Research Article

The Healing Rate of Type II Odontoid Fractures Treated With Posterior Atlantoaxial Screw-rod Fixation: A Retrospective Review of 77 Patients

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Abstract

Background: In theory, temporary posterior atlantoaxial screw-rod fixation for type II odontoid fractures is a way to preserve rotatory motion. However, the healing rate of type II odontoid fractures treated in this way is unknown; that is, the risk associated with conducting a temporary screw-rod fixation for type II odontoid fractures is unknown. This study investigates the healing rate of type II odontoid fractures treated with posterior atlantoaxial screw-rod fixation by CT imaging and evaluates the feasibility of conducting a temporary screw-rod fixation for type II odontoid fractures.

Methods: Patients with type II odontoid fracture who underwent posterior atlantoaxial screw-rod fixation in our spine center from January 2011 to December 2014 were identified. Patients older than 65 years or younger than 18 years were excluded. Those who were confirmed to have healing odontoid fractures on CT imaging were included. Those in whom fracture healing was not confirmed were asked to undergo a CT examination. Fracture healing was confirmed on the basis of the presence of bridging bone across the odontoid fracture site on CT imaging.

Results: Seventy-seven patients (56 men and 21 women) were included in the study. The average age of the patients was 40.7 ± 11.6 years (range, 18 to 64 years). The mean duration of follow-up was 26.4 ± 4.6 months (range, 24 to 40 months). Fracture healing was observed in 73 patients (94.8%).

Discussion: The healing rate of type II odontoid fractures (with an age range of 18 to 64 years) treated with modern posterior atlantoaxial fixation is relatively high. For patients at that age range, posterior atlantoaxial temporary screw-rod fixation for type II odontoid fractures can be conducted with a low risk of nonunion.

Level of Evidence: Level IV, therapeutic

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Type II odontoid fracture is the most common type of odontoid fracture.[1,2] In contrast to the healing rate of other types of odontoid fractures, the healing rate of type II odontoid fractures treated non-surgically is relatively low.[3-5] Therefore, many surgeons treat this kind of fracture surgically. Posterior atlantoaxial fusion is a common method used to manage such cases, but this sacrifices the mobility of the

C1-C2 segment.[6-8] In 2001, Harms and Melcher[9] introduced a screw-rod system for atlantoaxial fixation. In theory, temporary posterior atlantoaxial screw-rod fixation for type II odontoid fractures is a way to preserve rotatory motion. However, the healing rate of type II odontoid fractures treated with posterior atlantoaxial screw-rod fixation is unknown; that is, the risk associated with conducting a temporary screw-rod fixation for type II odontoid fractures is unknown. A few studies, based on small case series, have investigated the healing rate of type II odontoid fractures treated with posterior atlantoaxial screw-rod fixation.[10-12] However, most of the authors assessed fracture healing using radiographs, which is not reliable.[10,11] In the current study, we investigate the healing rate of type II odontoid fractures treated with posterior atlantoaxial screw-rod fixation using CT imaging, based on a relatively large number of patients, to evaluate the feasibility of conducting a temporary screw-rod fixation for type II odontoid fractures.

Methods

Patients

Consecutive patients with type II odontoid fracture who underwent posterior atlantoaxial screw-rod fixation in our spine center from January 2011 to December 2014 were identified. Patients older than 65 years or younger than 18 years were excluded. Those who were confirmed to have healing of the odontoid fracture on CT imaging were included. Those in whom fracture healing had not been confirmed were asked to undergo a CT examination. The medical records and the imaging data of the included patients were reviewed. The study protocol was approved by the local institution review board at the author's affiliated institution.

Surgical Technique

After general endotracheal anesthesia, all patients were placed in the prone position and the posterior elements of C1-C3 were exposed by a standard posterior approach. The medial and lateral margins of the lateral mass of the axis and the posterior surface of the posterior lamina of the atlas were dissected. Screws were placed in accordance with Tan's technique,[13] which has been shown to achieve the highest screw placement success rate compared with a variety of published techniques for atlas pedicle screw placement. If the C1 pedicle was too narrow to accommodate a screw, we used the C1 lateral mass screw technique described by Harms and Melcher[9] instead. The C2 pedicle screws were inserted regularly.[7,9] The ipsilateral C1 and C2 screws were connected by a rod. After atlantoaxial fixation by the screw-rod system, the bone graft bed was prepared using a high-speed burr. An autograft or allograft was used for fusion.

