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Treatment of type II odontoid fracture with a novel technique

Titanium cable-dragged reduction and cantilever-beam internal fixation

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Abstract

Surgical methods for type II odontoid fracture can be classified into 2 main groups: anterior or posterior approach. A more effective way to achieve bone fusion with the lowest possible surgical risk is needed. Therefore, the aim of our study was to describe and evaluate a novel technique, cable-dragged reduction/cantilever beam internal fixation for the treatment of type II odontoid fracture.

This was a retrospective study enrolled 34 patients underwent posterior cable-dragged reduction/cantilever-beam internal fixation surgery. Medical records, rates of reduction, the location of the instrumentation and fracture healing during follow-up were analyzed. Once fracture healing was obtained, instrumentation was removed. Neck pain (scored using a visual analog scale [VAS]), neck stiffness, patient satisfaction, and neck disability index (NDI) were recorded before and after removing the instrumentation during follow-up.

The mean duration of follow up was 22.8 ± 5.3 months. There was no iatrogenic damage to nerves or blood vessels. Radiographic evaluation showed complete reduction in the 20 patients with fracture displacement and satisfactory fracture healing in all 34 cases. Titanium cable breakage was observed in 4 patients after fracture healing. After removal of instrumentation, significant improvements were seen in neck-pain VAS score, neck stiffness, patient satisfaction, and NDI (all $P < .01$).

Posterior cable-dragged reduction/cantilever-beam internal fixation was an optimal salvage maneuver to conventional surgical methods such as anterior screw fixation and C1–C2 screw-rod system. The operative difficulty and incidence of nerve and vascular injury were reduced. Its major disadvantage is the exposure and screw-setting at C3, which is left intact in traditional surgery, and it is suitable only for patients with intact C1 posterior arches.

Abbreviations: AOSF = anterior odontoid screw fixation, MRI = magnetic resonance imaging, NDI = neck disability index, VAS = visual analog scale.

Keywords: cantilever beam, internal fixation, odontoid fracture, surgical treatment

1. Introduction

Fracture of the odontoid process comprises 10% to 15% of cervical spine fractures.[1] Type II fractures are the most common, accounting for approximately 60% of odontoid fracture in the general population.[2,3] Surgical treatment proved to have a higher rate of fusion and shorter bone healing times than conservative treatment.[4] And surgical methods for these fractures can be classified into 2 main groups based on approach[5,6]: the posterior approach, which includes posterior wire or cable fixation techniques and rigid segmental techniques (C1–C2 transarticular screws fixation and lateral-mass or pedicle screw fixation), and the anterior approach, which includes anterior odontoid screw fixation (AOSF). Reports on postoperative status after surgical treatment of odontoid fractures are limited to small case series, and it is unclear whether one technique has better outcomes than the others.[7–9] AOSF can preserve atlantoaxial motion with immediate rigid stabilization and high union rates, but requires a reduced odontoid, an intact transverse ligament, and a favorable fracture line to achieve adequate fracture compression.[7] Additionally, the procedure carries associated complications, including screw loosening, loss of reduction, need for reoperation, neurologic injury, dysphagia, dysphonia, and pneumonia.[10–12] Posterior screw fixation of C1–C2 is an increasingly popular surgical method and has wider range of indications and higher rate of fusion compared with AOSF.[7,13] However, screw insertion into this region allows only a small margin for error, especially for placement of the C1 screw, and risks injury to the vertebral artery or spinal cord. In addition, placement of a C1 screw is not suitable in cases of a broken C1 pedicle screw trajectory or anomalies of the C1

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CZ and LW contributed equally to this work.

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Table 1

Baseline data for all patients (N = 34).

