

# The Long-term Clinical Outcomes of Magerl's Technique Combined with Single Lamina Clamp Internal Fixation in Treatment of Reducible Atlantoaxial Dislocation

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## Research article

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# Abstract

**Background.** To evaluate the long-term clinical outcomes of Magerl's technique combined with single laminar clamp internal fixation in treatment of reducible atlantoaxial dislocation. **Methods.** Data of 21 patients diagnosed with reducible atlantoaxial dislocation underwent Magerl's technique (C1-2 posterior transarticular screw fixation) combined with single laminar clamp internal fixation and fusion were retrospectively reviewed from January 2004 to September 2015. The clinical and radiological outcomes were investigated according to the Symon and Lavender clinical standard, the score of Japanese Orthopaedic Association (JOA), and the imaging index space available for the cord (SAC), the atlas-dens interval (ADI), respectively. The perioperative complications, operative data, and status of bony fusion were also collected and analyzed. **Results.** All the patients were followed up successfully. All the patients achieved substantially bone fusion according to the X-ray and CT scan. There were no intra-operative complications observed. The ADI was corrected significantly with the mean preoperative  $6.13 \pm 1.84$  mm, initial postoperative  $1.62 \pm 0.77$  mm, and the final follow-up  $2.02 \pm 1.01$  mm respectively ( $P < 0.05$ ). The SAC was also improved significantly with the mean preoperative  $10.42 \pm 2.53$  mm, initial postoperative  $17.83 \pm 2.41$  mm, and the final follow-up  $16.91 \pm 2.02$  mm respectively ( $P < 0.05$ ). The clinical recovery rate according to the Symon and Lavender clinical standard and the JOA recovery rate was 90.5% and 81.2% respectively, which showed significantly improved following surgery ( $P < 0.05$ ). **Conclusions.** This study demonstrates that Magerl's technique combined with single laminar clamp internal fixation is effective and reliable in management of reducible atlantoaxial dislocation, which can simplify the operative manipulation and decrease the risk of iatrogenic spinal cord injury.

## Introduction

Atlantoaxial dislocation (AAD) is a common upper cervical spine disorder with or without neurological dysfunction. It occurs when the atlantoaxial joint loses its normal anatomy due to trauma, rheumatoid arthritis, congenital deformities and other reasons<sup>[1]</sup>. Even though conservative treatment, such as halo brace or cast, could be appropriate for few patients, surgical intervention is usually imperative for most patients who suffer from atlantoaxial dislocation.

Conventional posterior atlantoaxial fixation techniques, including wiring, halifax clamps, had been seldom used alone due to frequent association with high rates of pseudoarthrosis and internal fixation breakage<sup>[2, 3]</sup>. With the advent and wide use of pedicle screw insertion techniques in the clinic, it has also been used to treat atlantoaxial dislocation; however, the high vary of the peculiar anatomy of the upper cervical spine makes the transpedicular screw fixation more technically challenging<sup>[4]</sup>. Intraoperative neurological and vascular injuries due to misplacement of screws were reported from 11–66% of injury rate in its early application<sup>[5–7]</sup>.

In 1979, Margel developed a C1-2 transarticular screw fixation technique (Magerl's technique)<sup>[8]</sup>, which was considered as one of the most effective method for management of atlantoaxial dislocation currently<sup>[9, 10]</sup>. This technique outweighs wiring and laminar clamps for outstanding rotational control

proved by biomechanical studies<sup>[11, 12]</sup>. In order to achieve greater stability, some authors combined the Magerl's technique and Gallie or Brooks wiring to treat atlantoaxial dislocation, which could provide a three-point fixation with more stability<sup>[13, 14]</sup>. However, the application of Gallie or Brooks wiring carries a neurologic risk because sublaminar wires are passed under the C1 arch<sup>[2, 15]</sup>.

To solve these problems mentioned above, a modified technique (Magerl's technique combined with bilateral C1 laminar hook fixation) was described<sup>[16]</sup> and showed a better biomechanical stability in treatment of atlantoaxial dislocation<sup>[11]</sup>. In order to simplify this technique and reduce the risk of iatrogenic spinal cord injury caused by operative manipulation, we proposed Magerl's technique combined with single laminar clamp internal fixation as an alternative treatment for atlantoaxial dislocation and this technique showed satisfactory short-term clinical outcomes. In this retrospective study, we aimed to further evaluate the long-term clinical and radiological outcomes of this technique.