Five patients underwent an internal fixation construct removal surgery 12 months after fusion surgery; a CT scan indicated that the posterior fusion failed, though the odontoid fracture healed.

Evaluation of Fracture Healing, Atlantoaxial Fusion, and Functional Outcomes

Fracture healing and posterior atlantoaxial fusion were confirmed on the basis of the presence of bridging bone on CT imaging. If bridging bone was not found across the fracture site or between the C1 and C2 laminas on CT images, the patient was asked to undergo a CT scan again 12 months after surgery and for every 12 months thereafter until the end of the study or until both fracture healing and atlantoaxial fusion were confirmed. For patients with atlantoaxial fusion failure, dynamic radiographs were obtained at the final follow-up visit to access atlantoaxial stability. Fracture non-healing was defined as an absence of bridging bone across the fracture site on CT images obtained 24 months after surgery or later. Neurologic deficits were measured by the American Spinal Injury Association (ASIA) grades. Neck pain was assessed by Visual Analogue Scale (VAS) score. The patients who underwent an internal fixation construct removal surgery were asked to begin practicing cervical rotation from 2 weeks after surgery. Thus, in our opinion, they may return to the maximum cervical rotation at the time of 12 months after fixation construct removal surgery. Therefore, their cervical range of motion was measured by the cervical range of motion device (Performance Attainment Associates) 12 months after surgery.

Statistical Analysis

The fracture healing rate and the atlantoaxial fusion rate were calculated. Wilcoxon Signed Ranks Test was used to compare ASIA grades before surgery and at the final follow-up and the VAS scores before surgery and at the final follow-up. SPSS version 18.0 statistical software (SPSS) was used for data entry and analysis. A P value of less than 0.05 was considered statistically significant.

Results

Seventy-seven patients (56 men and 21 women) were included in the study. The general information is shown in Table 1. The average age of the patients was 40.7 ± 11.6 years (range, 18 to 64 years). The cause of fracture was motor vehicle accidents in 48 patients (62.3%) and falls from height in 29 patients (37.7%). The mean time interval between injury and surgery was 5.6 ± 2.7 days (range, 3 to 18 days). All the patients were followed up for at least 24 months,

Table 1

General Information on Patients (n = 77)	
Age, yr	
Mean ± SD	40.7 ± 11.6
Range	18-64
Sex, n (%)	
Male	56 (72.7)
Female	21 (27.3)
Cause of fracture, n (%)	
Motor vehicle accidents	48 (62.3)
Falls from height	29 (37.7)
Time interval between injury and surgery, d	
Mean ± SD	5.6 ± 2.7
Range	3-18
Duration of follow-up, mo	
Mean ± SD	26.4 ± 4.6
Range	24-40

with a mean follow-up period of 26.4 ± 4.6 months (range, 24 to 40 months). Fracture healing was observed in 73 patients (94.8%) (Figure 1). Fracture healing was confirmed by a CT scan taken at 6 months after surgery in 62 patients, 12 months after surgery in 4 patients, 18 months after surgery in 2 patients, 24 months after surgery in 2 patients, 28 months after surgery in 1 patient, 38 months after surgery in 1 patient, and 40 months surgery in 1 patient (Table 2). For the patients who did not heal at the fracture site, they all had a fracture gap of more than 5 mm (Figure 2), whereas none of the patients with fracture healing demonstrated this finding in preoperative CT imaging. Posterior graft bone fusion was observed in 46 patients (59.7%) by CT imaging. However, all of the patients with atlantoaxial fusion failure show no movement on dynamic radiographs. None of the patients with atlantoaxial fusion failure consented to additional surgery because they were asymptomatic, with the exception of five patients who hoped to preserve C1-C2 mobility and who underwent an internal fixation construct removal procedure 12 months after fusion surgery when the CT scan indicated that the posterior fusion had failed even though the fracture healed (Figure 1). Cervical rotatory motion was preserved mostly in these five patients (Table 3). Preoperative ASIA grades were C in 2 patients, D in 14 patients, and E in 61 patients. At the final follow-up visit, ASIA grades were D in 3 patients and E in 74 patients ($P < 0.05$). The mean preoperative VAS score was 7.1 ± 0.7 (range, 6 to 8). At the final visit, it decreased to 0.9 ± 0.7 (range, 0 to 2) ($P < 0.05$) (Table 4).

