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Evaluation of postoperative drainage necessity in posterior atlantoaxial fixation via intermuscular approach for odontoid fracture

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The necessity of routinely placing closed suction wound drainage in spinal surgery has been questioned. This study aims to assess if closed suction wound drainage is necessary for posterior atlantoaxial fixation via intermuscular approach. The functional outcomes of these 40 patients who underwent posterior atlantoaxial fixation via intermuscular approach without drainage tube (Group A) were compared with that of a control group, which consisted of 68 randomly enrolled cases with posterior atlantoaxial fixation via intermuscular approach with drainage tube (Group B). Outcome assessments included American Spinal Injury Association (ASIA) scoring grade and Visual Analog Scale Score for Neck Pain (VASSNP). The postoperative analgesic consumption, the incidence of subcutaneous and surrounding ecchymosis and the time of ambulation were compared between two groups. Bone fusion was evaluated through computed tomography (CT) reconstruction. Postoperative paravertebral tissue edema was evaluated by the edema coefficient. The use of drainage tube had no significant influence on the postoperative analgesic consumption, wound ecchymosis, the time of ambulation and paravertebral tissue edema ($P > 0.05$). There were no statistically significant differences in the VASSNP and bone fusion rates during the follow-up period between the two groups ($P > 0.05$). All patients achieved ASIA grade E 3 months after surgery. No complications such as wound infection occurred in either group. Posterior atlantoaxial fixation via intermuscular approach does not necessitate postoperative drainage tube placement if there is no accidental vascular injury or excessive muscle bleeding occurs intraoperatively.

Keywords Drainage tube, The intermuscular approach, Odontoid fracture, Fracture fixation

Postoperative suction drainage was widely used in spinal surgeries to drain blood and fluid from the surgical site¹, aiming to reduce the occurrence of postoperative hematomas². With hematoma decrease, the risk of wound ecchymosis, wound dehiscence, infection and particularly neurologic compromise will mitigate³. Nevertheless, patients with drainage tube may need longer bed rest after surgery, which can cause complications such as back pain, urinary tract infections, and deep vein thrombosis⁴. The insertion of the drainage tube can lead to local pain and scarring in the postoperative placement area, and patients are prone to fear and anxiety during the perioperative drainage tube extraction process, thus reducing the overall experience and satisfaction of patients⁵.

For a fresh odontoid fracture not suitable for anterior odontoid screw fixation, posterior fixation using the C1–C2 screw-rod system was an optimal salvage maneuver⁶. However, traditional open approach results in significant damage to the paravertebral muscles attached to C1 posterior arch and C2 laminar and spinous process. Although studies on posterior surgery for other parts of the spine have demonstrated that no difference in infection rates and risk of postoperative haematoma whether suction drainage was used or not^{7–11}, because

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of the anatomical position of the atlantoaxial, we still place the suction drainage tube before closing the incision to prevent local hematoma accumulation and neurological complications. In recent years, innovations and advances in atlantoaxial surgical technique can limit paravertebral tissue dissection, lessen blood loss. Literatures have explored the anatomical feasibility and technical key points of preserving the intrinsic muscles of the craniocervical junction in the atlantoaxial surgery through the intermuscular approach^{12,13}. As a muscle-preserving minimally invasive surgical technique, posterior atlantoaxial fixation via intermuscular approach significantly reduced intraoperative paravertebral tissue destruction and blood loss. But the role of drainage tube in posterior atlantoaxial fixation via intermuscular approach remains undetermined. Therefore, this study aims to assess if closed suction wound drainage is necessary in the posterior atlantoaxial fixation via intermuscular approach.

Materials and methods

Data of 40 patients with a new odontoid fracture who underwent posterior atlantoaxial fixation via intermuscular approach without drainage tube between January 2021 and December 2022 was reviewed. Functional outcomes of these 40 patients (Group A) were compared with those of a control group that consisted of 68 patients (Group B) undergoing posterior atlantoaxial fixation via intermuscular approach with drainage tube between January 2019 and December 2020. The indications included (1) Grauer¹⁴ type IIC fractures, (2) Grauer¹⁴ type IIA and IIB fractures that could not be fixed via an anterior approach, and (3) patients with Anderson and D'Alonzo¹⁵ type III fractures who could not tolerate long-term external fixation. All fractures were confirmed radiologically with adequate reduction (at least 2/3 of fracture surfaces were in contact¹⁶) and intact transverse ligament. Approval for this study was obtained from our hospital ethics committee. Written informed consent was obtained from all patients in this study. This study have been performed in accordance with the Declaration of Helsinki.

