Robot-assisted Anterior Odontoid Screw for the Treatment of Type Ⅱ Odontoid Fractures: Safety and Effectiveness Analysis

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Research Article

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Abstract

Background: Anterior odontoid screw fixation is considered to be preferred surgical treatment for the type Ⅱ odontoid fractures. However, due to the high difficulty to insert odontoid screw with barehand, the high risk of screw misalignment and damage to surrounding important tissue structures, we urgently need robot-assisted screw insert navigation technology to improve the safety and accuracy of inserting odontoid screws.

Methods: We retrospectively analyzed 7 patients with type II odontoid fractures who underwent Tinavi robot-assisted screw insert technology from May 2018 to May 2019 at our hospital. All patients had received 64-row CT scans and 3D reconstructions completed preoperatively, and magnetic resonance (MRI) were performed to verify the severity of odontoid fractures, soft tissue injuries and vertebral artery height. Postoperative CT was repeated in 6 months after surgery to evaluate cervical stability and confirm whether the screw had breached the bone cortex, the accuracy of screw placement based on Rampersaud A-D grade. Functional recovery was assessed using the post-traumatic Mayor scoring system for the cervical spine.

Results: All 7 patients successfully completed the robot-assisted operation without nerve and blood vessel damage. What is the operation time 103.3 minutes, intraoperative blood loss 11.1 ml. The angulation and displacement of the fracture were basically corrected by closed reduction during the operation. Postoperative CT of these 7 patients showed that the cervical spine was stable, the accuracy of “perfect” and “clinically acceptable” odontoid screw implantation was 100% (7/7), none of the seven odontoid screws breached the bone cortex. Reexamination of X-rays showed that the fractures were all healed, and the average fracture healing time was average 13.7weeks (12-15weeks). During the follow-up period, 7 patients had no surgical complications, postoperative cervical spine trauma mayo score: excellent in 6 cases and good in 1 case.

Conclusion: Tinavi robot-assisted screw insert technology is a minimally invasive, accurate, safe and feasible method for the treatment of type Ⅱ odontoid fractures.

Background

Anterior odontoid screw fixation is the preferred surgical method for the type II odontoid fractures as for as it can preserve the range of motion of the atlantoaxial joint(1). More and more scholars advocate the treatment of type II odontoid fractures with fixed surgery within first stage(2). However, due to the high difficulty of the operation and the complex anatomical structure of the upper cervical spine, the clinical application of anterior odontoid screw fixation is limited. Even though surgeons who under high doses of radiation may still be impossible to safely and accurately complete the anterior screw insertion(3). The surgical robot system has many characteristics such as high operation accuracy, good operation repeatability, excellent surgical stability, less traumatic surgery, in addition, it’s worth noting that surgeons are exposed to less radiation, meanwhile, its application in upper cervical spine surgery has get more and more attention and research from clinicians(4, 5).

Tinavi orthopedic robot system is the world's first surgical robot that combines computer-aided navigation, real-time optical tracking and robotic arm technology(6), which is based on intraoperative three-dimensional (3-D) images (Figure 1). Tinavi orthopedic robot system has three components: navigation design system, optical tracking system and robotic arm system(7). The actual workflow is as follows: first, clinicians apply the 3-D C-arm (Siemens Medical Solutions, Erlangen, Germany) to acquire a set of intraoperative images. Due to the need for high-precision calculations on the computer, the 5 positioning points on the positioning ruler must be included in the 3-D C-arm scan range. Then the clinician upload the image to the robot workstation,and design the screw entry point, screw insertion trajectory and screw specifications in the workstation according to the intraoperative 3-D images. The optical tracking system consists of an infrared stereo camera and two tracers. One tracer is fixed on the patient’s spinous process or skin, and the other is fixed on the end of the robotic

arm. This enables the optical tracking system to locate the robotic arm and the patient, it also could guide the robotic arm to the planned surgical location. The robotic arm can cover all spine parts. Under the guidance of navigation design and optical tracking system, the robotic arm automatically moves to the desired position accurately(8, 9). The author has treated 7 cases of type Ⅱ odontoid fractures with anterior odontoid screw internal fixation under the navigation of Tinavi orthopedic robot from May 2018 to May 2019 (Demographic data and general clinical information of seven patients, Table 1).