## Materials And Methods

### Study Design

This study is a retrospective review of two prospective multicenter databases. One database captured data on upper cervical disease patients from The First Affiliated Hospital of Sun Yat-sen University, and the other captured data from The Seventh Affiliated Hospital of Sun Yat-sen University.

This study was approved by the institutional review board of The First and Seventh Affiliated Hospital of Sun Yat-sen University. Written informed consent had been provided by the subjects (or their representatives) involved in this study.

### Inclusion and Exclusion Criteria

Patients diagnosed with reducible atlantoaxial dislocation were included in this study. Patients with irreducible atlantoaxial dislocation, dysplasia or absence of the posterior arch of the atlas, high arch deformity of vertebral artery or severe organ dysfunction such as heart, liver and renal failure leading to intolerance of surgery were excluded.

### Data Source

From January 2004 to September 2015, a total of 21 patients with reducible atlantoaxial dislocation were included in this study. There were 14 males and 7 females. Mean age at surgery was  $34.3 \pm 7.1$  years (range 23-48yrs). Clinical information was shown in Table 1. The atlantoaxial dislocation resulted from traumatic dislocation in 9 cases (42.9%), rheumatoid arthritis in 4 cases (19.0%), and congenital deformity in 8 cases (38.1%). Four cases (19.0%) accompanied with odontoid fracture. Referring to the Symonand Lavender clinical standard<sup>[17]</sup>, 8 patients were graded mild, 9 patients graded moderate, 3 patient graded severe, and one patient graded very severe. According to the scoring of Japanese Orthopaedic Association (JOA)<sup>[17]</sup>, the average score was  $9.27 \pm 2.76$  points preoperatively.

# Preoperative Care

All patients underwent preoperative skull traction. According to the type of the individual case, a weight of 3–6 kilogram with an appropriate angle was applied to stabilize and reduce the dislocation. For patients with insufficient reduction, bidirectional traction was conducted until the reduction was satisfactory. A thorough preoperative imaging analysis of the atlantoaxial articulation, based on X-ray, three-dimensional CT scan, and MRI was conducted to evaluate the status of dislocation, whether the spinal cord was compressed, and whether there was a high-riding VA(vertebral artery) under the lateral mass of C2 for the safe placement of the C1-2 transarticular screw.

## Surgical Procedure

All surgeries were performed with the patients placed in the prone position after anesthesia. Mayfield head holder was used to fix the head while maintaining C1-C2 reduction confirmed with C-arm fluoroscopy (Fig. 1). Posterior midline exposure was made from the C1 to the C2 spine process. The Vertex laminar elevator was used to strip away the soft tissue above the posterior arch of C1 and below the laminar of C2. Exposure of the posterior C1 arch should not be exposed too wide to damage the vertebral artery. After the excision of ligament and soft tissue between C1 and C2 spinal process, epidural space was exposed. Careful dissection with a small dissector was used to expose the upper and inner side of C2 vertebral lamina. The inner wall and the angle of C2 pedicle and the screw trajectory was probed and determined with greater occipital nerve retracted cranially.

The screw entrance point was approximately at 3 mm superior-lateral the inner edge of the C2 inferior articular process. The 3.5 mm drill bit was used to drill cautiously into the C2 isthmus. The appropriate drill direction, which were determined according to the C-arm fluoroscopy, was 40°-45° cephalad aiming to the anterior tubercle of C1 and 5°- 10° medially near the inner surface of the isthmus of the C2. The drill bit passed through the posterior part of the atlantoaxial articulations and went into the lateral mass of C1. The length and wall of the hole was palpated using a small ball probe to guarantee that no cortical breakthroughs into the spinal canal or other spaces. A hollow screw with diameter of 3.5 mm and appropriate length was cautiously inserted under the C-arm X-ray fluoroscopy, confirming that the screw had passed through C2 lateral mass, atlantoaxial joint, and reached the anterior tubercle of anterior C1 arch on the lateral view.