Discussion

Odontoid fractures are usually caused by high-energy trauma, such as falls from height and traffic accidents[12,15,16]; they account for 9% to 18% of all cervical fractures.[15,17-19] Such injuries are thought to be extremely dangerous owing to the potential risk of upper cervical cord injury following traumatic instability. Anderson and D'Alonzo[1] defined the following three types of such injuries: type I fractures were described as oblique fractures through the upper portion of the odontoid process, type II fractures run across the base of the odontoid process near the junction with the axis body, and type III fractures include the odontoid and extend into the body of the axis. The healing rate of type II odontoid fractures treated nonsurgically is relatively low (range, 43% to 72%).[3-5] Hence, many surgeons tend to treat such fractures surgically.[6-8] Classic surgery options are the anterior odontoid screw fixation and the posterior atlantoaxial fusion. Both methods are subject to advantages and disadvantages. Anterior odontoid screw fixation is one treatment option that maintains atlantoaxial mobility. However, such fixation is highly technically demanding, with the risk of secondary spinal cord injury, and is hard to accomplish in patients with a barrel chest, short neck, subaxial cervical spondylosis, or thoracic kyphosis.[20-22] In addition, postoperative dysphagia and pneumonia have been reported after anterior odontoid screw fixation.[23] Posterior atlantoaxial fusion is less technically demanding and more familiar to most spinal surgeons. However, such a fusion technique will sacrifice the mobility of the atlantoaxial segment, accounting for approximately 60% of the total rotation of the neck.[24] The loss of atlantoaxial mobility may also increase the incidence of lower cervical spine degeneration.[25]

In 2001, Harms and Melcher[9] introduced a screw-rod fixation technique for atlantoaxial fixation and pointed out that this technique could be used to obtain temporary stabilization without definitive fusion, because it could avoid damage to the atlantoaxial articulation. Nevertheless, a few reports are available on the application of this temporary fixation technique.[9,12] In fact, the C1-C2 screw fixation technique was first

Figure 1

A B C

Imaging of a 24-year-old male patient diagnosed with odontoid fracture. **A**, Preoperative CT images showed that the patient had type II odontoid fracture with a transversal displacement of more than 2 mm, which was reported as a risk factor for failure of halo immobilization.[14] Besides, the fracture gap was more than 2 mm (red arrow), which was also negative for fracture healing according to our experience. Thus, surgery was considered for this patient. Because the bone quality of the screw path was affected by trauma (yellow arrow), anterior odontoid screw fixation was not feasible for this patient. Therefore, he underwent posterior C1-C2 screw-rod fixation and fusion surgery with allograft. **B**, Fracture healing and posterior fusion failure were confirmed by CT images obtained 12 months after surgery. Then he underwent an internal fixation construct removal surgery. **C**, CT image obtained after construct removal surgery showed that internal fixation construct had been removed.

described by Goel and Laheri in 1994.[26] However, they used a screw-plate fixation system and not the screw-rod fixation system, nor did they mention the possibility of obtaining temporary stabilization by their fixation system. The healing rate of type II odontoid fractures should be investigated before deciding to do a temporary fixation without fusion for patients with this type of fracture. Maiman and Larson[8] reported the management of odontoid fractures with posterior cervical fixation and fusion. A fusion rate of 100% at the posterior surgical site was gained, whereas the healing rate at the fracture site was only 35%. However, the instrument they used for atlantoaxial fixation was not a screw-rod system but a wire or cable that offered much less stability than the modern atlantoaxial screw-rod fixation system.

