Original Article

Management of Combined Atlas Fracture with Type II Odontoid Fracture: A Review of 21 Cases

Abstract

Purpose: To evaluate the therapeutic effects of combined atlas fracture with type II (C_1-type II) odontoid fractures and to outline a management strategy for it. **Patients and Methods:** Twenty three patients with C_1-type II odontoid fractures were treated according to our management strategy. Nonoperative external immobilization in the form of cervical collar and halo vest was used in 13 patients with stable atlantoaxial joint. Surgical treatment was early performed in 10 patients whose fractures with traumatic transverse atlantal ligament disruption or atlantoaxial instability. The visual analog scale (VAS), neck disability index (NDI) scale, and American Spinal Injury Association (ASIA) scale at each stage of followup were then collected and compared. **Results:** Compared to pretreatment, the VAS score, NDI score, and ASIA scale were improved among both groups at followup evaluation after treatment. However, in the nonsurgical group, one patient (1/11) developed nonunion which required surgical treatment in later stage and one patient (1/13) with halo vest immobilization had happened pin site infection. Two patients of the surgical group (2/11) had appeared minor complications: occipital cervical pain in one case and cerebrospinal fluid leakage in one case. Two patients (2/23) were excluded from nonsurgical treatment group because their followup period was less than 12 months. Twenty one patients were followed up regularly with an average of 23.9 months (range 15–45 months). **Conclusions:** We outlined our concluding management principle for the treatment of C_1-type II odontoid fractures based on the nature of C_1 fracture and atlantoaxial stability. The treatment principle can obtain satisfactory results for the management of C_1-type II odontoid fractures.

Keywords: *Atlas, cervical spine, fracture, odontoid, pedicle screw fixation*

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Introduction

Combined atlas fracture with type II (C_1-type II) odontoid fracture is extremely rare and accounts for <2% of all cervical spine injuries.[1-3] Recently, the incidence of C_1-type II odontoid fractures has increased due to the increase of high energy injury. Compared to other types of upper cervical spine trauma, C_1-type II odontoid fractures are more frequently associated with increased morbidity and neurological impairment, with a reported mortality of 12%–34%.[3-5] The fractures often present management challenges owing to the unique anatomy, complicated injury mechanism, and potential venture of treatment.[5,6] Specifically, the classification of C_1-type II odontoid fractures is complex because of existing simultaneously atlas and axis fracture. It is difficult to determine when choosing nonsurgical or surgical treatment. Although there are many treatment methods, the specific choice is based on clinical experience rather than treatment guidelines. The fractures have a high nonunion rate in nonsurgical treatment, especially in odontoid fracture. In addition, the nerve and vertebral artery (VA) were potentially injured during surgical treatment.

Overall, goals in treating C_1-type II odontoid fractures are to achieve early maximum stability to protect spinal cord and VA and to maintain spinal motor function as much as safely possible.[4,5] These are often contradictory process with many problems. Although various treatment methods have been reported, the clinical treatment strategy for C_1-type II odontoid fractures is still under debate about what approaches allow for the optimal achievement of management goals.[3-5] To this end, the highly debated question of C_1-type II odontoid fractures are the criteria for choosing nonoperative treatment or surgical treatment and ultimate therapeutic

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method.[3,7] Therefore, with the treatment based primarily on the nature of C_1 fracture and the atlantoaxial stability, we conducted a retrospectively clinical study to better assess the treatment options for C_1-type II odontoid fractures.

Patients and Methods

Clinical data

From June 2012 and January 2016, 23 cases (7 females and 16 males; ranged 24–72 years old, mean age of 52.4 ± 13.1) were selected with C_1-type II odontoid fractures and treated according to our management principle [Figure 1]. The injury causes were road accident injury in 12 cases, drifting-down injury in eight cases, and the bruise injury caused by heavy object in three cases. A cervical collar was performed immediately in the patients after injured or admitted to our hospital. If the patients show severe displacement, skull traction (3–5 kg) was the necessary measures. General examinations and chest X-rays were routinely performed on all patients. The three-dimensional (3D) computed tomography (CT) and magnetic resonance imaging (MRI) were mainly used to evaluate the stability of C_1–C_2 and to confirm the injury of VA or spinal cord. Patients who had pathological fracture, rheumatoid arthritis, and congenital atlantoaxial vertebral deformity or dislocation were excluded from the study. According to the Jefferson's Classification of atlas fracture and modified Anderson-D'Alonzo Classification of axis fracture,[8,9] all cases included Jefferson type II odontoid fractures in three cases, anterior ring type II odontoid fractures in eight cases, posterior ring type II odontoid fractures in eight cases, lateral mass type II odontoid fractures in four cases [Table 1]. Based on the nature of C_1 fracture and the atlantoaxial stability, 13 patients underwent nonsurgical treatment in the form of a cervical collar or halo vest, while the remaining 10 received posterior pedicle screw fixation or occipitocervical fusion. In addition, we obtained prior treatment written and informed consent from all patients. This study was approved by the institutional review board of Fujian University of Traditional Chinese Medicine.

