

Original Article

Three-dimensional image navigation system-assisted anterior cervical screw fixation for treatment of acute odontoid fracture

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Abstract: This study is to investigate the role of three-dimensional image navigation system for surgical treatment of odontoid fracture. A total of 21 patients were enrolled in this study. The anterior cervical hollow screw fixation was performed for treatment of acute odontoid fracture under monitoring of isocentric C-arm three-dimensional navigation system (Iso-C 3D) navigation system. The postoperative follow-up investigation duration was 13.8 ± 4.4 months. Twenty patients with odontoid fracture had bone union without intraoperative and postoperative complications. No loosening, dislocation or fracture of screw occurred. The average healing time was from 3 to 4 months. The cervical postoperative organ function evaluation of patients was scored by Smiley-Webster scoring methods. Eighteen cases were scored as excellent; 2 cases were scored as fine; 1 case was scored as good; and no case was scored as poor. Iso-C 3D image navigation system-assisted anterior cervical screw fixation is an effective approach for treatment of odontoid fracture.

Keywords: Odontoid fracture, navigation, three-dimensional image, hollow screw

Introduction

Odontoid fracture, a kind of severe spinal trauma, may result in paraplegia, even threatening the patient's life if necessary treatments are not available. According to the Anderson-D'Alonzo classification, patients with type II and III fractures need surgeries. Anterior cervical screw fixation may preserve the atlantoaxial physiological activities, characterized by minor trauma, solid fixation and high rate of fracture healing. Anterior cervical screw fixation is commonly used as approaches for treating type II and III odontoid fractures [1-7].

Appropriate imaging monitoring is required for successful completion of surgery. Currently, C-arm is considered as the major clinical modality used for monitoring reduction and fixation although it cannot provide real-time monitoring and often results in radiation injuries. Recently, intraoperative CT scan is used for monitoring during surgery, which can increase accuracy of

surgery. However, it either cannot monitor the surgery process in real time. The ideal intraoperative imaging monitoring techniques, which can facilitate the determination of the best location of screw and reduce radiation and surgery risk, are needed. Intraoperative isocentric C-arm three-dimensional navigation system (Iso-C 3D) is a kind of technique with intraoperative imaging monitoring ability and has been used in spinal surgery [8, 9]. In this study, we applied Iso-C 3D system in anterior cervical screw fixation for treatment of acute odontoid fractures.

Materials and methods

Patients' data

In this study, 21 patients were enrolled. They received anterior cervical hollow screw fixation for acute odontoid fractures. All surgeries were accomplished under monitoring of Iso-C 3D navigation system. Clinic data was collected for

Table 1. Clinical characteristics of patients

Item	Data	Item	Data
Gender ratio (F:M)	13:8	Ulnar fracture (case)	1
Mean age (year)	42.9 ± 13.2	Femoral fractures (case)	1
Cause (case)		Tibial fractures (case)	1
Traffic accident	12	Interval from injure to surgery (day)	5.3 ± 4.3
High fall injury	7	Operative duration (min)	88.1 ± 16.0
Heavy pound injury	2	Intraoperative blood loss (ml)	65.7 ± 31.3
Type (Anderson-D'Alonzon) (case)		Complication (case)	3
II	17	Dysphagia (case)	1
III	4	Transient superior laryngeal nerve paralysis (case)	1
Comorbidity (Site)	6	Atelectasis (case)	1
Cranio-cerebral injury (case)	2	Length of Stay (day)	11.1 ± 4.5
T12 compression fracture (case)	1	Duration of follow-up (month)	13.8 ± 4.4
Rib fractures, hemothorax (case)	1		

Table 2. The degree of fracture angulation and displacement

Displacement	No	Forward	Backward
Angulation (case)	4	7	10
Distance (case) (mm)	2 (0)	9 (3.78 ± 2.22)	10 (4.90 ± 2.02)

retrospective analysis (Tables 1, 2). The patients included 13 males and 8 females, whose ages were between 25 and 71 years, with an average of 42.9 years. Diagnoses of patients were confirmed by cervical vertebra poster-anterior and lateral X-ray, CT, and MRI scan (Figure 1A-D). According to the Anderson-D'Alonzo classification, the type II and type III fractures were detected in 17 and 4 cases, respectively. Displacement of those fractures in most patients was greater than 2 mm. The duration from injure to surgery was 1 to 17 days, with an average of 5.3 days.