Table 1
Demographic data and general clinical information of seven patients.

Demographic data and general clinical information of seven patients *M male,F female*	Patients	1	2	3	4	5	6	7	P
	Sex	M	M	M	F	M	F	M	-
	Age	43	63	29	42	36	53	33	42.7
	Cause of injury	traffic accident	traffic accident	falling injury	traffic accident	traffic accident	falling injury	traffic accident	-
	Operation time(min)	90	75	85	110	100	85	75	103.3
	Intraoperative blood loss(ml)	5	10	8	20	12	8	15	11.1
	Rampersaud score(A-D grade)	A	A	A	A	A	A	A	-
	Pain VAS score	0	1	0	2	1	1	0	0.7
	Fracture healing time(week)	15	12	15	12	15	12	15	13.7

Materials And Methods

General information Inclusion criteria: (1) Type II odontoid fracture, mild to moderate displacement ; (2) Without nerve or vertebral artery injury; (3) 18-70 years old. Exclusion criteria: (1) Combined with severe medical disease or multiple injuries and unable to tolerate surgery; (2) Combined with nerve/vascular injury requiring open surgical exploration and decompression; (3) Lost to follow-up within three months after surgery. Include 7 cases, 5 males and 2 females, aged 29-63 years old, average 42.7 years old. Causes of injury: 5 cases were injured by car accidents, 2 cases were injured by falling from height; 3 cases had limb fractures, 2 cases had closed chest injuries, and 2 cases had only neck pain and limited mobility. Before surgery, all patients had completed 64-slice CT scans and 3-D reconstructions, and performed MRI examinations to understand type Ⅱ odontoid fractures, soft tissue injuries and vertebral artery heights.

Operation method: General anesthesia, take the supine position, fix the patient's head on the Mayfeild head frame, confirm the fracture reduction under the C-arm X-ray machine, and connect the robot parts and accessories, including the mechanical arm, surgical planning and navigation system, and optical positioning Tracking system and 3-D C-arm. Intraoperative CT scan to obtain 3D images: send the images to the dimensity Robot Surgery Planning and Navigation System. The assistant calls up the reconstructed image on the planning workbench, and plans the needle insertion point and needle direction in the odontoid axis, sagittal, and coronal positions, so that the guide needle passes through the main fracture line, confirm it not breached the bone cortex, and the mechanical arm is moved to simulate the running track. Measure the diameter and length of the required dentate screw. The guide needle is inserted under the guidance of the

robot arm and verified. The robot arm is operated according to the predetermined trajectory, so that the tip of the guide needle sleeve on the robot arm slightly touches the bone at the needle insertion point, and the power drill is inserted under the guide of the sleeve Guide needle, confirm the position and insertion depth of the guide needle under fluoroscopy; Measure the diameter and length of the required dentate screw. The guide needle is inserted under the guidance of the robot arm and verified. The robot arm is operated according to the predetermined trajectory, so that the tip of the guide needle sleeve on the robot arm slightly touches the bone at the needle insertion point, and the power drill is inserted under the guide of the sleeve Guide needle, confirm the position and insertion depth of the guide needle under fluoroscopy.

Postoperative treatment and follow-up: Antibacterial drugs were routinely used within 24 hours after surgery. Patients were encouraged to wear a cervical collar to protect them from getting out of bed on the first day after surgery. Cervical X-rays and CT scans were reviewed 3 days after surgery. The neck brace was removed after 4 weeks, and active neck exercises were started. Regular follow-ups were performed after the operation, and the cervical spine was taken in front and side view and dynamic position, and CT thin-layer scanning was performed to evaluate the stability of the cervical spine and fracture healing. Six months after surgery, the Mayor scoring system after cervical spine trauma was used to evaluate the patient's functional recovery.

