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CASE REPORT

Cement-augmented pedicle screw insertion assisted by spinal robotic systems for widespread spinal metastases

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Abstract
Widespread spinal metastases can obscure bone landmarks and severely hinder surgical safety during pedicle screw insertion. Robot-assisted spinal surgery has demonstrated an excellent safety profile for pedicle screw insertion. Moreover, spinal surgery robotic systems can facilitate pedicle screw insertion with high-accuracy. We present a patient who had breast cancer with widespread spinal metastases, pathological vertebral fracture, and spinal cord compression with a challenge of intraoperative image recognition. To overcome this problem, she received surgical decompression and stabilization through the insertion of cement-augmented pedicle screws with the assistance of a spinal robotic system. At the 1-year follow-up, no implant loosening was observed, and the patient exhibited notable physical improvements, demonstrating that cement-augmented pedicle screw insertion with the assistance of spinal robotic systems is an effective method for treating widespread spinal metastases.

Keywords Spine metastases · Robotic · Navigation · Cement augmentation · Pedicle screw

Introduction

Widespread spinal metastases may obscure bone landmarks and severely hinder surgical safety during pedicle screw insertion [1]. Robot-assisted spinal surgery has demonstrated an excellent safety profile for pedicle screw insertion (98.9%). Robotic systems for spinal surgery (Renaissance, Mazor Robotics, Caesarea, Israel) can facilitate pedicle screw insertion with high screw accuracy [2]. In this case report, we present a patient who had breast cancer with widespread spinal metastases, pathological vertebral fracture, and spinal cord compression with a challenge of intraoperative image recognition. To overcome the problem, she received surgical decompression and stabilization with the insertion of a cement-augmented pedicle screw assisted by a spinal robotic system. This study has been approved by the Institutional Review Board (TMU-JIRB no.: N201807046).

Case report

A 54-year-old female patient was admitted to our spine unit because of lower back pain. The patient presented with lower back pain and bilateral lower limb weakness that had persisted for 3 months as well as an increased frequency in urination and a partial loss of anal tone persisting for 3 weeks. The patient's lower limb weakness had gradually worsened. Physical examination revealed decreased muscle power, with a score of 4 out of 5 on hip flexion and knee extension on both sides of the body. Her ambulatory status was determined to be grade III because of her need for a walker. Her back pain was determined to be 75.5% on the Oswestry Disability Index because of her crippling conditions, which affected all aspects of her life. Her visual analog scale (VAS) score was 6 for her back and 7 for her leg. The Frankel grade of the patient was D, meaning preserved sensation and function. Her Tokuhashi Score was 9, signifying her a 6–12-month survival period [3].

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Regarding radiographic studies, an X-ray revealed multiple levels of pathological fractures. Computed tomography (CT) and magnetic resonance imaging showed diffuse bone metastases with T9–T12 and L3 spinal cord compression (Fig. 1). Presurgical planning included preoperative angioembolization, pulmonary function training, and nutrition supplementation. The patient was initially cachexic and had increased her weight from 36 kg to approximately 40 kg before the surgery. Furthermore, the severely osteoporotic condition of the affected bone justified the use of robotic assistance.

The surgical plan for the patient was that she first undergo decompression at the levels of T10–T12, L2–L3 laminectomy, followed by the robot-assisted percutaneous placement of cement-augmented pedicle screws (NOVA pedicle screw, Baui Spine, New Taipei City, Taiwan and Cortoss® cement, Stryker, Malvern, PA) at T8–L1 and L2–L5 to treat a curved apex at T9 and a compression fracture at L4. Fixation rods were placed at T8–L1 and L2–L5 because the length of the fixation exceeded the longest percutaneous rod available. Finally, vertebroplasties were performed at T7 and L3 to prevent adjacent failures. With the assistance of the robotic system, 11 screws were inserted; the right L2 screw, however, remained loose due to poor bone quality and was removed, and the screw placed at L5 was also removed because it did not offer any additional fixation benefit. The robotic system was in use for 2 h and 2 min, with a total surgery time of 5 h and 45 min. The total time that the fluoroscope was in use was 164 s. During segmentation and registration, a total of 14 registration trials were conducted, with a total registration time of 18 min and 48 s. The total blood loss was recorded to be 550 cc.