Case no.	Sex	Age, y	Cause of injury	Course of fracture, d	Traction time, d	Traction weight, kg	Diagnosis
1	M	44	High falling injury	4	5	5	Fracture with C1–C2 dislocation
2	M	35	Traffic accident	1	4	3	Isolated odontoid fracture
3	F	48	Fall down	2	3	4	Fracture with C1–C2 dislocation
4	M	42	Fall down	2	5	3	Isolated odontoid fracture
5	M	51	Fall down	3	3	2.5	Isolated odontoid fracture
6	M	50	Traffic accident	1	2	5	Fracture with C1–C2 dislocation
7	M	43	Blunt force injury	4	4	5	Fracture with C1–C2 dislocation
8	F	37	Traffic accident	3	2	3	Isolated odontoid fracture
9	F	40	High falling injury	2	6	5	Fracture with C1–C2 dislocation
10	M	29	Blunt force injury	1	7	3	Isolated odontoid fracture
11	M	30	Traffic accident	2	3	5	Fracture with C1–C2 dislocation
12	F	45	Traffic accident	1	3	5	Fracture with C1–C2 dislocation
13	M	38	Fall down	1	4	3	Isolated odontoid fracture
14	M	22	Blunt force injury	6	5	5	Fracture with C1–C2 dislocation
15	M	34	High falling injury	7	4	5	Fracture with C1–C2 dislocation
16	F	36	Fall down	2	3	3	Isolated odontoid fracture
17	M	37	Traffic accident	5	5	5	Fracture with C1–C2 dislocation
18	F	39	Traffic accident	4	5	4	Fracture with C1–C2 dislocation
19	F	40	Fall down	2	4	3	Isolated odontoid fracture
20	M	56	High falling injury	13	4	5	Fracture with C1–C2 dislocation
21	M	52	Fall down	2	2	5	Fracture with C1–C2 dislocation
22	M	38	Fall down	1	3	3	Isolated odontoid fracture
23	M	31	High falling injury	1	3	5	Fracture with C1–C2 dislocation
24	F	32	High falling injury	1	6	5	Fracture with C1–C2 dislocation
25	M	38	High falling injury	2	12	3	Fracture with C1–C2 dislocation
26	M	41	Traffic accident	1	6	3	Isolated odontoid fracture
27	F	40	Traffic accident	3	5	3	Isolated odontoid fracture
28	M	37	High falling injury	8	8	5	Fracture with C1–C2 dislocation
29	M	38	High falling injury	3	6	3	Isolated odontoid fracture
30	M	42	High falling injury	1	7	5	Fracture with C1–C2 dislocation
31	M	40	Traffic accident	2	4	3	Isolated odontoid fracture
32	F	29	High falling injury	2	4	3	Isolated odontoid fracture
33	M	33	High falling injury	1	3	5	Fracture with C1–C2 dislocation
34	M	44	Traffic accident	1	4	5	Fracture with C1–C2 dislocation

posterior arch, lateral mass, or vertebral artery.[14,15] We therefore devised a novel technique: titanium cable-dragged reduction and cantilever-beam internal fixation. In this study, we aimed to describe and evaluate our technique in the treatment of type II odontoid fracture.

2. Materials and methods

2.1. Patients

This was a retrospective study. Between May 2012 and August 2013, we enrolled 34 consecutive patients (10 women, 24 men; mean age, 37.5 years [range, 22–56 years]) treated in our department for type II odontoid fracture with or without atlantoaxial dislocation. Of these 34 patients, 14 had isolated type II odontoid fracture and 20 had type II odontoid fracture with atlantoaxial dislocation, and all patients had no neurological damage. Skull traction (2.5–5.0 kg) was performed in each patient preoperatively. Exclusion criteria were odontoid fracture combined with atlas or other segment fracture, atlantooccipital malformation, severe osteoporosis, active infection, diabetes mellitus, inflammatory spondyloarthropathies such as ankylosing spondylitis or rheumatoid arthritis, and known allergy to titanium. Baseline data of all patients are shown in Table 1.