The bone grafting bed was prepared with use of the high speed drill to remove the cortical bone of the lower part of the C1 posterior arch and the upper edge of the C2 laminar, and a superior notch was made in the spinous process of C2. The bone ridge between the laminar and spinal process of C2 was trimmed to fit the shape of the laminar clamp. A bone block of double-cortex iliac bone, approximately 3cm × 2cm × 1 cm, was harvested from the left posterior superior iliac spine and trimmed to be amphicoelous at the lower edge. The bone block was inserted and wedged between the C1 posterior arch and the C2 spinous process.

The upper laminar clamp was inserted firstly, hanging on the posterior arch of atlas, and then the lower one was inserted through the C2 spinous bifurcation and hanging on the junction of C2 lamina and spinous process. Finally, the sleeve was used to connect the two clamps on the middle line and the compressor was applied to tighten the inner fixation systems at both sides simultaneously (Fig. 2).

Closure of the wound was performed in layers with the routine use of a suction drain which was removed within 24 hours. All patients had prophylactic antibiotics coverage for 24 hours. A hard cervical collar was used for postoperative immobilization for 6 ~ 10 weeks.

## Clinical and Radiological Evaluation

The clinical and radiological outcomes were assessed preoperatively, at 1,3,6,12,24- month postoperatively, and at final follow-up period, respectively. Clinical assessment was performed by an independent examiner at each visit, according to the Symonand Lavender clinical standard<sup>[17]</sup>, and the score of Japanese Orthopaedic Association (JOA). The recovery rate of JOA score = (preoperative JOA score-postoperative JOA score)/(17-preoperative JOA score)<sup>[18]</sup>. Radiological assessment involved plain x-ray film and MRI for the assessment of the atlas-dens interval (ADI) and the space available for the cord (SAC), respectively<sup>[19]</sup>. The perioperative complications, operative data, and status of bony fusion were also collected and analyzed. Atlantoaxial fusion standard was defined as appearance of continuous callus between the posterior arch of C1 and the spinal process of C2 based on the CT scan<sup>[20]</sup>.

## Statistic Analysis

All the data were analyzed statistically using SPSS package (version 25.0, Chicago, IL, USA). The data of JOA score, ADI and SAC were analyzed using One-way Analysis of Variance. The recovery rates was calculated by Wilcoxon signed rank test, with a confidence interval of 95%. Data were presented as the mean  $\pm$  standard deviation. Statistical significance was indicated at  $P < 0.05$ .

## Results

All the patients obtained sufficient reduction and internal fixation with no intraoperative complications happened. All the patients had no neurological deterioration after surgery. The average total operative time and blood loss was  $116.3 \pm 28.9$  minutes (range, 72  $\pm$  160minutes) and  $174.3 \pm 91.6$  ml (range, 70  $\pm$  420 ml), respectively. The average hospital stay was  $11.4 \pm 2.4$  days (range, 8-17days). All the patients were followed up successfully, and the average follow-up period was  $78.2 \pm 35.7$  months (range, 25–131 months). Fusion was evident at 3–6 months postoperatively in all cases (Fig. 3).

## Clinical and radiological outcome

A summary of clinical outcomes was provided in Table 2. Of the total 21 patients, 17 patients improved at least one grade at one month postoperatively, and the mean improvement rate was 81.0% ( $Z=-3.318$ ,  $P = 0.001$ ). At the final follow-up, 19patients improved at least one grade and the mean improvement rate

was 90.5% ( $Z=-4.428$ ,  $P < 0.001$ , Table 2). There was a significant improvement between preoperative JOA score and either 1-month follow up or the final follow-up JOA score ( $F = 37.60$ ,  $P < 0.001$ ; Table 2), with the recovery rate of 81.2% at the final follow up period ( $Z=-5.164$ ,  $P < 0.001$ ).

A summary of radiological outcomes was provided in Table 3. The mean SAC at 1-month postoperation and at final follow-up was  $17.07 \pm 1.27$  mm and  $16.60 \pm 0.75$  mm respectively, both of which improved significantly compared with that of preoperation ( $F = 140.28$ ,  $P < 0.001$ ; Table 3). The mean ADI also corrected significantly after surgery ( $F = 19.41$ ,  $P < 0.001$ ; Table 3), and there were no significant correction loss at the final follow-up ( $F = 19.41$ ,  $P > 0.05$ ).

## Complications

The complications observed included wound lipoliquefaction and delayed union of one patient without any symptom complained. The wound was debrided and resutured successfully. One case suffered superficial infection, which was cured 2 weeks after medication. During the follow-up period, instrument related complications like breakage of screw were not found.

