Case Report

# MAZOR-X robotic-navigated percutaneous C2 screw placement for hangman's fracture: a case report

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**Abstract:** Robotic-navigated screw placement has potential for higher precision and accuracy. Robotic assistance is well-described in the lumbar spine, however only few studies have evaluated its use in the cervical spine. Surgical treatment for hangman's fractures after nonunion typically involves C2-3 anterior fusion or posterior occipito-cervical fusion. However, occipito-cervical fusion involves loss of mobility in the cervical spine with associated morbidity. We have previously described a minimally invasive approach using percutaneous screw fixation with X-ray navigation. Robotic assistance is ideally suited for cervical fusion given smaller bony anatomy and adjacent critical structures. We describe a young healthy patient who presented with a hangman's fracture initially managed conservatively with immobilization. She presented with nonunion and persistent symptoms. Surgical options considered included anterior cervical discectomy and fusion, or posterior cervical fusion with or without extension to the occiput. These options would have involved some loss of flexion/extension and rotational motion with associated morbidity. We performed percutaneous screw fixation of the hangman's fracture using MAZOR-X robotic navigation and achieved good radiographic fracture reduction with accurate screw placement. To our knowledge this is the first case of a robotic-assisted percutaneous screw fixation for a hangman's fracture. Robotic-navigated screw placement can be used safely and accurately for cervical spine fractures.

**Keywords:** Hangman's fracture; robotic assistance; percutaneous screws; case report

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## Introduction

Hangman's fractures are defined by fractures through the lamina, articular facets, pedicles and/or pars of C2 (1). The Levine-Edwards classification of hangman's fractures (2) identifies Type I and adequately reduced type II as stable fractures amenable to non-operative treatment with a rigid collar or halo immobilization. Cases that fail non-operative treatment, or select type II, type IIa and type III fractures usually require surgical fusion. Surgical management options for hangman's fractures include C2-3 anterior cervical discectomy and fusion, or C1-2 or C1-3 posterior cervical fusion with or without extension to the occiput (3-5). Each of these surgical options involves some loss of flexion/extension and rotational motion with its associated morbidity. Direct C2 transpedicular fixation has been used to overcome these shortcomings (6), however, variable anatomy, risk of neurovascular injury and motion associated with an unstable fracture limit this approach. Buchholz *et al.* demonstrated a minimally-invasive percutaneous direct screw fixation using O-arm neuronaviation as a novel motion-preserving and physiologic operation with shorter operative times, faster recovery, decreased blood loss and decreased muscle disruption (1).

Robotic-assisted spine surgery using the MAZOR-X system (Mazor Robotics Ltd., Caesarea, Israel) was FDA approved in 2004 and has the potential to decrease radiation