2.2. Operative technique

All operations were performed by the same surgeon under general anesthesia and neuromonitoring. Skull traction was removed after the anesthesia and the patient was placed in prone position with the head and cervical spine maintained in neutral position using a Mayfield headstock. Surgery was performed via a posterior approach using lateral mass screw-rod fixation and cable as implants (Fig. 1). Before incision, epinephrine diluted to a concentration of 1:500,000 was injected subcutaneously to minimize blood loss. A midline incision and dissection of soft tissue were carried out from the external occipital protuberance to the C3 spinous process to achieve exposure of the posterior arch of C1 and posterior appendicular structures of the C2 and C3 vertebrae. Care was taken that all procedures were done within a distance of 1.2 cm from the midline bilaterally to avoid possible injury to vertebral artery or vein. M6 multidirectional lateral mass screws were then inserted into C2 and C3 bilaterally using the Magerl method (in most cases, 14- or 16-mm multidirectional screws were used). A rod was bent into a U-shaped structure with its head slanting slightly backwards according to the size of the atlantoaxial complex and the degree of subluxation, to provide space for reduction. The 2 arms of the U-shaped rod were then fixed to the 4 screws in a head-up-arm-down position to form a cantilever beam. Subperiosteal

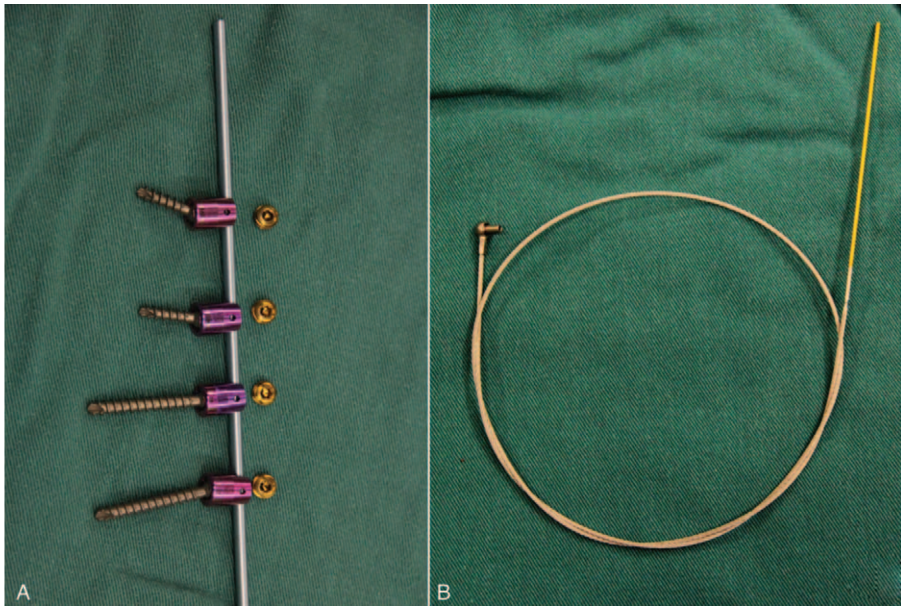

Figure 1. (A) Rod and 4 screws used in the operation. The rod is bent into a U-shape with its head slanting slightly backward according to the size of the patient's atlantoaxial complex; (B) titanium cable used in the operation.

dissection was meticulously done across the interior surface of the posterior arch of C1, using a nerve dissector. On each side, a cable, with its head molded into a hook was then stretched across the interior surface of the posterior arch carefully. When the head of the cable came out from the inferior border of the atlas, it was fastened to the U-shaped cantilever beam to tie it to the posterior arch of C1. The cable was then tightened with a cable tensioner (Medtronic Co., Minneapolis, MN), this instrument was used for tightening the wire during the operation. It gradually pulled the atlas to the top of U-shaped ring, made the atlas and odontoid process move posteriorly relative to the C2 vertebra, and finally made them attach to each other to meet the purpose of reduction and fixation. The whole reduction process took about 5 to 8 minutes. This stem became very simple if satisfactory reduction had been achieved by manual traction during headstock fixation and confirmed by C-arm radiography (26 cases achieved satisfactory reduction by manual traction under general anesthesia) (Fig. 2). Once satisfactory reduction was confirmed by C-arm radiography, the redundant part of cable was removed, the remaining end of cable was bent into a snap-lock to avoid unnecessary injury, the nuts were then wrenched tight to fasten the cantilever beam firmly (Fig. 3), then the incision was closed with a drainage tube left inside. No bone graft was placed in the atlantoaxial region.