Table 1: Demographic and clinical data of the patients

Information of the patients	*n*
Cases	23
Excluded case (%)	2 (8.6)
Female (%)	7 (30.4)
Male (%)	16 (69.6)
Age (years)	52.4 (24-72)
Etiology (%)	
Traffic accident	12 (52.2)
Fall down	8 (34.8)
Bruise injury	3 (13.0)
Fracture's classification (%), Type II odontoid fractures	
Jefferson	3 (13.0)
Anterior ring	8 (34.8)
Posterior ring	8 (34.8)
Lateral mass	4 (17.4)
Followup (months)	23.9 (15-42)

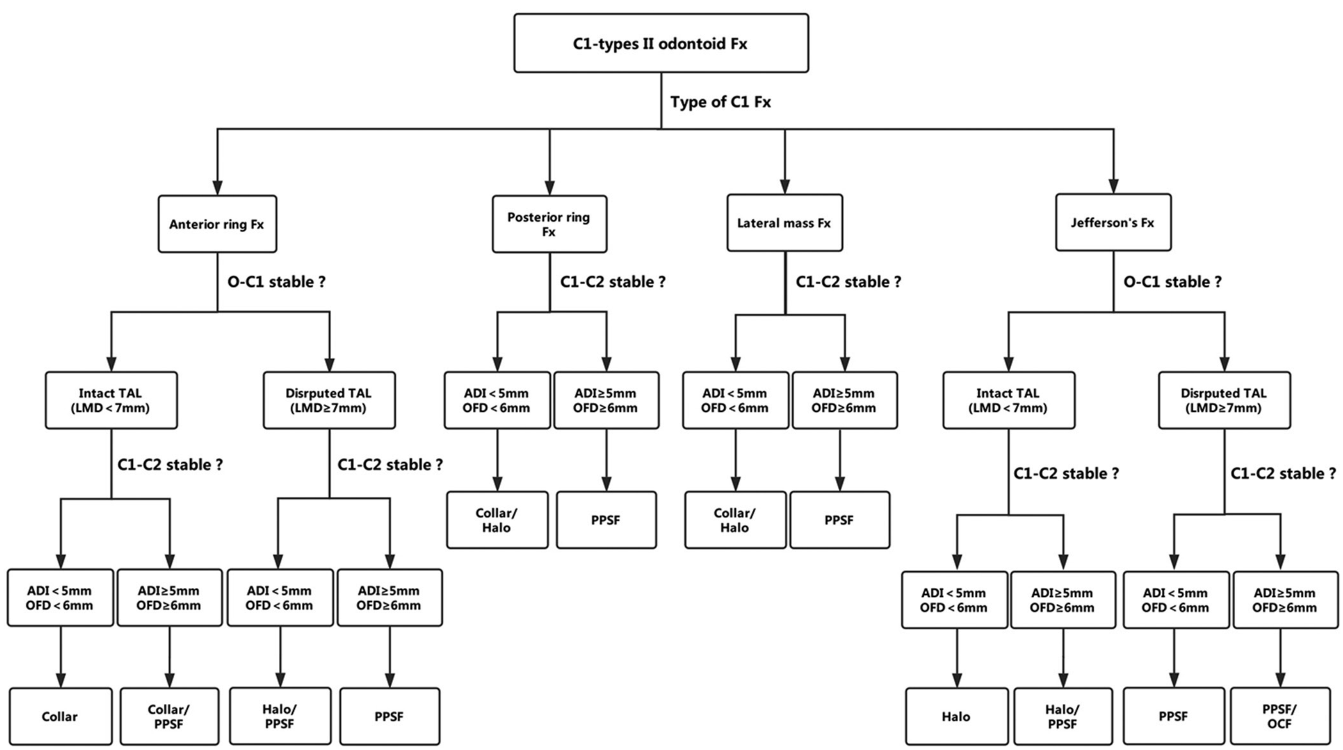

Figure 1: Management principle for C_1-type II odontoid fractures depend upon the type of C_1 fracture and atlantoaxial stability. Fx=Fracture, TAL=Transverse atlantal ligament, OFD=Odontoid fracture displacement, PPSF=Posterior pedicle screws fixation, OCF=Occipitocervical fusion