Surgical technique

After induction of general anesthesia, patients were positioned prone on a custom plaster bed with the cervical spine in neutral position. C-arm was used to confirm fracture reduction after skull traction.

A midline skin incision was made, the interspace between the trapezius muscle and the splenius capitis muscle were firstly identified. The deep-seated semispinalis capitis muscle (SEM) was subsequently exposed. Then, blunt dissection is employed to separate its vertical muscle fibers to expose the deep muscles, including the rectus capitis posterior major (RCPM) and the obliquus capitis inferior muscle (OCI). The C1 posterior arch and C2 lamina were palpated through the muscle gap. The C1 posterior arch is situated between the RCPM and OCI, while the C2 lamina is located caudal to the OCI. Then, the points for C1 and C2 screws insertion were exposed. After the C2 pedicle screw was inserted using a free-hand technique through the muscle gap, the C1 pedicle screw was inserted with a dissector to slightly displace the RCPM toward the cephalic side. Lift the OCI and insert the titanium rod. Finally, the screw-rod system was locked. (Fig. 1) Place one suction drainage tube at each side before the incision was closed for Group B. For Group A, the incision was closed without placing suction drainage tube.

Clinical outcomes evaluation

American Spinal Injury Association (ASIA) scoring grade¹⁷ and Visual Analog Scale Score for Neck Pain (VASSNP) were compared before and after operation. Patient demographics, including age and gender, fracture type, complicated injuries and the time from trauma to surgery were recorded. The operative time, the intraoperative blood loss, the additional analgesic (parecoxib sodium, mg) consumption within one week postoperatively, the time of ambulation, the number of cases with subcutaneous and surrounding ecchymosis within one week postoperatively, and complications were recorded and compared between the two groups. An analgesic pump (intravenous injection of fentanyl citrate 100ug, intravenous injection of dexmedetomidine hydrochloride 100ug, intravenous injection of tramadol hydrochloride 100 mg) was used immediately after operation in all patients. Postoperative drainage volume was reviewed for patients in Group B.

Radiographic imaging

Preoperatively, cervical computed tomography angiography (CTA) was performed to identify aberrant vertebral artery (VA). Bone fusion was assessed using three-dimensional computed tomography (CT) scan reconstruction, meanwhile the duration required to achieve bone fusion was recorded.

Postoperative paravertebral tissue edema was evaluated on T2-weighted sequence of magnetic resonance imaging (MRI) at 3 days after operation. Three successive layers of cross-sectional images at the level of the C2 spinous process were selected. The cross-sectional area (CSA) of the paravertebral tissue was measured using digital image processing software (Image J, National Institutes of Health, Bethesda, MD, USA). (Fig. 2) The degree of postoperative paravertebral tissue edema was compared using the edema coefficient. The edema coefficient = (The postoperative mean CSA of the paraspinal tissues- The preoperative mean CSA of the paraspinal tissues)/ The preoperative mean CSA of the paraspinal tissues. The preoperative and postoperative mean CSA of two groups was calculated and compared.

Statistical analysis

The analysis was conducted using SPSS statistical software version 26.0. Quantitative data were expressed as mean \pm standard deviation. T-tests, chi-square test and fisher's exact test were performed and the significance level was set at $P < 0.05$.