Results

All 7 patients in this group successfully completed the operation without nerve and blood vessel damage. What is the operation time 110 minutes, intraoperative blood loss 11.1 ml. The angulation and displacement of the fracture were basically corrected by closed reduction during the operation. Postoperative re-examination of the cervical spine in positive and lateral and dynamic position X-rays showed that the cervical spine was stable, and there was no failure of internal fixation or fracture displacement during the follow-up. All 7 cases were followed up satisfactorily, average follow-up time 12.4 Month (6-24 month), during the follow-up period, 7 patients had no surgical related complications. Postoperative CT showed that the fractures were all healed, and the average fracture healing time was average 13.7 weeks (12-15weeks) (Table 1). Pain VAS score 0-2 points, average 0.7 points. The cervical spine range of motion is scored 2-5 points before surgery, with an average of 3.43 points, 3 days after surgery, cervical motion score was 1-2 points, with an average of 1.43 points(Figure 2). 6 months postoperative cervical spine trauma mayo score: excellent in 6 cases and good in 1 case.

Discussion

Odontoid fractures account for 15%-20% of all cervical spine fractures, and type II fractures account for 65%-74% of all odontoid fractures. Type II odontoid fractures are unstable fractures, and the rate of nonunion in conservative treatment is relatively high(10). Anterior odontoid screw internal fixation can achieve immediate fracture fixation and it can preserve the range of motion of the atlantoaxial joint. The advantage is that it retains the rotation of the C1-C2 vertebral body, has a higher fusion rate and better clinical effects than external fixation(11). Due to the special anatomical structure of the odontoid process and the distribution of important nerves and blood vessels around it, coupled with unstable fractures and displacement after fractures, it increased the difficulty of inserting screw under the guidance of traditional freehand fluoroscopy for surgeons(12).

Orthopedic robots can assist clinicians in intelligent surgical planning and precise intraoperative operations, effectively reduce clinicians' human errors during the operation, realize intelligent human-computer interaction, and perfectly control surgical accuracy through digital navigation throughout the process(13). Robot-assisted screw insert technology has achieved higher accuracy than traditional barehand fluoroscopy in other positions of the spine, and can provide real-time dynamic adjustment during the operation(7). If the pedicle screw implantation deviation occurs during the operation, the orthopedic robot can also be timely. The feedback on the screen is convenient for the doctor to adjust to the preoperative setting position(14). The results of meta-analysis by Fan et al. showed that compared with hand nail placement, the proportion of robot-assisted nail placement reaching A (Gertzbein-Robbins's classification) was higher ((odds ratio 95%,

"perfect accuracy" confidence interval: 1.38-2.07, P < .01; odds ratio 95% "clinically acceptable" Confidence Interval: 1.17-2.08, P < .01).) (14, 15). Molliqaj et al. reported that in the placement of pedicle screws, the clinical acceptance rate of robot-assisted screws was 93.4%, which was higher than 88.9% of traditional fluoroscopy(16). Intelligent surgical planning technology is based on CT for 3D intelligent modeling, providing patients with personalized surgical plans(17). According to the patient's personal situation, select the appropriate pedicle screw size, set the implant position and angle, and simulate soft tissue. The balance of the situation.

The robot performs intelligent operation, the operation process is stable, and the operation time is shortened to 103.3 minutes, effectively reducing the amount of bleeding during the operation(11.1ml). The actual size, screw position and angle of the pedicle screw used are consistent with the preoperative plan height, reducing the possibility of surgical complications. As far as post-operative rehabilitation is concerned, it is also conducive to shorten the length of hospitalization, speed up post-operative rehabilitation, and reduce hospitalization costs(18). Especially for patients with atlantoaxial fractures, the biggest advantage of the robotic surgery system is that the pedicle screw placement is safer and more precise, the incision is smaller, the injury is less, the bleeding is less, and the patient recovers more quickly(19). Compared with traditional treatment methods, the robot-assisted nail placement has no X-ray exposure during the entire operation. However, this study also has limitations. First of all, it is difficult to draw more reliable conclusions due to fewer cases(20). However, the purpose of this study is to illustrate the feasibility of a new treatment method for odontoid fractures, so a small sample size can basically be Meet the needs of research. Secondly, this study did not conduct a prospective randomized controlled study of robot-assisted nail placement and other treatment methods. Therefore, it is necessary to further carry out multi-center and large-sample randomized controlled trials to further verify the results of this study.

Conclusion

Robotic assisted laparoscopic nephropexy can be safely and effectively performed in a spinal surgery. Tinavi robot-assisted screw insert technology is a minimally invasive, accurate, safe and feasible method for the treatment of type odontoid fractures.

Abbreviations

MRI: magnetic resonance; CT: computed tomography

Declarations

Ethics approval and consent to participate

This study is based on the SEER database and does not require ethical approval.