Prior written and informed consent was obtained from every patient and the study was approved by the ethics review board of Shandong University.

Surgical procedure

A minor incision was made at left middle clavicle. A reference frame with infrared light was installed above the clavicle. Then, Iso-C 3D (ARCADIS Orbic, Siemens AG, Forchheim, Germany) was set up to do 190° scanning. The three-dimensional information of surgery site was collected. The image was transferred to a spinal navigation system workstation (Med-

tronic, Sofamor Danek, Broomfield, CO, USA). Median sagittal and coronal section images were selected for navigation. Transverse incisions (4-6 cm) just beneath thyroid cartilage on the right side of the neck were made. The upper edge of anterior C3 vertebra body was selected. One 1.2 mm guide pin was inserted into the top of odontoid through predetermined track, which was consecutively 190° scanned by the intraoperative navigation system. By this way, the position of guide pin through coronal, sagittal and cross-sectional section was monitored. A hollow cancellous bone screw with a diameter of 3.5 mm guide pin was used. The poster-anterior and lateral X-ray examination was carried out after fixation (Figure 1E and 1F). The respiratory and wound drainage status was closely monitored. Neck was immobilized with brace for 6 weeks. The healing status was monitored by the X-ray and CT scanning at week 6, 12, and 24 after operation.

Statistical analyses

Analyses were conducted using SPSS version 19.0. The quantitative data were expressed as mean ± SD, and t test were used to analyze data for statistical significance between groups. A P-value of less than 0.05 was considered as statistically significant.

Results

All surgeries were successfully operated without occurrence of iatrogenic nerve and vascu-

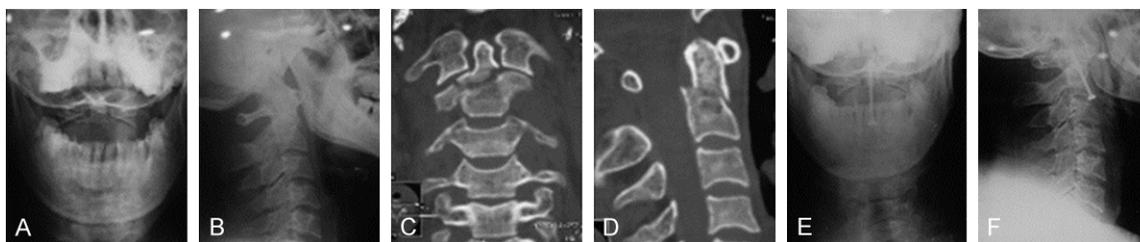


Figure 1. Representative imaging data of cervical vertebra with odontoid fracture before and after surgery. The imaging data from a case (42-year old, male) with type III odontoid fracture were obtained by X-ray and CT. The patient was admitted into hospital 1 day after he was injured in traffic, with pains in his neck and shoulder. A. Poster-anterior X-ray result of type III odontoid fracture before surgery. The fracture was in the right articular surface of the epistropheus. B. Lateral X-ray result of fracture before surgery. The odontoid fracture was displaced forward. C. Coronal CT result of fracture before surgery. The fracture was in the right articular surface of the epistropheus. D. Sagittal CT result of fracture before surgery. The odontoid fracture was displaced forward. E. Poster-anterior X-ray result of fracture at 1 week after surgery. The localization of the hollow cancellous bone screw was showed. F. Lateral X-ray result of fracture at 1 week after surgery.