Immediately after the completion of the surgery, the patient was transferred to the intensive care unit, where she remained for 2 days as a result of the multiple decompression levels and length of the surgery. After her first day in the intensive care unit, the patient was in stable condition, and the endotracheal tube was removed. Postoperative care included the following: protection over the Boston brace, which she was required to wear at all times; Tamoxifen, which was administered once every day; and an injection of Denosumab, which she received every month. At the 1-year follow-up, all of the implants were sufficiently fixed, and the global alignment appeared to be well balanced on X-ray and CT scans (Fig. 2). Significant improvement was noted regarding the patient's Oswestry Disability Index (from 75.5 to 31.1%), VAS of the back (from 6 to 1), and VAS of the leg (from 7 to 0), without any analgesics being reported within 3 months after surgery. Furthermore, her Frankel grade changed to E, her ambulation status changed to V, and her wound from surgical instrumentation and decompression was fully healed.

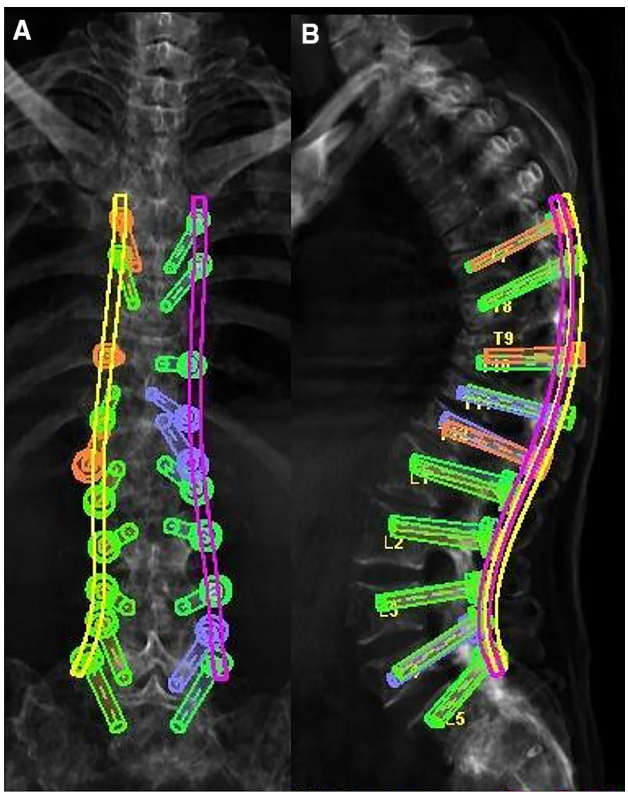

Fig. 1 Preoperative registration surgical plan from the spinal robotic system: **a** anteroposterior view; **b** lateral view

Discussion

Breast cancer metastases to bone causes interference with the progression of normal bone remodeling by promoting osteoclast activity. This leads to the release of bone-derived

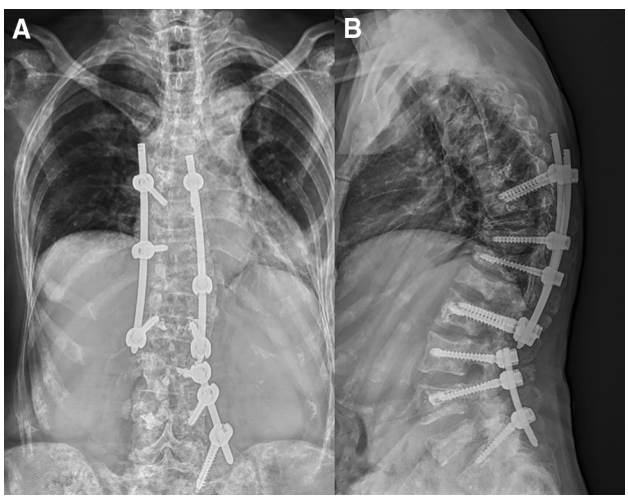

Fig. 2 X-ray image from the 12-month follow-up: **a** anteroposterior view; **b** lateral view

