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Mazor X robot-assisted upper and lower cervical pedicle screw fixation: a case report and literature review

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Abstract

Background Manual placement of cervical pedicle screws is risky, and robot-assisted placement of atlantoaxial pedicle screws has not been reported.

Case report We describe a 74-year-old female patient with atlantoaxial fracture and dislocation combined with spinal cord injury caused by a car accident. The left lower limb muscle strength was grade 0, the right upper limb muscle strength was grade 1, and the right lower limb muscle strength was grade 2. Loss of sensation below the clavicle level, decreased superficial sensation in the extremities, loss of deep sensation in the left lower extremity, and incontinence were observed. We successfully placed atlas pedicle screws with the assistance of the Mazor X robot. One week after the operation, radiological imaging revealed that the reduction effect was good, the placement of the pedicle screws was satisfactory, the left upper limb and left lower limb muscle strength was level 2, the right upper limb and the muscle strength of the right lower limb were grade 3, and the sensory function was partially restored. No complications related to screw placement were found at the 3-month postoperative follow-up.

Conclusions Mazor X robot-assisted descending pedicle screw fixation of the atlas is feasible and safe.

Keywords Atlas, Pedicle screw, Mazor X, Robot-assisted

Introduction

Pedicle screws have been widely used in internal spinal fixation because of their excellent mechanical stability. It has been reported [1] that the mechanical strength of cervical pedicle screws is 4 times greater than that of lateral mass screws. However, the atlas does not have a cone and is composed of only two lateral masses and the anterior and posterior arches. The placement through the "pedicle" refers to passing through the posterior arch and the narrow part of the posterior arch at the vertebral artery groove to the lateral mass of the atlas. Moreover, its anatomy is adjacent to important nerves and blood vessels. Traditional manual screw placement is very difficult. Punyarat et al. [2] reported that the failure rate of pedicle screw placement with the freehand technique is 23%. Moreover, screw misalignment can increase the operation time, radiation dose and blood loss, reduce mechanical stability, and even lead to neurological complications. In recent years, intraoperative imaging and robot-assisted technology have developed rapidly. Robotic systems commonly used in spinal surgery include the Renaissance Spine Assist and Mazor X. Mazor X is the most recent

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Medtronic product and has a wide range of applications because of its high accuracy, automatic navigation and positioning system. All 90 Pedicle Screws Placed for the First Time with Mazor X Achieve Gertzbein-Robbins Grade A Accuracy [3]. Owing to deviations in the relative position of the body, the patient's breathing movements and swing amplitude during nail placement may lead to failure of nail placement [4]. Robot-assisted atlantoaxial pedicle screw fixation has not been reported to date. We report the first successful case of Mazor X-assisted pedicle screw fixation for the atlantopivot and lower cervical vertebra.

Case report

A 74-year-old female patient experienced general pain and limited limb movement after a car accident. Physical examination revealed loss of sensation below the clavicle. The superficial sensation in the extremities was reduced, and the deep sensation in the left lower limb was lost. Muscle strength in the left upper limb and left lower limb was 0, muscle strength in the right upper limb was 1, and muscle strength in the right lower limb was 2. No physiological reflexes or pathological reflexes were observed. Impaired perineal sensation and incontinence. Imaging revealed a type II odontoid fracture with atlantoaxial dislocation, congenital C3–4 fusion malformations, cervical spinal cord signal abnormalities, and cervical spinal stenosis (Fig. 1). The patient was diagnosed with a type II odontoid fracture with atlantoaxial dislocation. Spinal cord injury (ASIA A). After the vital signs stabilized, the patient underwent surgery. The patient's CTA showed left-sided dominance, mild stenosis of the right vertebral artery, calcified plaque, and no high span of the vertebral artery.

After general anaesthesia, cranial traction was applied, and after turning to the prone position, approximately 2 cm on both sides of the posterior arch of the C1–5 spinous processes, vertebral plates and lateral blocks were exposed. A tracer was installed in the position of the C2–3 spinous process, and after real-time position scanning of the O-arm, an intraoperative plan was developed (Fig. 2). The working path w0as subsequently drilled under direct vision, the probe was verified, and screws 3.5*24 mm, 3.5*28 mm, 4.0*26 mm, and 8 titanium screws were subsequently placed on the left and right sides of C1-2 and C4-5, respectively (Fig. 2). The surgery lasted a total of approximately 180 min, with the robotic system being used for approximately 85 min, and the average time for nail placement was 9.6 min. The total intraoperative fluoroscopy use time was approximately 176 s, and the total blood loss volume was approximately 200 ml.