2.3. Postoperative management

Because the cervical spine regained stability after the operation, skull traction was not performed in order to facilitate movement. The drainage tube was usually removed within 24 to 48 hours, depending on the amount of drainage fluid. All patients were kept in bed for 3 days before they were allowed to sit up and leave the bed for functional exercises of the extremities. Once the patient became ambulatory, a custom-built orthosis was applied for additional protection for 6 to 8 weeks. Frontal and lateral radiographs of the cervical spine were taken 1, 3, 6, and 12 months postoperatively (Fig. 4), and 3-dimensional CT scans of the cervical spine were taken 3, 6, and 12 months postoperatively to assess bone healing and the location of the instrumentation (Fig. 5). Arrangements were made for patients to undergo a second operation for removal of instrumentation as soon as bone fusion was confirmed on CT scan. Neck pain (scored using a visual analog scale [VAS]), neck stiffness (none/mild/severe),[16] patient satisfaction,[17] and neck disability index (NDI) were recorded before and after removing the instrumentation during follow-up.

2.4. Statistical analysis

Data are presented as mean and standard deviation. The paired t test and Mann–Whitney U test were used for statistical analysis. Probability values less than .05 were considered statistically significant. Analyses were conducted using SPSS Statistics for Windows, Version 17.0 (SPSS, Inc., Chicago, IL).

3. Results

Thirty-four consecutive patients with type II fresh odontoid fractures without neurological symptoms underwent posterior cable-dragged reduction/cantilever-beam internal fixation at our hospital between April 2012 and May 2013. Five patients were not candidates for placement of a C1 screw because of anatomic anomalies (vertebral artery in 2 and lateral mass or posterior arch of C1 in 3) seen on preoperative 3-dimensional CT scans. And the rest of the patients had normal anatomies. The preoperative magnetic resonance imaging (MRI) of all these 34 patients showed no rupture of the transverse ligament, alar ligament, or other ligaments.

No technical problems occurred during placement of the titanium cable or C2 and C3 screws, and no abnormal signal was detected during the process of neuromonitoring. Additionally, no patients experienced neurologic or vascular complications. The operation lasted from 110 to 130 minutes (mean, 122.7 ± 11.0 minutes) with 60 to 220 mL (mean, 112.8 ± 34.5) of blood loss.