## Discussion

The objective of surgical intervention is to reconstruct the stability of atlantoaxial articulation. The surgical methods can be divided into anterior and posterior approach. However, the anterior approach is seldomly used due to the difficulty of exposure and high frequency of complications. The posterior approach, including wiring, apofix clamp, C1-2 pedicle or transarticular screws is the preferred method to be selected in the clinic. Each type of technique has a unique set of risks and benefits.

Although posterior wiring techniques, such as Gallie and Brooks technique, are still used currently, they are considered as less stable compared to C1-2 pedicle or transticular screws based on a biomechanical point of view<sup>[21-23]</sup>. In addition, it has a potential risk of neurological deficit when the sublaminar wires are passed under the C1 arch. In order to avoid the neurologic risk caused by the sublaminar wires, some professors designed apofix laminar clamp, which uses laminar hook to fix the C1-2 posterior structure, however, it does not improve biomechanical stability as a simple one-point fixation<sup>[24]</sup>.

In 1986, Magerl and Seemann initially described posterior atlantoaxial transarticular screw fixation technique for stabilization of C1 and C2 (Magerl's technique). It has been considered to be one of the most rigid atlantoaxial posterior stabilization techniques multidirectionally<sup>[24]</sup>, and was reported to achieve good clinical outcomes<sup>[8, 25, 26]</sup>. However, from a biomechanical viewpoint, it is merely a two-point fixation and cannot provide the good stability in 3-D motion of the atlantoaxial articulation, especially in extension and flexion<sup>[22]</sup>. To achieve more stabilization, Guo et al<sup>[24]</sup> reported using Magerl's technique combined with bilateral laminar clamps internal fixation for treatment of atlantoaxial dislocation in 36 cases, and attained effective anatomic reduction and satisfactory clinical outcomes, with no intraoperative complications<sup>[24]</sup>. Bone fusion was obtained in all cases 6 months after surgery, and no failure of internal fixation was observed during the 7-years follow up period. It revealed that Magerl's

technique combined with bilateral laminar clamps internal fixation could provide reliable biomechanical stability, as well as carry a higher bony fusion rate and reduce the risk of iatrogenic injury of vertebral artery and spinal cord<sup>[24]</sup>.

Based on the technique mentioned above, we modified the former technique as Magerl's technique combined with single laminar clamp internal fixation, composed of bilateral atlantoaxial transarticular screws and middle laminar clamp fixation, to create a 3-point fixation which could result in stronger stabilization theoretically. In our study, we used this modified technique in management of atlantoaxial dislocation in 21 cases. All the patients showed satisfactory bone union and anatomic reduction, with the atlas-dens interval (ADI) corrected from preoperative  $6.25 \pm 0.74$  mm to postoperative  $2.17 \pm 2.50$  mm and final follow-up  $2.61 \pm 3.08$  mm. The space available for the cord (SAC) at C1-2 segment also significantly increased from 10.42 mm to 16.91 mm, similar to the data reported by Guo<sup>[24]</sup>. In addition, the clinical function also improved significantly with the JOA recovery rate of 81.2% at the final follow up period. In addition, there was no instrument complications occurred during the follow up. Therefore, we thought that this technique further simplified the operative manipulation by merely using one atlantoaxial laminar clamp to establish an ideal 3-point fixation and reduced the risk of spinal cord injury associated with operation, which meet the need of clinics.

Many of the posterior surgery-associated complications were graft-related problems<sup>[27-29]</sup>. In the report published by Bahadur et al<sup>[27]</sup>, patients with atlantoaxial dislocation underwent Magerl's technique combined with laminar bone graft and Brooks technique. The outcome suggested that failure of bone fusion still existed despite of sufficient stabilization, which may be related to insufficient preparation of bone graft bed or unsuitable placement of bone graft. In our experience, in order to increase the fusion rate, the cortical bone of the lower part of the C1 posterior arch and the upper edge of the C2 laminar and spinal process should be removed using the high speed bur, to prepare for the bone graft bed. In addition, the bone block harvested from the iliac bone should be trimmed to butterfly shape, which could keep it riding on the C2 spinal process steady. What is more, the lower single laminar clamp should be exactly inserted through the C2 spinous bifurcation, which makes it more stable. The compressor should be used to tighten the two laminar clamps that were connected with a sleeve in the middle line, which could keep the bone graft compact.

