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Spine Surgery Image-guided Navigation: Past Developments and Future Prospects

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Introduction

Spine surgery, with its complex anatomy and critical function, has always been a highly challenging field for surgeons. The advent of image-guided navigation in spine surgery has significantly transformed the approach to spinal procedures, enhancing precision, improving patient outcomes, and reducing complications. This article explores the history, advancements, and future prospects of image-guided navigation in spine surgery. Spinal surgery typically involves procedures such as decompression, fusion, and correction of deformities. These surgeries are inherently difficult due to the intricate anatomy of the spine, the risk of nerve damage, and the requirement for high precision. Traditionally, spine surgeries were guided solely by the surgeon's visual and tactile skills, often with the help of fluoroscopy (real-time X-ray imaging) to confirm correct placement of screws, for example. However, fluoroscopy carries risks of radiation exposure to both the patient and the surgical team, and its real-time imaging is often not detailed enough to ensure optimal outcomes [1,2].

Description

The introduction of image-guided navigation systems has revolutionized spine surgery by providing high-definition, real-time 3D imaging, enabling greater precision and reducing the dependency on fluoroscopy. This technological breakthrough has allowed for improved accuracy in the placement of screws, reduced surgical time, and a lower incidence of complications such as nerve injury, infections, or implant misplacements. The development of image-guided navigation in spine surgery can be traced back to the 1990s, when early attempts were made to integrate computer-assisted technologies with conventional surgical methods. Initially, these systems were designed for simpler applications, such as guiding the placement of spinal instrumentation. The first-generation image-guided navigation systems were based on 2D fluoroscopic images combined with preoperative CT or MRI scans. These systems were primarily used to create a preoperative map of the spine, which surgeons could then refer to during the operation. The system used a combination of infrared tracking and optical sensors to detect the position of surgical instruments relative to the preoperative images. Modern image-guided navigation systems combine preoperative CT or MRI scans with intraoperative data to generate real-time 3D images of the spine. These images are displayed on monitors that show the surgeon the exact position of instruments, screws, and other implants. Surgeons can adjust the trajectory and placement of instruments dynamically during surgery, improving the accuracy of spinal procedures [3-5].

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Conclusion

Image-guided navigation in spine surgery has come a long way from its inception in the 1990s. Today, these technologies are essential in providing surgeons with real-time, precise, and fluoroscopy-free navigation, thereby improving the safety and outcomes of spinal procedures. As advancements in AI, AR, VR, and robotics continue to shape the future of spine surgery, these systems will likely become even more sophisticated, enabling more personalized treatments and improving patient care. With these innovations on the horizon, the future of spine surgery looks promising, marked by further reductions in complications, faster recovery times, and enhanced surgical precision.

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Conflict of Interest

None.

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