cytokines that promote tumor growth [1]. Bone metastases often cause the disappearance of normal bone markings, which are integral to identifying locations during spinal surgery. The bone markings in widespread metastases are distorted and cannot be identified through intraoperative fluoroscopy. Moreover, the vertebrae usually become extremely brittle, preventing multiple attempts for screw insertion; this results in the demand for a high-accuracy method of pedicle screw insertion and a decrease in the demand for intraoperative image confirmation [4].

Pedicle screw systems have been commonly employed in spinal surgery. However, screw implantation poses a monumental challenge, especially in patients with severe spinal deformities, osteoporosis, or bone metastases [5]. Many complications can occur, such as the possibility of screw misplacement causing vascular and neurological issues [2, 6]. Therefore, new methods have been developed, such as robot-assisted spinal surgery and computer-assisted navigation. Robotic-assisted pedicle screw placement is especially helpful with deformity or revision surgeries with altered or obscured spinal landmarks.

Various studies have demonstrated the advantages of using robotic guidance. A study conducted by Sukovich et al. revealed that 93% of robot-assisted spinal surgical procedures were correctly performed, with the screws in 96% of cases placed within 1 mm of their planned position [7]. Another study, conducted by Hu et al., reported a 98.9% success and accuracy rate in surgical procedures performed using robotic guidance [2]. Other surgical methods, such as fluoroscopy, navigation, cone-beam CT, intraoperative CT, and 3D printing of a surgical guiding plate, may be helpful; however, the image quality might not be adequate for safe screw placement, and the recognition of intraoperative bone landmarks may be challenging [8]. There have been new technologies developed to drastically increase the surgeon's ability to accurately perform surgical procedures in various conditions with the use of intraoperative CT scan imaging with infrared guidance technology systems or 3D printing guiding plate [9]. However, these systems have some technique pitfalls related to surgeon or patient factors including poor handling of navigation tools or inadequate soft tissue preparation. Robot-assisted spinal surgery provides a presurgical plan with highly precise execution ability to avoid above human errors during screw placement.

In minimally invasive robotics surgery there is a decrease in radiation dose due to the 56% reduction of fluoroscopy use [2, 10]. Tradition methods of spine surgery such as the use of fluoroscopy has a very high radiation dose. For this reason, spine surgeons have 50 time greater lifetime radiation dose compared to that of hip surgeons [11]. Patients who undergo robotic spinal surgery also have less pain postsurgery, faster recovery time, less blood loss due to the preservation of surrounding healthy tissue [12].

Robotic spinal surgery also has a fast learning curve. There are various studies that have shown quick learning curve. In the study done by Devito et al., the execution rate of robotically placed screw was 83.7% increased to 90.8% at their most recent procedure. The speed of the placement of the screw also decreased showing the familiarity of the surgeon with the robotic system which also benefited in the lowering of the radiation dose [13].

The insertion of cement-augmented pedicle screws with the assistance of spinal robotic systems can be performed with high levels of safety for the treatment of widespread metastatic spinal tumors.

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Compliance with ethical standards

Conflict of interest Christopher Wu, Ching-Yu Lee, Tsung-Jen Huang and Meng-Huang Wu declare that they have no conflict of interest.

Ethical approval All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

Informed consent Informed consent was obtained from all patients for being included in the study. Written informed consent was obtained from the patient for publication of this Case Report/any accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

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