A few studies, based on small case series, have investigated the healing rate of type II odontoid fractures treated with posterior atlantoaxial screw-rod fixation.[10-12] However, most of the authors assessed fracture healing using radiographs, which is not reliable.[10,11] Therefore, the healing rate of type II odontoid fractures treated with posterior atlantoaxial screw-rod fixation is still unknown; that is, the risk associated with conducting a temporary screw-rod fixation for type II odontoid fractures is unknown. In the current study, we investigated the healing rate of type II odontoid fractures treated with posterior atlantoaxial screw-rod fixation using CT imaging, which is considered the "benchmark" imaging modality for assessment of fracture healing and fusion,[27] based on a relatively large number of patients. Fracture healing was observed in 73 of 77 patients, with a healing rate of 94.8%, indicating that a high healing rate of type II odontoid fractures could be achieved by posterior atlantoaxial screw-rod fixation. Our study provides supportive data for the application of the posterior atlantoaxial temporary screw-rod fixation technique for the management of type II odontoid fractures. However, it is important to note that the results of the current study were based on a case series with an age range of 18 to 64 years. The geriatric odontoid fractures are a different entity. Previous study has showed that the healing rate of odontoid fractures is much lower in elderly patients.[14,28] Therefore, from the results of the current study, we cannot draw the risk associated with conducting a temporary screw-rod fixation for type II odontoid fractures in patients older than 65 years.

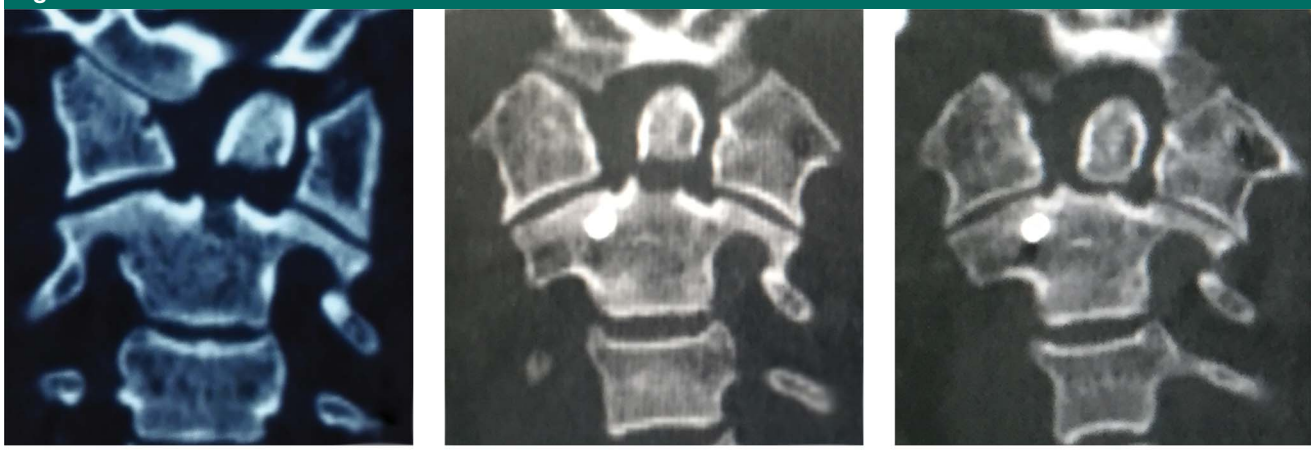
Table 2

The Time When Fracture Healing Was Confirmed (n = 73)

Fracture Healing Confirmed, mo	No. of Cases
6	62
12	4
>12	7

In theory, for patients with an age range of 18 to 64 years and without other concomitant injuries, the temporary posterior C1-C2 screw-rod fixation can be considered as a treatment option for all patients with acute type II odontoid fracture, except for those who have a fracture gap of more than 5 mm. However, compared with this technique, anterior odontoid screw fixation is cheaper and requires only one surgery without the need to do internal fixation construct removal. Therefore, anterior odontoid screw fixation may be a better treatment

Figure 2



A B C

A, Preoperative CT images showed the wide fracture gap of more than 5 mm. **B**, CT image obtained immediately after surgery showed that the fracture gap was still more than 5 mm. **C**, CT image obtained 24 months after surgery showed nonunion at the fracture site.