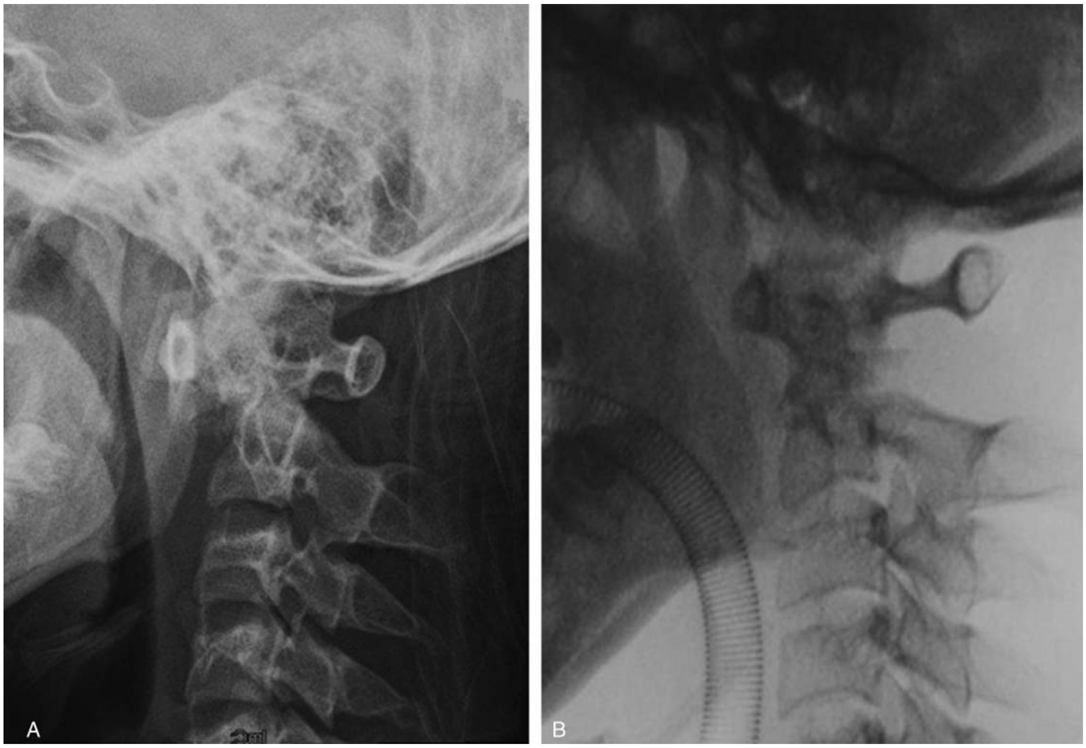

Figure 2. (A) Lateral X-ray of a typical case of odontoid fracture combined with atlantoaxial dislocation; (B) lateral X-ray showing satisfactory restoration of C1–C2 after stabilization on a Mayfield headrest.

No deterioration of neural function, delayed myelopathy, infection, or leakage of cerebrospinal fluid was observed.

The average follow-up period was 22.8 months. Radiographic evaluation of the group at follow-up showed excellent postoperative stability and satisfactory healing of odontoid fracture in all cases, including complete reduction in the 20 cases of preoperative fracture displacement. There were no cases of screw pullout, instrumentation loosening, or rod rupture before bone healing. The titanium cable broke after fracture healing in 4 cases. All patients underwent a second operation to remove instrumentation and returned to work 6 months postoperatively in 22 cases and 8 to 12 months postoperatively in 12 cases. And all patients had not refractured or redislocated after the instrumentation was removed at the time of the last follow-up. Clinical data of all patients are shown in Table 2.

Table 3 presents neck-pain VAS, neck stiffness, patient satisfaction, and NDI scores. After removal of instrumentation, significant improvements were seen in neck-pain VAS score, neck stiffness, patient satisfaction, and NDI (all $P < .01$).

4. Discussion

Type II odontoid fracture is the most common type of dens fracture, often resulting in atlantoaxial instability.[18] Anterior

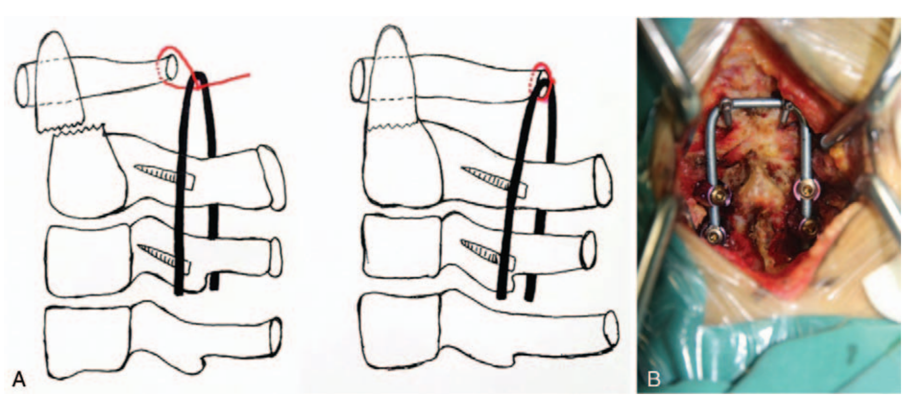

Figure 3. (A) The schematic diagram of the process and principle of cable-dragged reduction/cantilever beam internal fixation. The red part in the figure indicates the titanium cable and the “U”-shaped bold black line indicates the cantilever beam; (B) intraoperative photograph of titanium cable-dragged reduction and cantilever-beam internal fixation.

