of this technology? By avoiding one misplaced screw into the spinal canal that causes a neurologic injury, the robot has paid for itself. And you also have the ability to place hardware more accurately. If you revise something intraoperatively you have already made the mistake. Prevention is better."

A robot-assisted spine surgery

Beyond robotics, 3D printing is another area that Theodore sees advancing in the spinal surgery arena. "3D printed implants," he says, "I think, are very exciting. I don't know if it is going to change the world, but it is another example of engineering and surgery where we are able to make a device with this 3D printed surface that allows bony ingrowth so that the fusion is easier than having to pack in bone, or to use chemicals like bone morphogenic protein, where you probably eliminate the usage of that through various technologies."

Theodore also believes that employing data analytics in the spine theatre will create further benefits. He details a project being undertaken at Johns Hopkins, titled Spine Cloud, that is working towards this aim. "This involves utilising imaging, patients images throughout the course of their disease process, before and after surgery. We will be utilising data from the electronic medical record and then also patient reported outcomes, to predict who is going to do well and what surgeries work and what surgeries don't." The outcome from this, Theodore says, will be the ability to specify a set of patient parameters at the beginning of a treatment process, which are input into a software programme. These parameters can then be measured against data from outcomes of previous surgeries, allowing the software programme to predict how a patient will respond to a particular procedure. Theodore concludes: "This whole ability to predict how we are going to do it all, and also inform us of what might be the best procedure for any given patient is. To me that is mindblowing."

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