Nonsurgical treatment

These patients (n = 13) including five anterior ring type II odontoid fractures, six posterior ring type II odontoid fractures, two lateral mass type II odontoid fractures who have been recognized as stable fractures and atlantoaxial joint were underwent nonoperative therapy. In this group, nine patients without spinal cord injuries were managed with halo vest immobilization because of minimal displacement of the fractures [Figure 2]. Another three patients were treated by cervical collar. However, one patient with complicating spinal cord injuries received skull traction and followed by halo vest immobilization. The decision of removing the external fixation was dependent on the absence of clinical symptoms and radiography examination with evidence of fusion.[10] Nonsurgical case removed collar or halo vest after clinical healing and continued to achieve bone fusion.

Surgical treatment

In the surgical group, eight patients early underwent posterior C_1–C_2 pedicle screw fixation and two patients underwent occipital cervical fusion according to our management principle [Figures 3 and 4].[11-13] In the nonsurgical group, one patient who developed nonunion received the operation of posterior pedicle screw fixation [Figure 3]. After general anesthesia with the patient in the prone position, a midline incision was done to expose the posterior elements of C_1–C_2 from the occiput to C_3. The VA and the C_2 nerve root were carefully dissected from the surface of the C_1 posterior arch to the lateral mass for a distance of 2–3 mm. The entry point of C_1 pedicle screw (Medtronic, Inc., Minneapolis, MN, USA) which was formed at approximately 20-mm lateral to the midline and 4-mm long bone at the posterior arch inferior to VA groove along the direction of the trajectory. The trajectory was approximately 10° in the medial direction and 5°

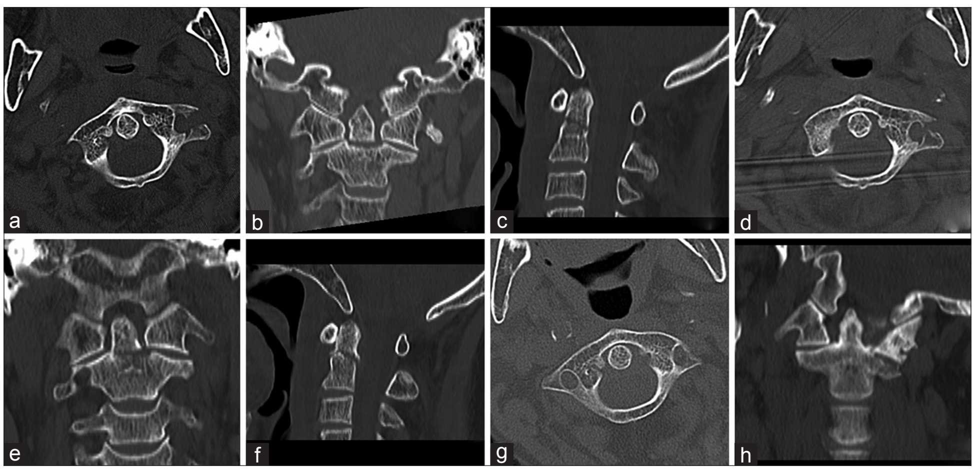

Figure 2: Pretherapy and posttreatment radiographs of the patient who had C_1-type II odontoid fractures treated with halo vest immobilization. (a-c) Computed tomography and three-dimensional reconstruction before the treatment. (d-f) Computed tomography and three-dimensional reconstruction at 1 week after treatment. (g and h) Computed tomography and three-dimensional reconstruction at 3rd month after treatment