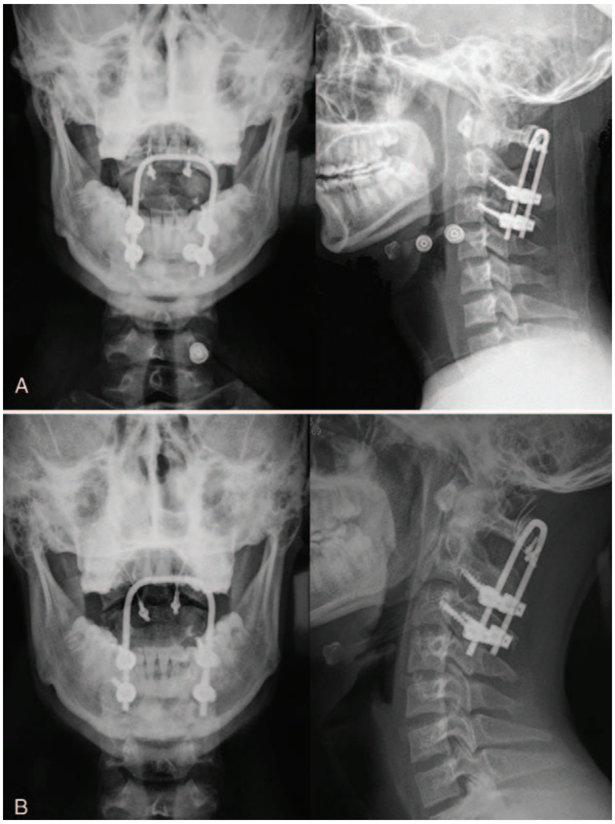

Figure 4. (A) Lateral X-ray 1 week postoperatively showing internal fixation and satisfactory restoration of C1–C2; (B) lateral X-ray 8 months postoperatively showing satisfactory sequence of C1–C2 but rupture of the titanium cables.

and posterior approaches can be used to stabilize these fractures and achieve satisfactory fusion.[19–22] AOSF was introduced in the early 1980s for internal stabilization of type II dens fractures, it provided immediate rigid stabilization and high union rates while preserving atlantoaxial mobility. However, because of reports of associated complications, including screw loosening, loss of reduction, need for reoperation, neurologic injury, dysphagia, dysphonia, and pneumonia,[10–12] this approach has become less popular. Several posterior rigid segmental techniques, such as C1–C2 transarticular-screw or lateral mass- or pedicle-screw fixation can provide excellent stability of the C1–C2 complex.[15,23,24] However, screw insertion into this region allows only a small margin of error, especially for C1 screw placement, and risks injury to the vertebral artery or spinal cord. C1 screw placement is not suitable in cases of interrupted C1 pedicle screw trajectory and anatomic anomalies of the vertebral artery, posterior arch, and lateral masses of the atlas.[14,15,23] It may be difficult to choose the optimal treatment in a patient with acute type II odontoid fracture treatable with either an anterior or posterior approach, and there is no level I evidence to support one surgical approach over another.[5,7,19,25] We believe the ideal operative approach should be simpler and produce the same or better clinical efficacy. In our clinical practice, we have noted the cable-dragged reduction/cantilever-beam internal fixation technique to be simpler to perform than other conventional surgical approaches.

Our technique contains 2 key steps: lateral-mass screw fixation and cable fixation; the procedure should therefore not be attempted before the technical skills of the 2 separate procedures are mastered. The reduction process of dragging and retracting the cable should be performed gently and slowly, with the help of a specialized cable tensioner, and should be monitored by C-arm radiography. Excessive force should be avoided because it may break the posterior arch, or even the cable, or pull the broken dens backwards and worsen cord compression.[26]

Excellent rates of bone union have been reported for conventional posterior approaches, such as C1–C2 wiring, clamping techniques, and C1–C2 transarticular screws,[9,27] but these approaches also have serious disadvantages, such as eliminating normal rotatory motion of the atlantoaxial complex and restricting flexion and extension of the cervical spine. In our