Consent for publication

Not applicable.

Availability of data and materials

The data set supporting the conclusion of this article is available on request to the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

GL and DJH designed the study. SCZ performed the study and analyzed the data. YB and HSW wrote the manuscript. SCZ provided the expert consultations and clinical suggestions. SCZ, YB, JPD, YL, HSW, JMW and LG conceived of the study, participated in its design and coordination, and helped to draft the manuscript. All authors reviewed the final version of the manuscript.

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Figures

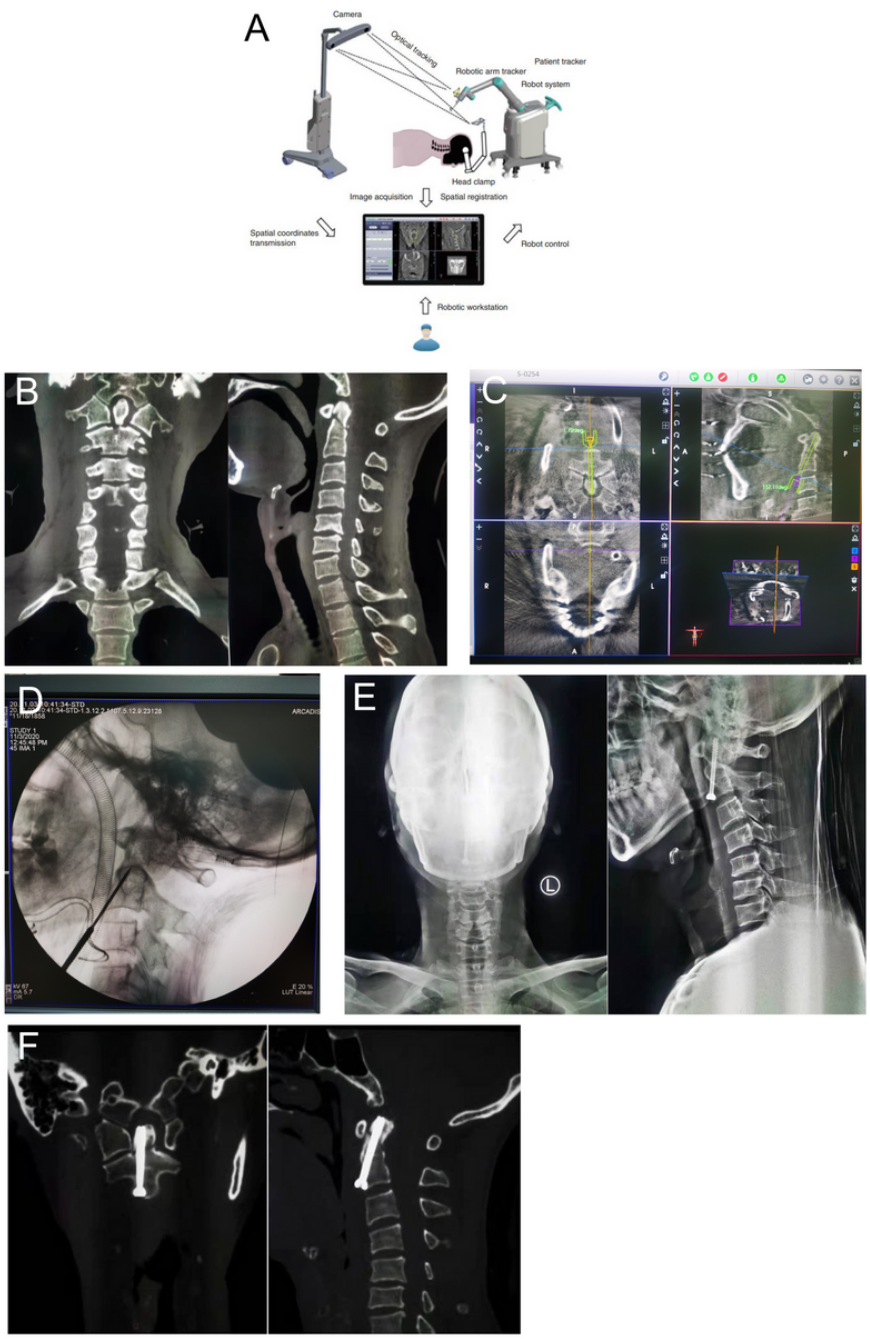

Figure 1

(A): Surgical wokflow of the Tinavi robot system assiatance; (B) Preoperative CT of the type Ⅱ odontoid fractures; (C) The guide needle insertion point, direction and the specification of screw are planned according to Intraoperative reconstructed 3D image in the odontoid axis, sagittal, and coronal positions; (D) The guide needle is inserted under the guidance of the robot arm and verified; (E) Postoperative CT showed good reduction of fracture and good screw position