After surgery, the surgical wound healed well, the muscle strength of the left upper limb and left lower limb was Grade 2, the muscle strength of the right upper limb and right lower limb was Grade 3, and the sensory function was partially restored. Postoperative X-rays with visualization of all the pedicle screws were performed, and CT visualization of the atlantoaxial pins was precise and without deviation (Fig. 3), without any implantation-related complications. At the last follow-up, the patient had grade 2 muscle strength in the upper extremities and left lower extremity, grade 4 muscle strength in the right upper extremity and right lower extremity, complete recovery of somatosensory sensation, and an ASIA grade of C. The patient was able to maintain a good level of muscle strength in the upper extremities and left lower extremity. All screws were free of deflection and loosening. Patients are satisfied with the treatment results.

Fig. 1 Preoperative images of patients (**A**–**B**) X-ray images; (**C**) Computed tomography (CT) scan: Type II odontoid fracture combined with atlantoaxial joint dislocation and congenital C3-4 fusion deformity; (**D**) magnetic resonance imaging (MRI). Cervical spinal stenosis and cervical spinal cord signalling abnormalities

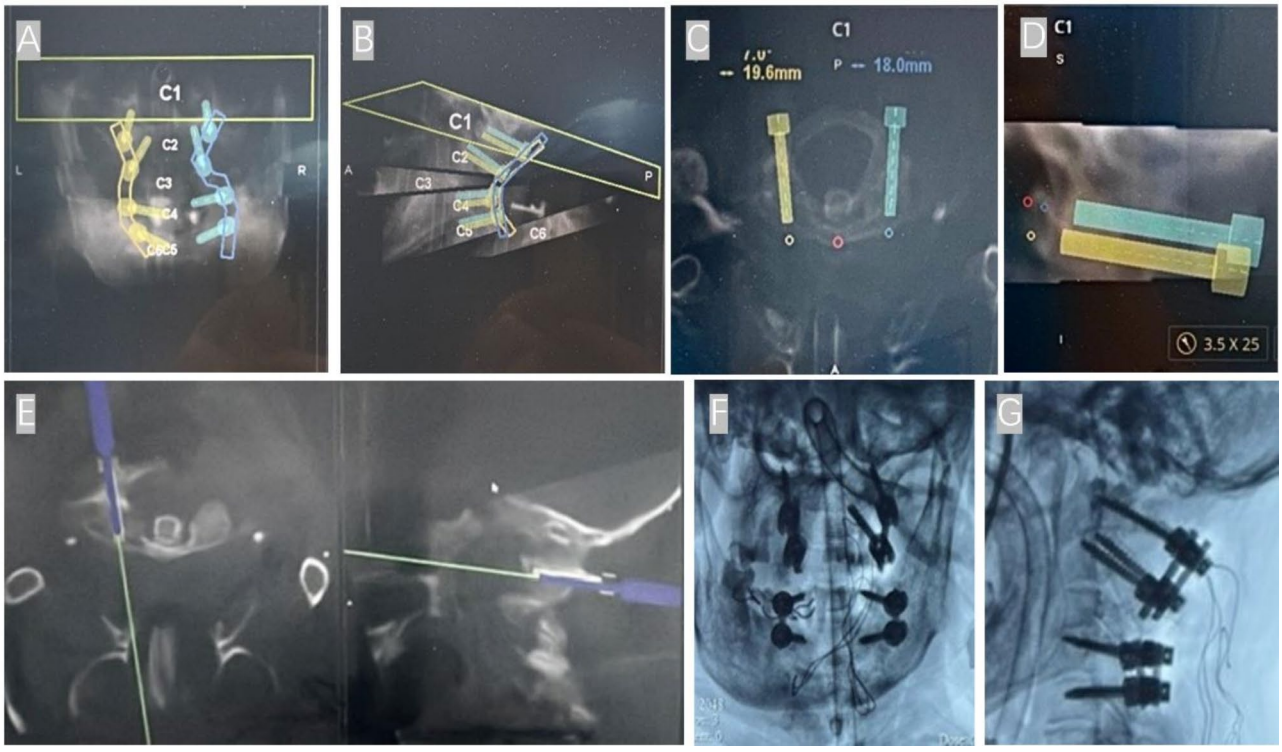

Fig. 2 (**A**–**D**) Intraoperative O-arm scanning, Mazor X for planning; (**E**) Drill the working path under direct vision, probe verification, and screw insertion; (**F**–**G**) Intraoperative X-ray images showing accurate pedicle screw placement