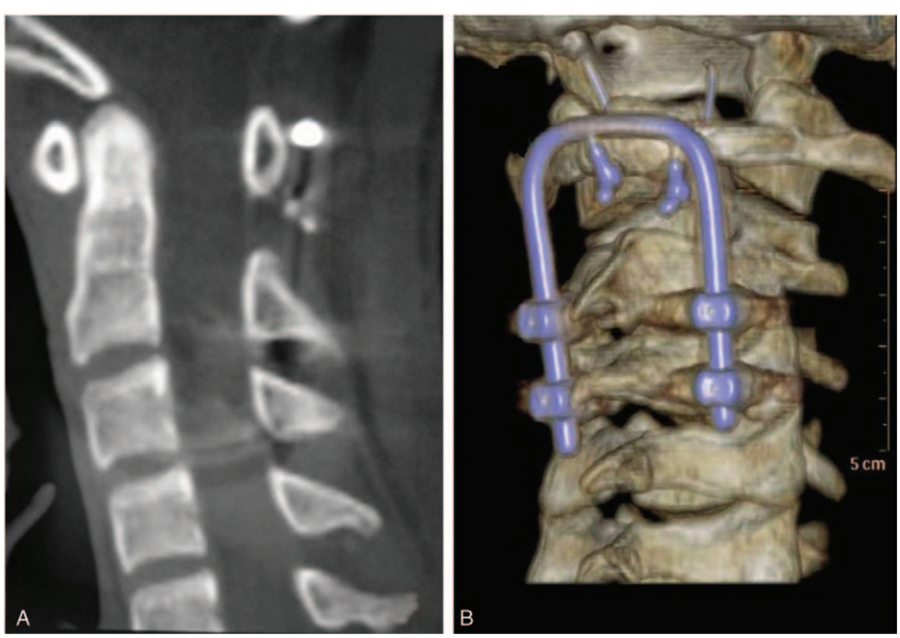

Figure 5. (A) Sagittal computed tomography showing satisfactory healing of odontoid fracture; (B) computed tomography reconstruction clearly showing rupture of the titanium cables.

Table 2

Clinical data for all patients (N = 34).

Case no.	Operation time, min	Blood loss, mL	Neural function (Frankel classification system) Preop	Neural function (Frankel classification system) Postop	Interval of 2 operations, mo	Complications of the internal fixation
1	130	100	E	E	6	None
2	120	80	E	E	6	None
3	125	120	E	E	8	None
4	120	60	E	E	6	None
5	110	70	E	E	10	Cable rupture
6	120	220	E	E	8	None
7	125	130	E	E	6	None
8	120	60	E	E	6	None
9	110	80	E	E	6	None
10	110	65	E	E	6	None
11	120	90	E	E	6	None
12	120	110	E	E	8	None
13	120	100	E	E	6	None
14	130	80	E	E	6	None
15	130	90	E	E	6	None
16	110	60	E	E	6	None
17	110	80	E	E	12	Cable rupture
18	120	130	E	E	6	None
19	120	150	E	E	10	None
20	130	160	E	E	8	None
21	120	90	E	E	10	Cable rupture
22	110	70	E	E	6	None
23	120	80	E	E	6	None
24	115	100	E	E	6	None
25	115	100	E	E	6	None
26	120	150	E	E	10	None
27	125	180	E	E	12	Cable rupture
28	130	100	E	E	6	None
29	130	150	E	E	6	None
30	120	130	E	E	8	None
31	115	160	E	E	8	None
32	115	150	E	E	6	None
33	110	200	E	E	6	None
34	120	140	E	E	6	None

study, bone grafting was not carried out and the instrumentation was removed as soon as possible after CT confirmation of bone healing during follow-up. This allowed patients to perform functional exercise to maximize rotatory and flexion/extension motion. We observed 4 cases of cable rupture during the second operation and analyzed the reasons as followed: all cable rupture happened after fracture union and at 8 to 12 months after the first operation (Table 2). Within 3 months after the first surgery, the cable-dragged reduction/cantilever beam internal fixation offered excellent stability and the patient would reduce the cervical activities because of collar utilization and psychological factors, but 3 months later, patients began cervical functional exercise including extension-flexion and mild rotation without the collar protection, at last, longstanding micromotion between cable, rod, and the posterior arch of atlas could unavoidably lead to fatigue break of the titanium cable. Although the locking of titanium cable could not provide the same solid fixing strength as the screw-rod system, but it did not have any effect on the fracture healing from our clinical results.