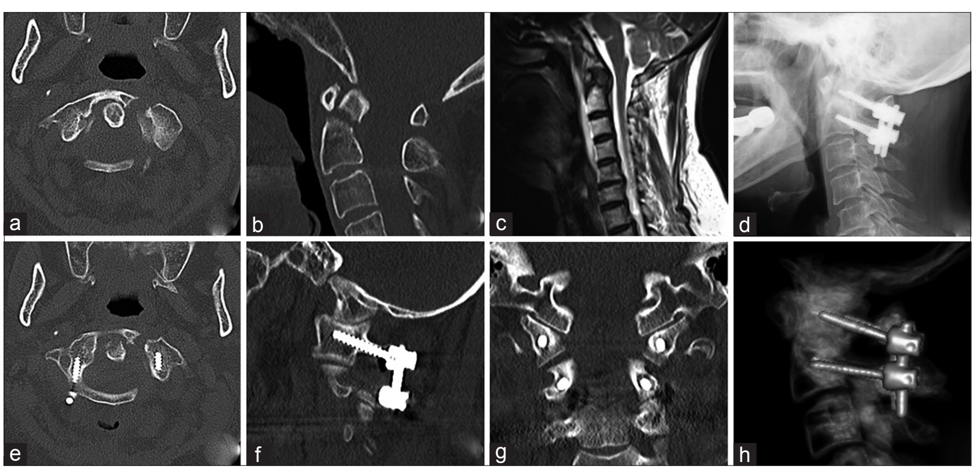

Figure 3: A 65-year-old female patient was admitted to our hospital due to neck pain and restricted neck motion from fall down injury 2 months after conservative treatments in halo vest. Computed tomography scanning (a and b) and magnetic resonance imaging (c) showed that this patient suffered Jefferson combined with type II odontoid fractures. Finally, the patient underwent the posterior C_1–C_2 pedicle screw internal fixation under general anesthesia (d-h)

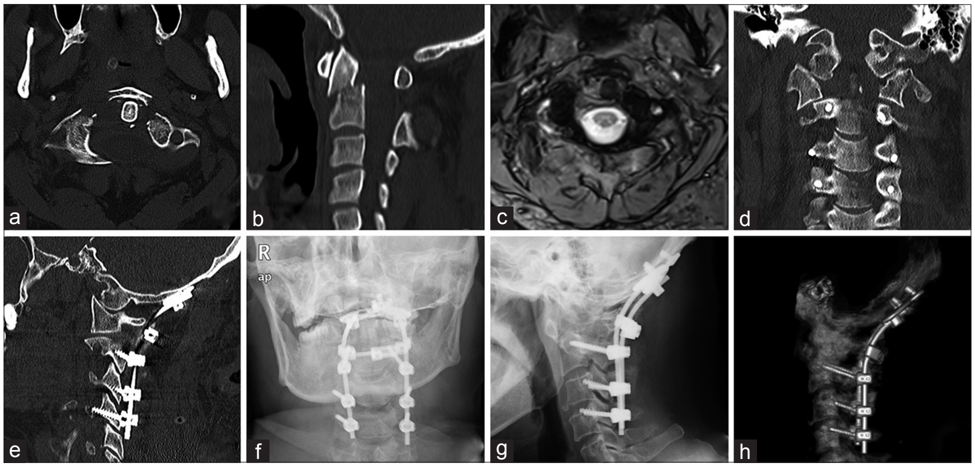

Figure 4: A 59-year-old male patient was admitted to our hospital due to neck pain and restricted neck motion as well as incomplete limbs paralysis (ASIA B) from fall down injury 5 h. The patient was treated with occipitocervical fusion for Jefferson fractures type II odontoid fractures. (a-c) Magnetic resonance imaging, computed tomography, and three-dimensional reconstruction before treatment. (d and e) Computed tomography and three-dimensional reconstruction at 5 days after operation. (f-h) X-ray, computed tomography, and three-dimensional reconstruction at 3rd month after operation

in the cephalad direction [Figure 5]. The entry point of C_2 pedicle screw was exposed at the cranial and medial quadrant of the isthmus surface of C_2 and the direction of screw insertion was approximately 20°–30° with respect to the medial and cephalad convergent directions [Figure 3]. In particular cases, the occipital screws ranged from 6 to 14 mm in length and were placed within 1 cm of the midline just caudal to the union [Figure 4]. The pilot hole of the screw was drilled, tapped, and inserted a 3.5-mm polyaxial screw and the screw position identified through C-arm fluoroscopy. Then, we carefully regulated the patient's head position with the help of the assistant to achieve a satisfactory reduction and fixed it to the rod to maintain the alignment used the reduction apparatus. If necessary, autogenous bone was tightly placed on the lateral portions of the posterior arches of C_1 and C_2.[14]

Dexamethasone injection (10 mg/day) and mannitol injection (250 ml/day) were given intravenously into patients with neurological symptoms for 3 days after operation.[15,16] The drainage tube was removed according to seroma volume of drainage during 48 h postoperatively. The operated patients were placed on a soft cervical collar for 2–3 months when they move down the ground.