Table 3

Cervical ROM Measurements of the Five Patients 12 Months After Instrumentation Removal

		Cervical ROM			
Case No.	Age (yr), Sex	Flexion (°)	Extension (°)	Left Rotation (°)	Right Rotation (°)
1	24, M	60	70	42	41
2	26, M	52	48	45	40
3	36, M	35	58	50	49
4	38, M	55	67	45	38
5	28, M	53	47	49	40

M = Male, ROM = range of motion

Table 4

Functional Outcomes Before Surgery and at Last Follow-up

Factor	Before Surgery	At Last Follow-up
ASIA grade[a]		
A	0	0
B	0	0
C	2	0
D	14	3
E	61	74
VAS score[b]		
Mean ± SD	7.1 ± 0.7	0.9 ± 0.7
Range	6-8	0-2

ASIA = American Spinal Injury Association; VAS = Visual Analogue Scale
[a] *P* value <0.05; the comparison of ASIA grade between "before surgery" and "at last follow-up."
[b] *P* value <0.05; the comparison of VAS score between "before surgery" and "at least follow-up."

option for those in whom ideal odontoid screw placement can be done. In our opinion, we prefer recommending the use of temporary posterior C1-C2 screw-rod fixation in patients who have risk factors for failure of nonsurgical treatment and are not feasible for anterior odontoid screw fixation. According to the existing literature[14,16,29,30] and our experience, at least, the risk factors for failure of nonsurgical treatment include the following: (1) aged older than 50 years, (2) fracture displacement of more than 2 mm, (3) fracture gap of more than 2 mm, (4) angulation of more than 11°, (5) secondary

loss of reduction, and (6) a fracture with comminution. Situations not feasible for anterior odontoid screw fixation include a fracture line from posterosuperior to anterior inferior, comminuted fractures, poor bone quality at the fracture site, failure of achieving satisfactory fracture reduction, body habitus that prevent proper trajectory for odontoid screw placement, such as barrel chest, short neck, subaxial cervical spondylosis, severe thoracic kyphosis.[16,20-22] In our case series, all the 4 patients with a fracture gap of more than 5 mm failed to heal at the fracture site even though they were treated via the rigid C1-C2 screw-rod fixation. Therefore, we consider a fracture gap of more than 5 mm as a contraindication to this temporary fixation technique. It is also important to note that we discuss only the situation of patients (with an age range of 18 to 64 years) with acute type II odontoid fracture without other concomitant injuries in the current study, because geriatric odontoid fractures or remote odontoid fractures are a different entity, and some concomitant injuries such as disruption of the transverse atlantal ligament and injury to the C1-C2 joints are contraindication to temporary fixation.

The limitations of the current study include its retrospective nature and the small number of patients included in the study. We did not document when the fracture healed, because the time at which patients underwent CT scan varied: some underwent CT scan at 6 months after surgery, whereas others underwent at 12, 18, or 24 months, etc. A prospective study involving a larger patient population is needed in the future.

Conclusions

The healing rate of type II odontoid fractures (with an age range of 18 to 64 years) treated with modern posterior atlantoaxial fixation is relatively high. For patients at that age range, posterior atlantoaxial temporary screw-rod fixation for type II odontoid fractures can be conducted with a low risk of nonunion.

Acknowledgments

Preliminary report of this study has been presented as an oral presentation at the 2016 AAOS Annual Meeting in Orlando, Florida.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, reference 10 is a level III study. References 1-4, 6-9, 11, 12, 14, 15, 17, 19, 21-26, and 28-30 are level IV studies. Reference 19 is a level V expert opinion. Reference 13 is an anatomy study. References 5, 16, 18, and 27 are review studies.

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