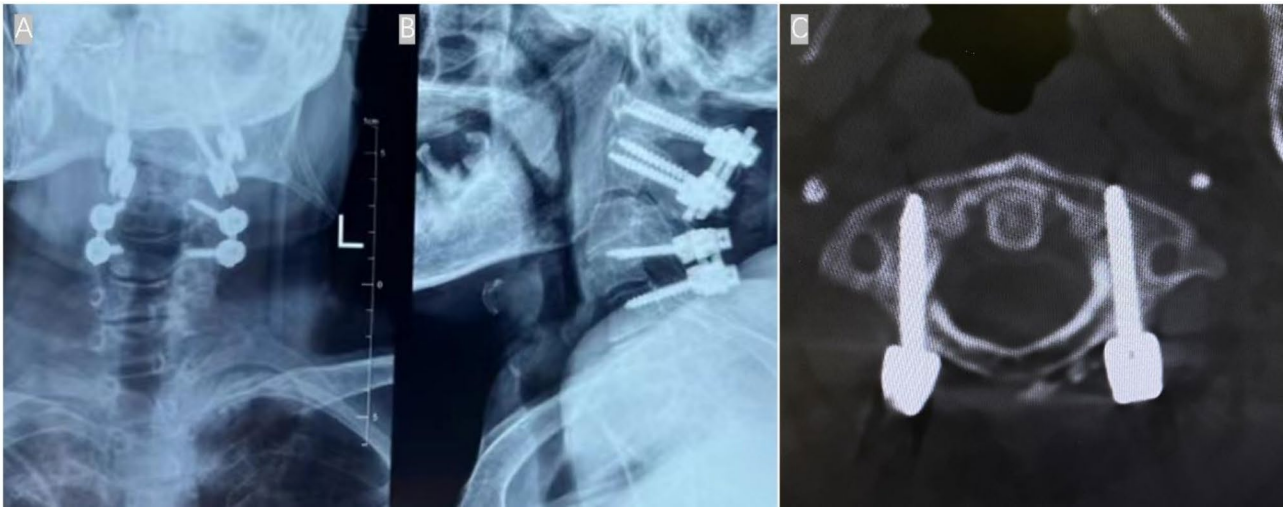

Fig. 3 Images showing that the screw position was accurate and without deviation 1 week after surgery. (**A**–**B**) X-ray images; (**C**) computed tomography (CT) scan of the atlas

Discussion

In recent years, spinal robots have been used for thoracolumbar and lower cervical spine surgical nailing, but previous-generation Mazor Renaissance robots have relied on preoperative CT scanning and surgical planning [5]. Like the Tinavi robot, the robot lacks real-time intraoperative detection [6]. However, the cervical vertebra is highly mobile. A previous study reported that after placing the screw on one side, displacement can easily lead to failure or poor placement of the screw on the other side [7]. Mazor X visualizes the patient's screw size, placement point, and trajectory through 3D rendering, which can effectively avoid damage to the spinal cord and vertebral arteries, personalize screw size and trajectory, and even handle complex and severe deformities or revision surgeries [8]. In addition, a greater degree of robot

arm flexibility and operational freedom is provided. The whole process of visualization also makes it possible to perform robot-assisted cervical screw placement.

To review this new robotic technology, we searched PubMed for articles published in the past decade on "Mazor X" and "Spine". The literature indicates that Mazor X has been extensively used for assisted placement of thoracic and lumbar pedicle screws. However, we have not yet found any reports of atlantoaxial pedicle screws being placed by the robot. This will also be the first application of Mazor X in atlas screw placement.

According to the literature review, the accuracy of Mazor X reached 97.0-100% (Table 1). Lee et al. [4] compared it with the Renaissance and found no significant difference in accuracy. However, both the breakage rate (Renaissance: 9.5% vs. X: 1.2%) and the robot abandonment rate (Renaissance: 22.7% vs. X: 2.3%) are significantly reduced, demonstrating the reliability of Mazor X. In addition, Abel et al.'s study showed that the robot abandonment rate reached 6.0%. Moreover, as the learning curve lengthened, the abandonment rate decreased.