Outcome measures and followup evaluation

Clinical assessments were done immediately after surgery 1 week after operation. Followup evaluation was scheduled for every 3 months within 1 year as well as every 6 months 1 year later. The visual analog scale (VAS) score and neck disability index (NDI) score were, respectively, used to evaluate residual pain and cervical vertebra activity, while the American Spinal Injury Association (ASIA) scale was used to assess neurologic function. Bone fusion was used as a means of radiological assessment on the cervical spine X-ray and CT scan. X-ray and CT scan done at every visit till fusion were seen according to our followup schedule. All data were collected by one independent spine surgeon (ZhongSheng Zhao and YingSheng Zhang) who was not participated in patient management.

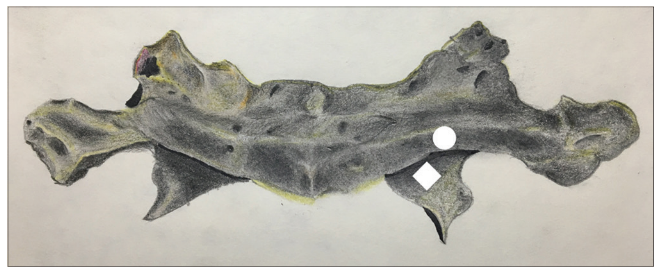

Figure 5: Sketch map of screw entry point. ◊=Screw entry point of Harms technique, ○=Screw entry point of Tan technique (our surgical method)

Statistical analysis

All data were analyzed by SPSS 20.0 software (IBM Corp, Armonk, NY, USA). The difference between preoperative and postoperative VAS score or NDI score was analyzed by independent-sample *t*-test or Mann–Whitney U-test of nonparametric tests, with $P < 0.05$ defined as being statistically significant.

Results

Two patients were excluded from nonsurgical group because their followup period was less than 12 months. Twenty one patients had regularly followed up for an average of 23.9 months and recovered from their fractures between 10 and 16 weeks. In the nonsurgical group, nine patients had finished the treatment by halo vest immobilization for a period of 10–16 weeks and two patients had worn collar for a period of 12–16 weeks. In the two groups, bone fusion was evident at a mean of 7.2 ± 1.5 (range 6–9) and 7.4 ± 2.1 (range 6–12) months after treatment with no statistical difference ($P < 0.05$).

There was no statistical difference in VAS score or NDI score at the two periods of pretreatment and the followup of 12 months (P < 0.05). The VAS score and NDI score in two groups are represented in Table 2 in detail. Our results showed that the mean VAS score decreased separately from 5.9 ± 1.1 and 6.1 ± 0.8 before treatment to 1.9 ± 0.3 and 1.7 ± 0.9 at the followup of 12 months in both nonsurgical group and surgical group. The mean NDI score improved from 41.3 ± 1.1 and 41.7 ± 1.6 preoperation to 11.1 ± 1.2 and 10.6 ± 2.0 at the followup of 12 months [Table 2]. No patient was experienced worsening neurological function related to the treatment or during followup. Compared with their preoperative ASIA scale (1 ASIA B and 8 ASIA D), we observed a preferable improvement of scales at the 3rd month followup (2 ASIA D and 7 ASIA E).

There are corresponding complications in both two groups. In the nonsurgical group, one patient had occurred nonunion at the 3rd month followup which required later surgical treatment [Figure 3] and one patient with halo vest immobilization had occurred pin site infection. In the surgical group, occipital cervical pain in one case was managed by neurotrophic drug treatment and symptomatic treatment, and cerebrospinal fluid leakage in one case was solved by lumbar cisterna drainage.[17]

Discussion

Treatment of combined atlas fracture with type II odontoid fractures

Combined atlas fractures and type II odontoid fractures are rare and unique acute injuries which account for nearly 1.2% of all cervical spine injuries, with a higher incidence of neurological morbidity than isolated C_1 and C_2 fracture.[1,3-5] In our study, the main causes are the bruise injury caused by heavy object in elderly populations, traffic accident injury in young adults, and drifting-down injury. Biomechanical researches have shown that the mechanism of C_1-type II odontoid fractures was a sudden axial load producing the C_1 fracture coupled with a flexion force resulting in odontoid fracture.[6,18] Always, the clinical treatment strategy for C_1-type II odontoid fractures is still under debate.[3,8,9] The fractures are often present management challenges owing to not only the unique anatomy and biomechanics of the atlantoaxial complex but also the occurrence of neurological deficits, VA injury, and mortality during trauma.