It's worth noting that Magerl's technique combined with single laminar clamp internal fixation is only appropriate for management of reducible atlantoaxial dislocation<sup>[30]</sup>. Thus, anatomic reduction of atlantoaxial dislocation should be confirmed before the surgery, In our experience, preoperative skull traction is essential for reducing atlantoaxial dislocation as much as possible. In addition, Mayfield head holder is helpful for maintaining C1-2 reduction, which should be confirmed with C-arm fluoroscopy or radiography preoperatively. It should be mentioned that, in the cases combined with vertebral artery deformity, such as vertebral artery high-riding or tortuosity, transarticular screws insertion will increase the risk of vertebral artery injury. Paramore et al<sup>[31]</sup> reviewed the CT scans of 94 cases with atlantoaxial dislocation, and found that the incidence of high-riding vertebral artery was 18%. In this study, three-

dimensional CT scan and MRA was performed for the patients to exclude the vertebral artery deformities before operation. In addition, this Magerl's technique combined with single laminar clamp internal fixation is also not appropriate for treatment of the patients with C1 posterior arch dysplasia or absence.

Although satisfactory clinical outcomes were obtained in this study, the current study has some limitations. This was a small-sized retrospective study and the number of patients was restricted due to the low incidence of atlantoaxial dislocation. Another limitation is that this study was just a preliminary report about an early technical experience. A multicenter prospective controlled study of atlantoaxial dislocation should be considered in the future.

## Conclusions

This study demonstrates that Magerl's technique combined with single laminar clamp internal fixation is effective and reliable in management of reducible atlantoaxial dislocation, which can simplify the operative manipulation and decrease the risk of iatrogenic spinal cord injury. One important reminder is that this method is merely suitable for the treatment of reducible atlantoaxial dislocation, without vertebral artery deformity, C1 posterior arch dysplasia or absence.

## Declarations

**Abbreviations:** AAD: Atlantoaxial dislocation; JOA: Japanese Orthopaedic Association; VA: vertebral artery; ADI: atlas-dens interval; SAC: space available for the cord.

**Ethics approval and consent to participate:** This study was approved by the Institutional Review Board of The First Affiliated Hospital and The Seventh Affiliated Hospital of Sun Yat-sen University. Informed consent was obtained from all individual participants included in the study.

**Consent for publication:** All the authors agree to publish this manuscript.

**Competing interests:** All the authors declare that they have no competing interest.

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**Authors' contributions:** XW, HW and GC carried out the acquisition and interpretation of data, and drafted the manuscript substantially. SC and LY carried out the clinical data collection. XP and LW carried out the radiological measurements, the acquisition and interpretation of data. DH and HS carried out the statistical analysis. FW and SL carried out the design of this study, revised the manuscript critically and gave final approval of the version to be published. All authors read and approved the final manuscript.

**Availability of data and materials:** The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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## Tables

Table 1. Summary of the Data of 21 Patients in this Study

Case	Age/gen-der	Cause	Symonand Lavender clinical standard	Hosp.stay (days)	Results
1	36/M	CD	moderate	13	Union
2	31/M	TD	severe	9	Union
3	28/F	CD	mild	12	Union
4	32/M	TD	moderate	12	Union
5	40/M	CD	moderate	10	Union
6	39/M	CD	mild	11	Union
7	38/F	CD	mild	10	Union
8	41/F	TD	severe	8	Union
9	42/M	TD	severe	11	Union
10	48/F	RA	very severe	14	Union
11	25/F	TD	mild	15	Union
12	39/M	CD	moderate	12	Union
13	42/F	RA	moderate	17	Union
14	43/M	RA	moderate	8	Union
15	31/M	CD	mild	10	Union
16	34/M	TD	severe	11	Union
17	29/M	CD	mild	9	Union
18	26/M	TD	moderate	9	Union
19	23/F	TD	moderate	12	Union
20	26/M	TD	moderate	13	Union
21	27/M	TD	mild	14	Union

TD, traumatic dislocation; RA, rheumatoid arthritis; CD, congenital deformity; ASIA, American Spinal Injury Association; FU, follow-up.