Owing to the combination of severe SCI and lower cervical deformity in this patient, the risk of unarmed placement increased, so we attempted to place cervical pedicle screws under Mazor X assistance for the first time, and the entire procedure was performed by the surgeon with the most experience in atlantoaxial spine surgery in our hospital. The C1-2 entry point of this patient was easy to expose, and the C4-5 entry point was located outwardly, which might affect the accuracy of the placement because of the difficulty in exposing the entry points due to the large tension of the skin. This may affect the accuracy of nail placement. Therefore, we chose C1-2 for open nail placement and C4-5 for percutaneous placement. In addition, Lee et al. [10] reported that the Stealth Edition system avoids errors through intraoperative navigation, further reducing fluoroscopic radiation time, robotic abandonment, and blood loss during Mazor X use. The surgical time, intraoperative blood loss, and radiation time of freehand nail placement reported in previous studies [15] were all longer than those reported in our study. Li et al. [16] reported that 30% of patients experienced proximal articular surface invasion when pedicle screws were inserted manually. This patient had no damage to any of his adjacent facet joints. In addition, Shi et al. [17] reported that the percutaneous placement of pedicle screws can preserve muscles and ligaments. The patient's wound healed well after surgery, and no wound complications occurred.

However, Mazor X still has limitations. Zhang et al. [18] reported that severe obesity or osteoporosis may affect the accuracy of robotic nail placement in patients. Ghasem et al. [19] reported that the entry point of the nail has a greater slope and can easily slip and cause deflection. In our opinion, the robot cannot handle patients with severe cervical instability. In addition, intraoperative checking needs to be repeated by the operator, who relies on the operator's experience and intraoperative navigation. The robot needs to be more precise and detailed at the cervical level.

Conclusions

We reported the first case of Mazor X robot-assisted pedicle screw fixation of the atlas. The pedicle screws were well placed after surgery, which broadened the scope of use of Mazor X in the orthopedic field.

Table 1 Summary of Mazor X-related clinical research within the literature

Reference	Country	Total of patients	Total of screws	Accuracy rate	Robot abandonment rate
Asham Khan, 2019 [9]	USA	20	75	98.7%	0
Nathan J. Lee, 2021 [10]	USA	186	1355	99.1%	2.2%
Nathan J. Lee, 2021 [4]	USA	43	859	98.5%	2.3%
Tsutomu Akazawa, 2023 [11]	Japan	125	1048	97.8%	2.2%
Frederik Abel, 2023 [12]	USA	196	1001	97.0%	6.0%
Wenhao Zhao, 2024 [13]	China	45	200	100%	0
N. S Hernandez, 2024 [14]	USA	17	100	97.0%	0

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-024-05447-7.

Supplementary Material 1

Supplementary Material 2

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No application.

Author contributions
Zilin Gao conceived the study design and drafted the manuscript. Xiaobo Zhang and Zhengwei Xu contributed to patient management and article revision. Wei Hu contributed to language editing. Chao Jiang and Haiping Zhang contributed to the literature review. Dingjun Hao was the chief surgeon and contributed to the revision. All the authors read and approved the final version of the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Ethics approval was approved at by the Xi'an Honghui Hospital Ethics Committee (202405010).

Consent for publication
The participant agreed to participate in the research by signing the informed commitment term.

Competing interests
The authors declare no competing interests.