In our study, nonsurgical treatments, which include traction, semi-rigid immobilization (collar), and rigid immobilization (halo vest),[19] could gain good efficacy in the treatment of stable C_1-types II odontoid fractures in 11 patients. However, one patient had developed nonunion after nonsurgical treatment which required surgical treatment [Figure 3]. Similarly, some studies have demonstrated that nonsurgical treatment for unstable C_1-type II odontoid fractures has a high risk of complications, especially nonunion of fracture result from loss of reduction.[1,10,20] Furthermore, the decision to use nonsurgical treatment requires a long treatment period and constant vigilance to prevent such complications and potential risks in treatment.[19] If the likelihood of nonunion was high when nonoperative therapy alone was undertaken, then early surgery was recommended. In short, we choose nonsurgical treatment or surgical treatment according to the following three aspects.

The nature of C_1 fracture

First, we have classified all cases of C1-type II odontoid fractures in a simple way [Figure 1]. The fractures were divided into four categories according to the Jefferson classification: type II odontoid fracture combined with anterior ring fracture, posterior ring fracture, lateral mass fracture, and Jefferson's fracture.[8,9] Then, the next treatment plan was analyzed and chose in this classification.

The stability of C_1 fracture

The stability of C_1 fracture can be determined to choose the treatment method by combining synthetically with clinical symptoms and radiography examination. The transverse atlantal ligament (TAL) is the key structure that gives the anterior stability of atlas and prevents atlas from slipping on the axis. The TAL was judged to evaluate the integrity of the TAL by measuring lateral mass displacement (LMD). According to "rule of Spence," there is high likelihood of TAL rupture if the total LMD exceeds 6.9 mm, and TAL injury is unlikely if LMD is <5.7 mm. If the TAL is intact, then the C_1 ring structure may heal if an external fixation alone is used.[8] Therefore, collar or halo vest immobilization would be appropriate treatment for those C_1-type II odontoid fractures with stability of atlantoaxial joint and atlantooccipital joint. If the TAL is disrupted, and in some cases of Jefferson's fracture of the atlas with widely splayed lateral masses, surgical fixation treatment may be desirable [Figure 1].

The stability of C_2 fracture and atlantoaxial joint

Atlantoaxial stability, one of the key points of treatment selection, can be estimated by the factors on the

Table 2: Clinical assessment of patients in the two groups

Groups	VAS			NDI			Bone fusion (months)	Complication (%)
	Pre	Post	Post 12 months	Pre	Post	Post 12 months		
Nonsurgical	5.9±1.1	3.6±0.8	1.9±0.3	41.3±1.1	24.8±1.2	11.1±1.2	7.2±1.5	18.2 (2/11)
95% CI	5.1-6.7	3.0-4.2	1.7-2.1	40.5-42.1	23.9-25.7	10.2-12.0	6.1-8.3	
Surgical	6.1±0.8	4.5±1.0	1.7±0.9	41.7±1.6	26.4±1.7	10.6±2.0	7.4±2.1	20.0 (2/10)
95% CI	5.5-6.7	3.8-5.2	1.1-2.4	40.7-42.8	25.2-27.5	9.3-12.0	6.0-8.8	

CI=Confidence interval, VAS=Visual analog scale, NDI=Neck disability index atlantodental interval (ADI), displacement of odontoid fracture, and angulation of displacement.[9] Studies have shown that there is high likelihood of atlantoaxial instability if the ADI exceeds 5 mm and odontoid fracture displacement with more than 6 mm. If the atlantoaxial joint was regarded as stable, nonsurgical treatment should advocate. If C_1-type II odontoid fractures with atlantoaxial instability, the surgical treatment should be received [Figure 1]. This is the key step to make choice of nonsurgical treatment or surgical treatment.