Table 3

Cervical functional outcomes before and after removal of instrumentation.

Variable	Before removal	After removal
VAS score	0.8 ± 1.2	0.3 ± 0.6
Neck stiffness		
Severe	5	0
Mild	23	5
None	6	29
Patient satisfaction	6.5 ± 1.2	9.4 ± 0.9
NDI score	8.5 ± 5.5	1.1 ± 1.3

Data are shown as mean ± standard deviation.
NDI = neck disability index, VAS = visual analog scale.

Richter et al[28] tested 6 atlantoaxial fixation techniques and concluded that, biomechanically, 3-point fixation with transarticular screws and the atlas claw provides rigid internal fixation but that, in cases where transarticular screws are not feasible, the claw or lateral-mass screws and isthmic screws are biomechanical alternatives, albeit with reduced immediate stability. Our titanium cable-rod-screw system is similar to the above-mentioned isthmic screws and claw, and is a biomechanical alternative. Although the resulting construct is quite rigid, and all 34 patients in this series had successful fusion, further study will be required to compare the stability of our titanium cable-rod-screw system to that of existing techniques such as the transarticular screw fixation method of Jeanneret and Magerl[29] or C1–C2 rod-screw fixation described by Harms and Melcher[24] and Resnick and Benzel.[30]

In our technique, the fixation segment is extended to C3 to increase the reliability and stability of the foundation of this internal fixation system. Two major advantages of this technique are the removal of risk injury to the vertebral and internal carotid arteries and hypoglossal nerves during C1 screw placement and application to cases not suitable for placement of a C1 screw. We have observed similar operative times and blood loss between conventional posterior surgical approaches, such as C1–C2 pedicle-screw fixation and occipitocervical fusion, and this new technique.

The major disadvantage of this method is that C3, which is left free in traditional atlantoaxial fusion, must be involved in fixation. Another shortcoming is that it can be used only in patients with intact posterior arches in C1. When designing this procedure, we first considered using pedicle screws or facet screws only in C2 to stabilize the support rod. However, we found that the C2 screws were relatively thin and C2 alone could not withstand the force and could slip in a ventral direction during reduction with traction. In our opinion, C1–C2 fixation relying on a rhomboid-shaped titanium cable-plate-screw construct cannot provide adequate stability to resist rotation and will ultimately lead to a reduced rate of bone-fusion rate. It should be noted, however, that a method of titanium cable-screw-plate fixation of the C1–C2 and a case series of eight patients treated successfully using the method has been reported.[31] Therefore, screws were also inserted into the C3 facets to distribute the load required to stabilize the support rod. The results of our clinical application of this technique demonstrated that when facet screws were inserted into both C2 and C3, they could satisfactorily tolerate the force required for reduction and rotation. Our patients were relatively young; it is possible that, in older or osteoporotic patients, C2 and C3 pedicle screws might not be sufficient and that C4 and C5 lateral mass screws might also be required.

Several limitations still exist. Firstly, our study was a retrospective study with small numbers of patients. Secondly, we failed to illustrate the advantage of the secondary surgery for removal of instrumentation, because we did not evaluate the rotatory and flexion/extension motion quantitatively. Thirdly, we did not compare the efficacy of our technique with existing approaches for the treatment of type II odontoid fracture. Therefore, future prospective and controlled studies with larger numbers of patients, various parameters and longer follow-up period are needed. Finally, most of the patients in our study were young and middle-aged adults and further studies with elderly patients who are at high risk for nonhealing of the fracture are needed to evaluate the influence of age.

5. Conclusions

Posterior cable-dragged reduction/cantilever-beam internal fixation was an optimal salvage maneuver to conventional surgical methods such as AOSF and C1–C2 screw-rod system. The operative difficulty and incidence of nerve and vascular injury were reduced, especially for the cases not suitable for placement of C1 screw or odontoid screw. Its major disadvantage is the exposure and screw-setting at C3, which is left intact in traditional surgery, and it is suitable only for patients with intact C1 posterior arches.

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