Table 3. Smiley-Webster scores of cervical function after surgery

Score level	Excellent	Fine	Good	Poor
Cases (Percentage %)	18 (85.7)	2 (9.5)	1 (4.8)	0 (0)

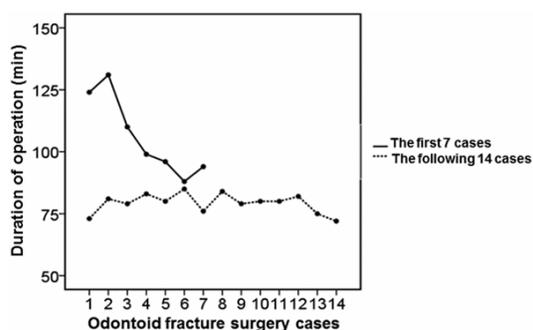


Figure 2. Duration of odontoid fracture surgery. Odontoid fracture surgery was firstly performed in 7 cases and then in 14 cases. The duration of surgery for each case was recorded. The solid line showed the operation duration of the first 7 cases and the dotted line showed the operation duration of the following 14 cases.

Table 4. The operation duration time (min)

The first 7 cases	The following 14 cases	t	p
106.0 ± 16.2	79.2 ± 3.9	4.301	0.004

lar injuries. Moreover, as shown in **Figure 1**, both reduction of odontoid fracture and localization of hollow screw during surgeries were good.

The operation time was 88.1 ± 16.0 min. The intraoperative blood loss was 65.7 ± 31.3 ml.

The mean hospital stay time was 11.1 ± 4.5 days. All patients received following-up investigation. The mean following-up duration was 13.8 ± 4.4 months (**Table 1**).

Twenty patients with odontoid fracture had bone union without intraoperative and postoperative complications. No loosening, dislocation, or fracture of screw was found. The average healing time ranged from 3 to 4 months. Only one patient displayed as fibrous connection without displacement and neurological symptoms. The cervical postoperative function of patients was scored by Smiley-Webster scoring methods. Among these cases, 18 cases were scored as excellent, 2 cases were scored as fine, 1 case was scored as good, and no case was scored as poor (**Table 3**).

As mentioned above, the overall operation duration was 88.1 ± 16.0 min. The duration of operation was shown in **Figure 2** and **Table 4**. The overall operation duration of the first 7 cases was 106.0 ± 16.2 min. However, the overall operation duration of the following 14 cases was 79.2 ± 3.9. There was significant difference in operation duration between these two groups (**Table 4**). This result suggests that operation time was dependent on proficiency of surgeons.

Discussion

Odontoid fracture, a kind of severe spinal trauma, accounted for 5-27% of cervical vertebra fractures and resulted in 5-10% of the related mortality rates [10]. The treatment of odontoid fracture usually depends on various factors,

such as classification and stability of fractures, ages, and whether the injury is new or old [11, 12]. During the procedure, fracture reduction and screw position, which requires close monitoring with intraoperative imaging, is crucial for the clinical outcome. Imaging monitoring can be used to help clinicians to promptly find the best location of screw, reduce radiation and surgery risk, and avoid repeat check, thereby decreasing radiation injuries.

With the assistance of navigation system, screw can be implanted into optimal position more promptly and accurately, thereby decreasing injury of bone surrounding screw channel and improving stability and healing rates. In this study, hollow screw was implanted into optimal position. And three-dimensional image navigation system obviously improved efficiency and safety of surgery and reduced surgical trauma and radiation damages. Combination of surgical procedures and three-dimensional image navigation resulted in accurate, real time and rapid effects.

The percentage of patients with type II odontoid fracture who underwent anterior cervical surgery was 65-95% [3, 5, 12-15]. It was suggested that delayed surgery, poor reduction and displacement more than 2 mm were considered as the major factors related to fracture healing [15, 16]. Eap et al. reduced odontoid fracture by curving thoracolumbar pedicle awl and fixing with anterior cervical screw and improved the healing rate to 95% [3]. Median sagittal and coronal reconstruction by intraoperative Iso-C 3D can clearly show displacement and separation. Thereby, solid fixation and prolonged neck immobilization after surgery could be obtained with the use of navigation system. The rapid and accurate effects of intraoperative three-dimensional image surgical navigation system promotes the accurate and safety of odontoid fracture surgery.

Disclosure of conflict of interest

None.

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