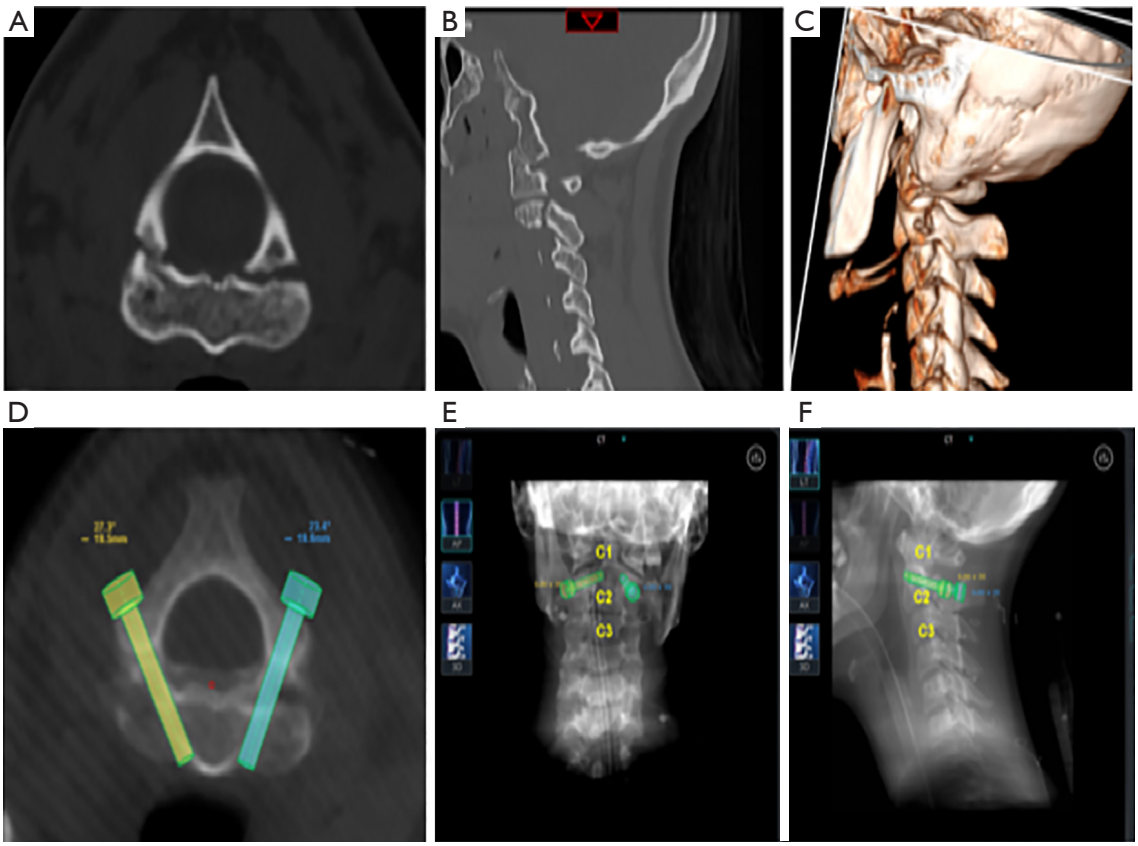


**Figure 1** CT imaging of a patient with Levine-Edwards Type II hangman's fracture of C2. (A) Axial CT showing bilateral pars defects; (B) sagittal CT through the left pars; (C) 3D reconstruction of the occiput and upper cervical spine showing partially displaced bone fragment; (D-F) axial, coronal and sagittal reconstructions using the MAZOR-X software to specify C2 lag screws including screw size and trajectory.

exposure and operative time while increasing accuracy (7,8). The robotic platform includes an operative planning module which uses a high-resolution pre-operative CT scan. Surgical screws can be specified for each level, and 3-dimentional renderings can be used to visualize and specify screw dimensions, insertion points and trajectories. Critical structures can thus be avoided, and ideal screw sizes and trajectories chosen to improve safety and accuracy. Two recent retrospective studies compared MAZOR-X to O-arm neuronavigation for spine surgery and respectively found improved precision and accuracy (9), and decreased fluoroscopy time, time-per-screw placement and patient length of stay (10). Robotic assistance is gaining wider applicability, however, its use in the cervical spine is still limited. Here we report the first case to our knowledge of MAZOR-X navigated percutaneous placement of C2 screws for a hangman's fracture.

We present the following case in accordance with the CARE reporting checklist (available at https://dx.doi.org/10.21037/jss-20-676).

## Case presentation

A 27-year-old female with no pertinent past medical history presented after an ATV accident with a Levine-Edwards type II hangman's fracture. All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient. She was treated non-operatively for 3 months in a rigid Aspen Vista cervical collar, however she continued to have significant neck pain despite conservative management. She developed upper extremity paresthesias which were described as tingling down the right triceps, dorsal forearm and 4$^{th}$ and 5$^{th}$ digits. A CT cervical spine at 3 months showed non-union and

increased distance between bony fragments at the fracture site (*Figure 1A-1C*). She also had motion of the pars fracture on cervical flexion and extension X-rays. Having tried and failed non-operative management she was indicated for surgery.

Pre-operatively high-resolution 3D CT scans were obtained, and screw trajectories were planned using the MAZOR-X software (*Figure 1D-1F*). Bilateral 5 mm lag screws were used (Synthes). The patient was placed in a Mayfield head frame in the prone position on an open Jackson surgical table. Intraoperative fluoroscopic images were used to register the anatomy to preoperative CT. Once accuracy and plan were confirmed, the MAZOR-X robotic arm was sent into position.

Using the robotic arm as a guide, transverse 1cm incisions were made bilaterally 3 cm lateral from midline at approximately the C3 level. We then docked the drill guide onto the pars surface and confirmed position with intraoperative fluoroscopy. Once docked we drilled across the fracture site using a Stryker cordless high-speed drill (*Figure 2A*). We again visualized this with intraoperative fluoroscopy to verify no movement of the fracture site. A K-wire was then placed down the trajectory across the fracture site (*Figure 2B*). A tap was inserted over the K-wire and we tapped across the fracture site. As a final step our lag screw was placed over the K-wire using fluoroscopy to confirm good position of instrumentation across the fracture site (*Figure 2C*).