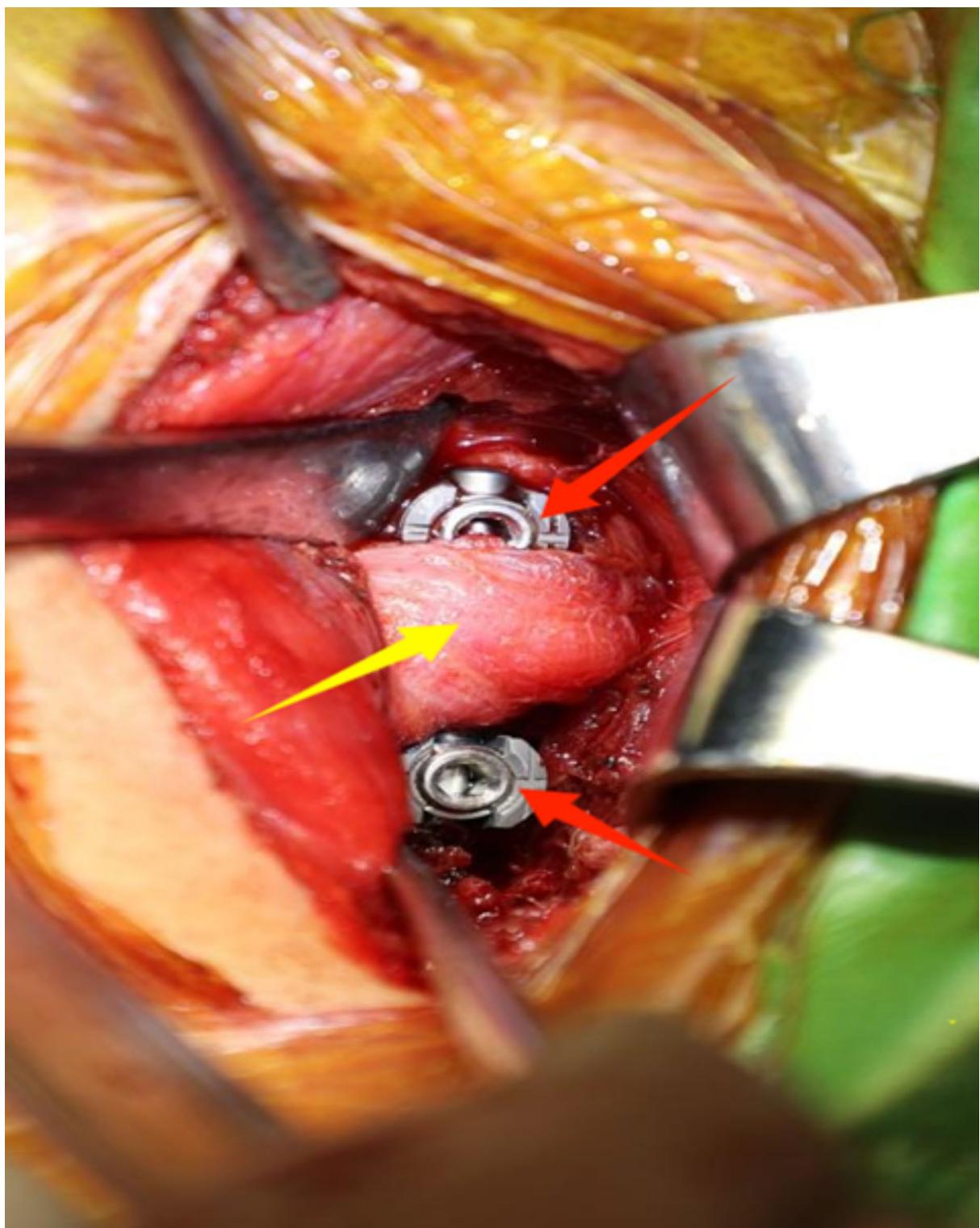


Fig. 1. Illustration to show the position of the C1 and C2 pedicle screws (red arrow) and the obliquus capitis inferior (OCI) muscle (yellow arrow) after locking the screw-rod system.

Results

Patients' general information was summarized in Table 1. There were no significant differences in patients' general information between two groups. There were no perioperative complications in either group.