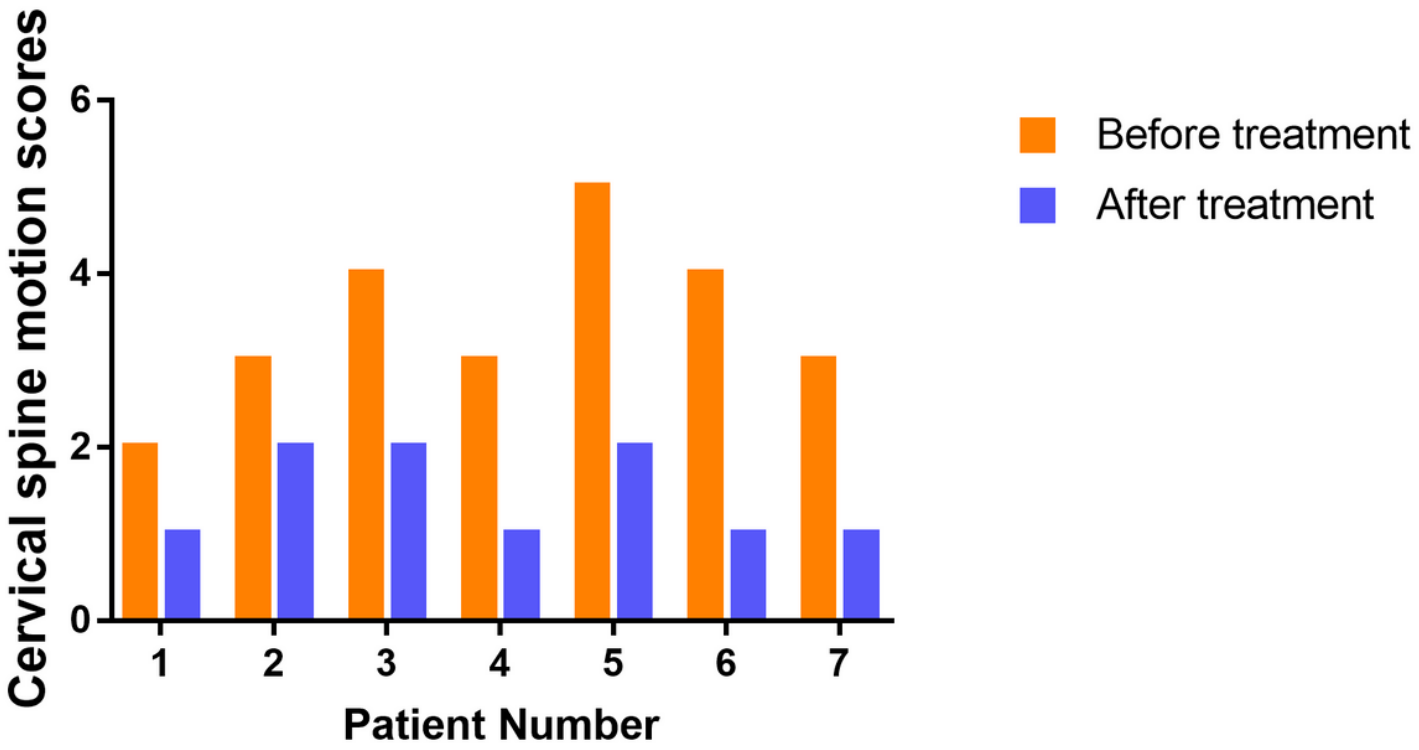

Figure 2

There is a significant difference in the cervical spine range of motion score before and after surgery. 2-5 points before surgery, with an average of 3.43 points, 3 days after surgery, cervical motion score was 1-2 points, with an average of 1.43 points.