The operative setup allowed for robotic arm placement as well as X-ray confirmation (*Figure 2D*). We performed an intraoperative O arm spin to confirm good position of instrumentation and confirmed bilateral screw placement and reduction of fracture. Incisions were closed with Dermabond. Post-operative X-rays confirmed proper screw placement and fracture reduction (*Figure 2E*). The patient recovered well post-operatively with resolution of her right-sided paresthesias. She was discharged home on post-operative day 1. The patient was seen at a 6 month follow up from surgery. She reported no neck pain or paresthesias and has normal range of motion. She has returned to work and is pleased with her care.

## Discussion

Owing to variable spine anatomy particularly after trauma, direct placement of C2 pars or pedicle screws is technically challenging (11-13). C2 pars and pedicle screw fixation have been described for Hangman's fractures (11,13). Open transpedicular screw fixation yields excellent anatomical and functional results with motion preservation in patients with Levine-Edwards Type II fractures (14), and appears to be safer and more cost effective than C2-3 anterior plating.

Percutaneous transpedicular screw fixation has also been described using preoperative imaging for planning and intraoperative fluoroscopy for verification of anatomic locations and screw position (15). Postoperative CT imaging showed 17 of 20 screws (85%) were placed satisfactorily and 3 of 20 screws (15%) showed a perforation of the pedicle wall (<2 mm), but all screws otherwise showed proper alignment with solid fusion and patients reported being asymptomatic from cortical breach (15).

Buchholz *et al*. reported the first series of direct, percutaneous, minimally invasive, CT-based-neuro-navigation-assisted repair of Hangman's fractures (1). The percutaneous technique was as safe and effective as the open procedures previously reported, without the pedicle wall perforation rate of 15% reported in the percutaneous approach taken by Wu *et al.* (15). In this report we showed for the first time robotic-assisted percutaneous minimally invasive repair of a Hangman's fracture.

Current robotic platforms include Renaissance (Medtronic), SpineAssist (Medtronic), ROSA Spine (Zimmer Biomet), Excelcius GPS (Globus) and MAZOR-X (Medtronic). Detailed technical notes on the MAZOR-X method have been recently published (16). Briefly, the robotic software suite calculates the most efficient and safest screw trajectories. After planning and registration, the robotic effector arm is sent sequentially to pre-determined screw entry points and provides a targeted docking arm through which cannulas and instruments are placed along pre-planned trajectories for accurate screw placement (10,16).

Despite its higher upfront costs and technical requirements, robotic-assisted spine surgery is gaining traction due to its increased accuracy and shorter operative times. In the cervical spine, accurate screw placement is imperative due to smaller bony structures and increased risk of vascular and visceral injuries. A recent prospective randomized controlled study of robotic-assisted versus traditional fluoroscopic-guided screw placement in the cervical spine found higher accuracy, decreased blood loss and shorter hospital stay despite similar operative times (17), demonstrating a clear clinical advantage to using this strategy.

In our case, robotic assistance provided a minimally invasive surgical option to treat the fracture and preserve