Choice of surgical method for combined atlas fracture with type II odontoid fractures

The goals of surgery for C_1-type II odontoid fractures are to reduce the fracture, recover spinal column sequence, obtain stability, preserve mobility, and protect neurological function.[3,5] It can be quite difficult to balance these factors equally when determining the most effective operation to perform. There are some issues to consider when choosing a specific fixation. According to our literature review and the results presented here, the first thing is to ensure the integrity and stability of the bone and/or ligament.[8,18] Meanwhile, the fixation and operation should maintain spinal motor function as much as safely possible. Besides, the rate of fusion and the incidence of complications are also essential considerations in the selection of fixed methods.

Currently, clinical researches have shown that three forms of internal fixation including Magerl technique,[21] Harms technique,[22] and posterior pedicle screw fixation[11,23,24] have been mainly used to $C_{1–2}$ fusion for C_1-type II odontoid fractures. Magerl technique needs to be operated in an advanced technology for reduction of atlantoaxial complex before screw placement and may easily injure VA due to sufficient available space in the pedicle during placement of the screw.[25,26] Harms technique was achieved atlantoaxial stabilization in the overall rigidity biomechanically using the C_1 lateral mass and the C_2 pedicle [Figure 5]. However, it is reported that the C_2 pedicle screw placement easily leads to C_2 nerve root injury, venous plexus hemorrhage and not easily stanched.[27,28]

Synthesizing various factors in the influence situation, posterior pedicle screws fixation, is dominating approach that has been mainly used in 11 patients of our study with the desired effect. Specifically, pedicle screw was held and gasped by the vertebral pedicle which is the strongest and tenacious bony structure in cervical vertebral body.[11,24] Atlantoaxial polyaxial screw and rod system can provide rigid stabilization of spinal three-column structure with more pull-out strength and a longer screw trajectory, and the connecting rod can promote to reduce and stabilize C_1 lateral masses. In addition, compared with the C_1 lateral mass screw of Harms technique, the pedicle screw fixation may avoid to dissect and injure the C_1–C_2 venous plexus and C_2 nerve root during exposure of the C_1 lateral mass [Figure 5].[28] Besides, the pedicle screw fixation, as short segment rigid fixation, reserves cervical vertebrate range of motion in largest extent and minimizes impact on physiological function. Furthermore, C_1-type II odontoid fractures without anatomical reduction preoperatively are reduced and fixed for using leverage principle with elevating pull effect by preshaping rod during operation.

As discussed previously, the nature of C_1 fracture and the atlantoaxial stability in C_1-type II odontoid fractures should be considered when selecting the exact approach. In view of type II odontoid fracture combined with posterior ring fracture or lateral mass fracture with stable atlantoaxial joint, collar or halo vest immobilization is advisable treatment. However, if atlantoaxial instability and/or the transverse ligament is disrupted in type II odontoid fracture combined with anterior ring fracture or Jefferson's fracture, posterior C_1–C_2 pedicle screws fixation can provide greater stability and a higher probability of fusion. Ultimately, if C_1 pedicle screws cannot be placed resulting from atlas pedicle bone defect or the potential risk of VA injury, occipitocervical fusion may be the only alternative.

However, there are potential limitations to our study. First, because complex atlas-axis fractures rarely occur, it was difficult to obtain a sufficient number of patients. Second, the results may be biased due to the small sample size. Third, the understanding of the fractures remained deficiencies; its classification and treatment need further exploration and research. Therefore, future studies with a large sample size and longer term monitoring need to be performed by multiple research center to verify our results.

Conclusions

The C_1-type II odontoid fractures is a very rare injury pattern that can be difficult to treat. We had managed C_1-type II odontoid fractures utilizing several methods of nonsurgical and surgical treatments and outlined our concluding management strategies for the treatment. The results presented here indicate that the treatment principle has yielded promising results as a satisfactory means for the management of C_1-type II odontoid fractures. Furthermore, future studies with a large sample size and longer term monitoring need to be performed by multiple research center to discuss the fractures.

Ethics approval and consent to participate

The research has been approved by The Ethics Committee of Fujian University of Traditional Chinese Medicine and consented by all participants.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Authors' contributions

LB and ZCS made a contribution to design the study and provide critical revisions to this article. ZZS and WGW were responsible for writing the article and acquiring the data. CZD and HYF made a contribution to collecting the data and performed the statistical analysis. LJ and ZYS were responsible for making pictures and searching literature. All authors read and approved the final manuscript.

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