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References

1. Coric D, Rossi V. Percutaneous posterior cervical pedicle instrumentation (C1 to C7) with Navigation Guidance: early series of 27 cases. Global Spine J. 2022;12(2suppl):s27–33.
2. Punyarat P, Buchowski JM, Klawson BT, Peters C, Lertudomphonwanit T, Riew KD. Freehand technique for C2 pedicle and pars screw placement: is it safe? Spine J Off J North Am Spine Soc. 2018;18(7):1197–203.
3. O'Connor TE, O'Hehir MM, Khan A, Mao JZ, Levy LC, Mullin JP, Pollina J. Mazor X Stealth Robotic Technology: a technical note. World Neurosurg. 2021;145:435–42.
4. Lee NJ, Zuckerman SL, Buchanan IA, Boddapati V, Mathew J, Marciano G, Robertson D, Lakomkin N, Park PJ, Leung E, et al. Is there a difference in Screw Accuracy, Robot Time per Screw, Robot Abandonment, and Radiation exposure between the Mazor X and the Renaissance? A propensity-matched analysis of 1179 Robot-assisted screws. Global Spine J. 2023;13(5):1286–92.
5. Huang M, Tetreault TA, Vaishnav A, York PJ, Staub BN. The current state of navigation in robotic spine surgery. Annals Translational Med. 2021;9(1):86.
6. Zhang RJ, Zhou LP, Zhang L, Zhang HQ, Zhang JX, Shen CL. Safety and risk factors of TINAVI robot-assisted percutaneous pedicle screw placement in spinal surgery. J Orthop Surg Res. 2022;17(1):379.
7. Li S, Du J, Huang Y, Hao D, Zhao Z, Chang Z, Zhu J, Wang X, Duan Y, He B. Comparison of the efficacies of TINAVI robot-assisted surgery and conventional open surgery for Levine-Edward type IIA (postreduction) hangman fractures. Sci Rep. 2023;13(1):15934.
8. Lieberman IH, Kisinde S, Hesselbacher S. Robotic-assisted pedicle screw Placement during spine surgery. JBJS Essent Surg Techniques. 2020;10(2):e0020.
9. Khan A, Meyers JE, Siasios I, Pollina J. Next-generation robotic spine surgery: first report on feasibility, safety, and learning curve. Operative Neurosurg (Hagerstown Md). 2019;17(1):61–9.
10. Lee NJ, Zuckerman SL, Buchanan IA, Boddapati V, Mathew J, Leung E, Park PJ, Pham MH, Buchholz AL, Khan A, et al. Is there a difference between navigated and non-navigated robot cohorts in robot-assisted spine surgery? A multicenter, propensity-matched analysis of 2,800 screws and 372 patients. Spine J Off J North Am Spine Soc. 2021;21(9):1504–12.
11. Akazawa T, Torii Y, Ueno J, Umehara T, Iinuma M, Yoshida A, Tomochika K, Ohtori S, Niki H. Safety of robotic-assisted screw placement for spine surgery: experience from the initial 125 cases. J Orthop Sci Off J Japanese Orthop Assoc. 2024;29(4):933–8.
12. Abel F, Avrumova F, Goldman SN, Abjornson C, Lebl DR. Robotic-navigated assistance in spine surgery. Bone Joint J. 2023;105–b(5):543–550.
13. Zhao W, Wang Y, Zhang H, Guo J, Han J, Lin A, Zhou C, Ma X. Analysis of the Screw Accuracy and Postoperative Efficacy of Screw Placement in single position and bipedal position in Robot-assisted oblique lumbar Interbody Fusion: preliminary results of Mazor X Stealth usage. Orthop Surg. 2024;16(2):401–11.
14. Hernandez NS, Diaz-Aguilar LD, Pham MH. Single position L5-S1 lateral ALIF with simultaneous robotic posterior fixation is safe and improves regional alignment and lordosis distribution index. Eur Spine J Off Publ Eur Spine Soc Eur Spinal Deformity Soc Eur Sect Cerv Spine Res Soc. 2024;33(9):3583–92.
15. Su XJ, Lv ZD, Chen Z, Wang K, Zhu C, Chen H, Han YC, Song QX, Lao LF, Zhang YH, et al. Comparison of Accuracy and Clinical outcomes of Robot-assisted Versus Fluoroscopy-guided Pedicle Screw Placement in posterior cervical surgery. Global Spine J. 2022;12(4):620–6.
16. Li HM, Zhang RJ, Shen CL. Accuracy of pedicle screw placement and clinical outcomes of robot-assisted technique versus conventional freehand technique in spine surgery from nine randomized controlled trials: a meta-analysis. Spine. 2020;45(2):E111–9.
17. Shi L, Deng R, Long QY, Chu L, Yu KX, Xu Z, Deng ZL. Endoscopically-assisted percutaneous unilateral atlantoaxial screw-rod nonfusion fixation treatment for type II odontoid fractures in geriatric patients: case series and technical note. Pain Physician. 2020;23(2):E241–50.
18. Zhang Q, Fan MX, Han XG, Liu YJ, He D, Liu B, Tian W. Risk factors of unsatisfactory Robot-assisted Pedicle Screw Placement: a case-control study. Neurospine. 2021;18(4):839–44.
19. Ghasem A, Sharma A, Greif DN, Alam M, Maaieh MA. The arrival of robotics in spine surgery: a review of the literature. Spine. 2018;43(23):1670–7.

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