Table 2. Clinical Outcomes Pre and Postoperatively

Variables	Preoperation	One-month post-operation	Final follow-up
Symon and Lavender clinical standard(No. of patients)			
Normal	0	12	17
Mild	7	4	1
Moderate	9	3	2
Severe	4	1	1
Very severe	1	1	0
JOA score	8.91±2.43	13.05±2.67*	15.48±2.34*

JOA indicates Japanese Orthopaedic Association;

\* Significantly difference when compared with that of preoperation

Table 3. Radiological Outcomes Pre and Postoperatively

Variables	Preoperation	One-month Postoperation	Final follow-up	P value*	P value**
SAC	10.01±2.19	17.07±1.27	16.60±0.75	<0.001	<0.001
ADI	6.25±0.74	2.17±2.50	2.61±3.08	<0.001	<0.001

All values are shown as average ± standard deviation

SAC indicates space available for the cord; ADI, atlas-dens interval

P\*: Postoperative VS Preoperative;

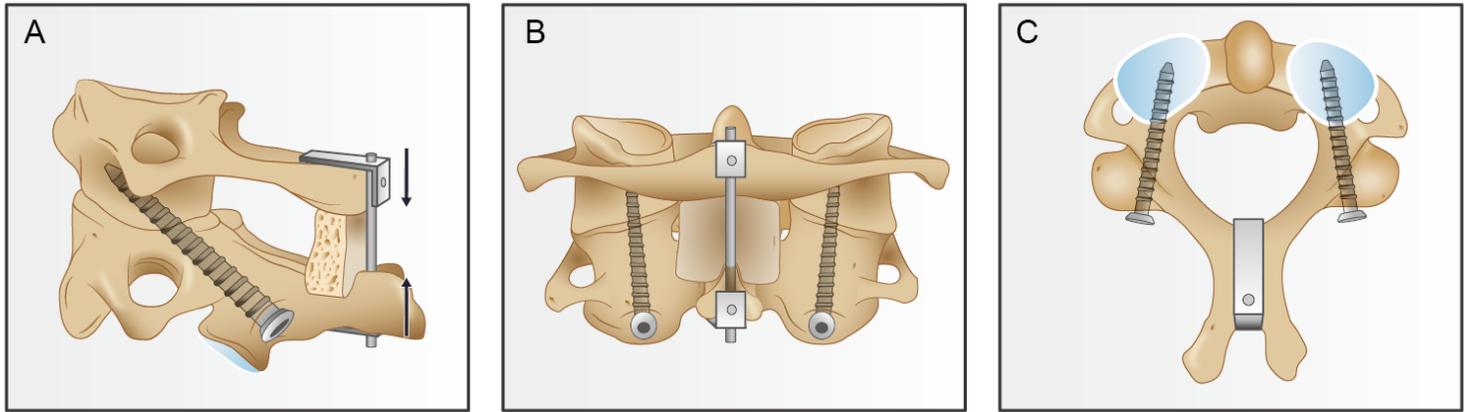
P\*\*: Follow up VS Postoperative

## Figures



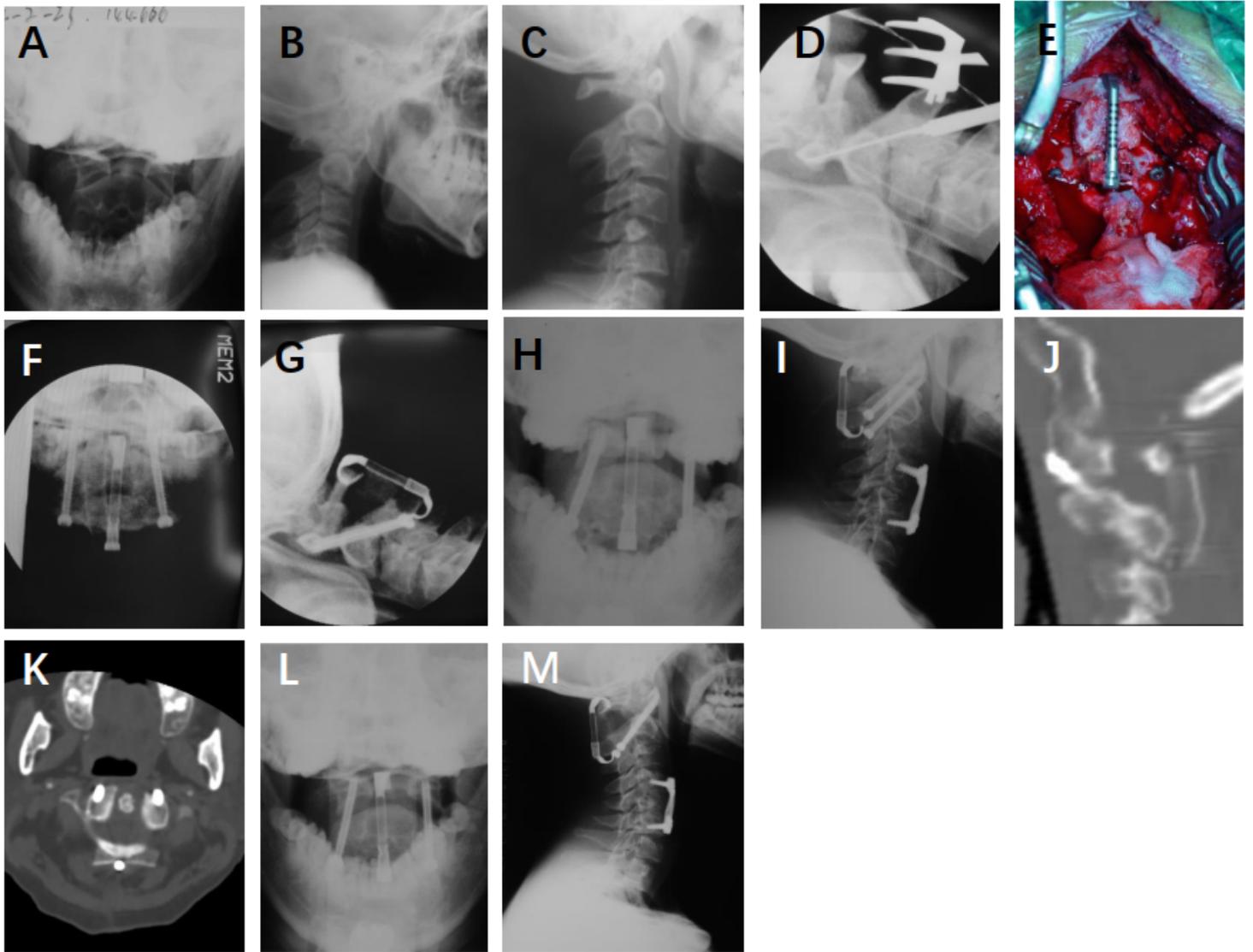
Figure 1

The prone position of the patients after anesthesia. Mayfield head holder was used to fix the head while maintaining C1-C2 reduction confirmed with C-arm fluoros-copy.



**Figure 2**

The schema of Magerl technique combined with single laminar clamp internal fixation in management of atlantoaxial dislocation. A: After bone grafting, we firstly inserted the upper laminar clamp which hung onto the posterior arch of C1, followed insertion of the lower laminar clamp, and then, the laminar clamps were connected using a sleeve and compressed from opposite direction, which