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Commentary

Expanding the Scope of Robotic Spinal Surgery With Bone Decompression: Commentary on "Advancements and Challenges in Robot-Assisted Bone Processing in Neurosurgical Procedures"

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Robotics in surgery has advanced to be nearly the standard of care for some operations. It has been 2 decades since the first U.S. Food and Drug Administration approved robotically assisted system for spine surgery. And despite significant experience with robotic spine surgery systems that have been developed worldwide, their application largely has been limited to the placement of pedicle screws in the lower spine. Specifically, these robots assist in aligning instruments so that pedicle screws can be placed in a predetermined trajectory.

Though many studies have demonstrated that robotically assisted screw placement is highly accurate,[1] there is limited compelling economic evidence to justify the costs associated with these systems. As such, expanding the scope of what a spine surgery robot can do beyond screw placement has been a longstanding topic of great interest.

The obvious next step for spinal robotics is to assist in bony decompression. Since a robot can accurately deliver an end effector such as a drill to a predetermined position and since most robots can directly move an end effector through a path and/or can limit its movement to a path, combining navigation to plan areas of decompression and areas to avoid such as the canal with a spine surgery robot can be used for bone removal. Some of the biggest hurdles to this are: (1) navigation system accuracy, (2) regulatory issues, and (3) end effector reliability.

All current robots can theoretically deliver an end effector to a plan assuming that the navigation is completely accurate and reliable. However, cases of misplaced screws are increasingly reported as experience with and adoption of spine surgery robots increases.[2] A misplaced screw due to navigation errors is stressful and can result in morbidity, but imagining a drill that is not delivered accurately is simply terrifying.

Though fully autonomous bony decompression is theoretically quite plausible, this would make the robot fully responsible for the decompression. Regulatory agencies have allowed for robotic pedicle trajectory placement which the physician verifies and executes. As such, early spinal decompression will likely be limited to "co-bot" applications where the robot will assist the surgeon ideally to quickly and more easily remove bone within set limits but would still be fully supervised by the surgeon. This has already been done in joint arthroplasty.[3] Further, total robotic assisted decompression may not be possible since removing all the bone may be beyond the safety margin of the drill and, thus, would limit maximum resection. So, unlike pedicle screws that can be fully placed with robotic assistance, will decompressing 95% and having to complete the task manually be sufficient?

Finally, there is a lot of development of advanced bone removal end effectors such as a drill with more effective tips that can address skiving and/or other forces at the tip. There is also interest in oscillating drills and other technologies which may make unsupervised and nonvisualized bone work safer, especially in cases where the navigation may be off.

A very important question is, if you have an effective drill and you put it on a robot that is informed by a navigation system, do you, in fact, deliver what you plan? Though navigation may go to a closed looped system at some time to provide real time accuracy, it is more likely that bone removal will remain open loop, meaning you will not be able to verify whether the bone removal planned was actually done since the required 3-dimensional imaging is not feasible nor safe nor cost effective.

This paper attempts to address this question and is one of the first to address this important concern about the end effector.[4,5] Using a robotic arm fitted with an endoscope and a drill, the authors train a robot to drill in a linear and cylindrical path on an iliac specimen. Their setup provides a setup to measure forces acting on the end effector which could be applied to sensing bone density changes.

They also report that though the linear path results in bone removal to plan, there was a 10% under removal of bone with the cylindrical path. This is despite being given an adequate robotic training process and planning and using a commercially available drill. They postulate that perhaps tool efficiency, machining speed, bone quality, and deflection were contributing factors, but ultimately, the tip did not reach the planned limits.

The significant error margin encountered during cylindrical grinding highlights concerns about the reliability and feasibility of robotically assisted procedures requiring precise bone resection. Errors in engineering systems tend to be additive, and many factors may cause this result, but ultimately failing to deliver exactly what is planned needs to be fully understood and addressed for safe and reproducible results that will result in wider adoption and greater value of robotic spine surgery.

• **Conflict of Interest:** The author has nothing to disclose.

REFERENCES

1. Fatima N, Massaad E, Hadzipasic M, et al. Safety and accuracy of robot-assisted placement of pedicle screws compared to conventional free-hand technique: a systematic review and meta-analysis. Spine J 2021;21:181-92.
2. Kirchner GJ, Kim AH, Kwart AH, et al. Reported events associated with spine robots: an analysis of the food and drug administration's manufacturer and user facility device experience database. Global Spine J 2023;13:855-60.
3. Bayoumi T, Kleeblad LJ, Borus TA, et al. Ten-year survivorship and patient satisfaction following robotic-arm-assisted medial unicompartmental knee arthroplasty: a prospective multicenter study. J Bone Joint Surg Am 2023;105:933-42.
4. Kitahama Y, Shizuka H, Nakano Y, et al. Advancements and challenges in robot-assisted bone processing in neurosurgical procedures. Neurospine 2024;21;97-103.
5. Babbar A, Jain V, Gupta D. In vivo evaluation of machining forces, torque, and bone quality during skull bone grinding. Proc Inst Mech Eng H 2020;234:626-38.

https://doi.org/10.14245/ns.2448210.105