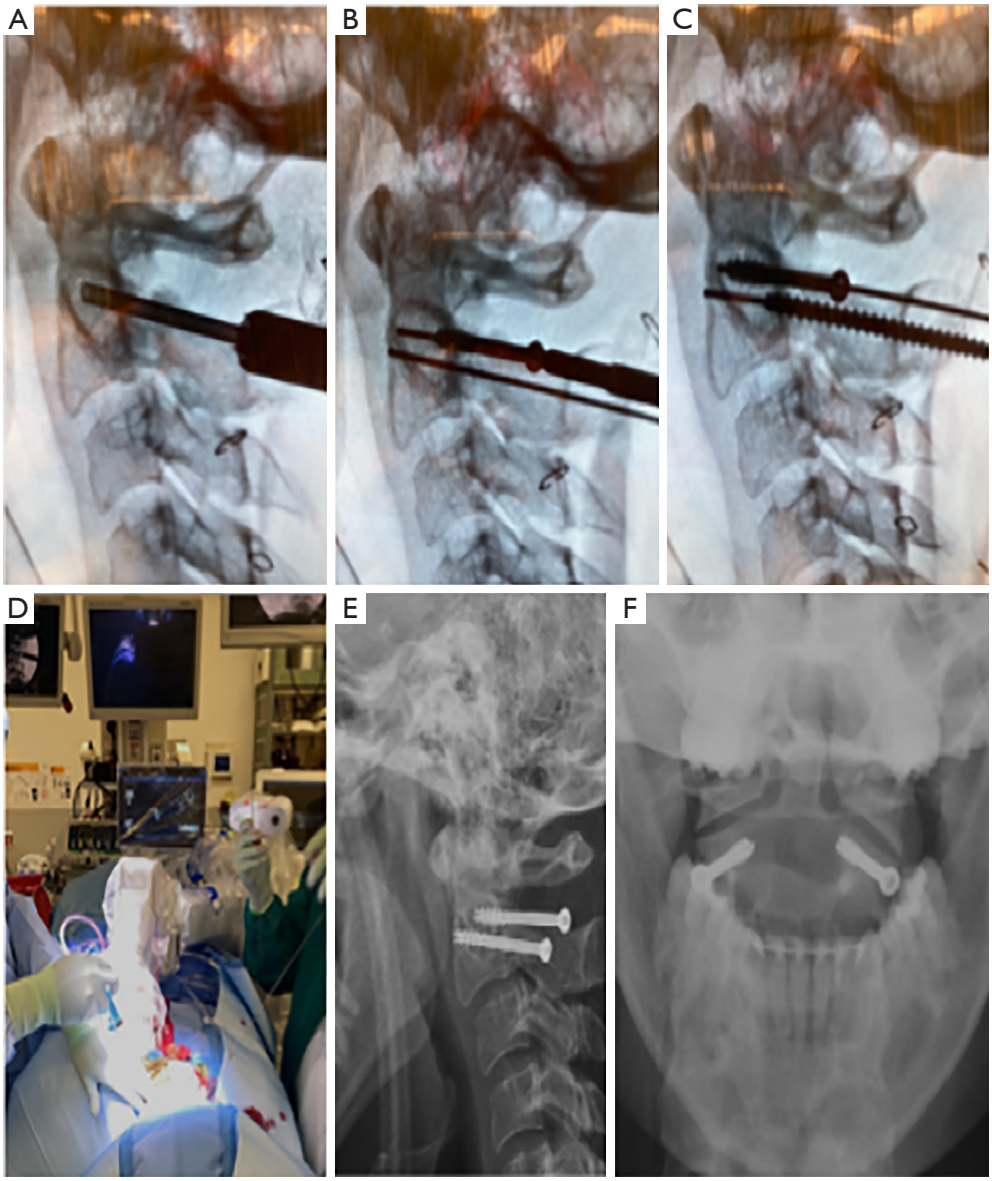


**Figure 2** Intraoperative and postoperative images. (A) Insertion of operating cylinder after drilling using the MAZOR-X robotic arm. (B) K-wires were inserted through the operating cylinder. The first screw was tapped, and the lag screw is shown being placed over the K-wire. (C) With the first lag screw in place, the second is shown being tapped over the K-wire. (D) Operating room setup with C-arm in place and robotic arm being used to place K wires at the lag screw sites. (E,F) Post-operative lateral and open-mouth X-rays confirming adequate screw placement and fracture reduction.

motion in a young active patient. Placement of C2 percutaneous pars screws, a technically challenging surgery, was aided by robotic assistance. This surgical description is not meant as a recommendation of treatment for Hangman fractures but rather presents a possible option in the appropriate patient. Further work is needed to refine indications and establish protocols for robotic assistance in the cervical spine.

## Conclusions

We describe the first case of MAZOR-X robotic-assisted percutaneous screw placement for stabilization of a Levine-Edwards Type II C2 hangman's fracture with good

radiographic fracture reduction. Robotic-assisted surgery for upper cervical injuries has potential for significant clinical impact in spine surgery.

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## Footnote

*Reporting Checklist:* The authors have completed the CARE reporting checklist. Available at https://dx.doi.org/10.21037/jss-20-676

*Conflicts of Interest*: Both authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/jss-20-676). The authors have no conflicts of interest to declare.

*Ethical Statement*: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors confirm they have no conflicts of interest. All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient.



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