made the bone graft and the lamina of C1-2 tightly touched each other. B: The bone block was trimmed to be amphicoelous at the lower edge and was compacted tightly between the posterior laminae of C1-2 and the laminar clamps. C: The scheme of transverse section at C2 level.



**Figure 3**

A 42-year-old male who was diagnosed old C5 and odontoid fracture combined with atlantoaxial dislocation. a,b: Preoperative X-ray at 5-month after traumatic injury showed odontoid fracture combined with atlantoaxial dislocation. c: After skull traction for one week, the atlantoaxial dislocation was reduced preoperatively. The preoperative lateral X-ray also showed old C5 vertebral fracture. d: The right location and length was confirmed under fluoroscopy during operation. e: The iliac-crest bone graft was cropped and compacted into the space between C1-2 and laminar clamp. f,g: The reduction of atlanto-axial dislocation and the location of internal fixation were confirmed under fluoroscopy during operation. h,i: The X-ray showed that the atlanto-axial dislocation was reduced and fixed by Magerl's technique combined with single laminar clamp internal fixation, the C5 vertebral fracture was treated with anterior discectomy and interbody fusion with plating. the location of internal fixation was satisfactory at 2 weeks postoperatively. j,k: The sagittal and transectional CT showed satisfactory C1-2 bone fusion at 3 months after operation. l,m: The X-ray showed no internal failure at 49 months after operation.