There were no statistically significant differences in the operative time or intraoperative blood loss between the two groups. The mean postoperative drainage volume of patients in group B was recorded. (Table 2) There were no statistically significant differences between the two groups in terms of the additional analgesic consumption

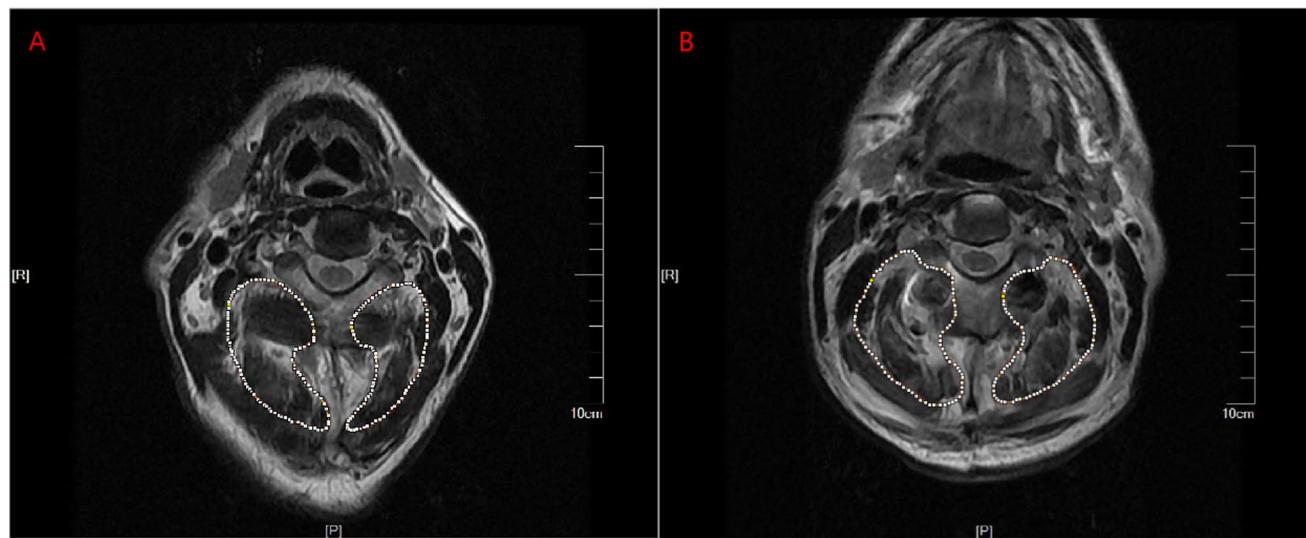


Fig. 2. Schematic representation of preoperative and postoperative measurements on the cross-sectional area (CSA) of the paravertebral tissue. The CSA of the paravertebral tissue was defined as the area circled by the dotted line. The measurement range of CSA after operation was consistent with that before operation. The postoperative CSA of the paraspinal tissues at the level of C2 spinous process on both sides (the area circled by dotted lines) (B) was significantly larger than the preoperative CSA (A).

Variable	Group A(<i>n</i> = 40)	Group B(<i>n</i> = 68)	<i>P</i>
Age, years	43.7 ± 8.4	40.1 ± 10.0	0.058
Gender, no. (%)			0.260
Male	24 (60.0)	48 (70.6)	
Female	16 (40.0)	20 (29.4)	
Anderson-D'Alonzo classification, no. (%)			0.547
Type II	33 (82.5)	59 (86.8)	
Type III	7 (17.5)	9 (13.2)	
Grauer classification, no. (%)			0.900
Type IIB	8 (20.0)	15 (22.1)	
Type IIC	25 (62.5)	44 (64.7)	
Complicated injuries, no. (%)			0.997
Head injury	4 (10.0)	7 (10.3)	
Thoracic trauma	2 (5.0)	3 (4.4)	
Limb fracture	3 (7.5)	5 (7.4)	
Solitary spinal process fracture between C3 and C7	2 (5.0)	4 (5.9)	
Time from trauma to surgery, days	10.3 ± 5.0	11.9 ± 5.8	0.134
Average follow-up time, months *	20.3 ± 4.8	25.1 ± 1.8	<0.001*

Table 1. Comparison of general outcomes between the two groups. Data expressed as mean ± standard deviation unless otherwise indicated. * $P < 0.05$, independent samples t-test, chi-square test or fisher's exact test.

within one week postoperatively, the number of cases with subcutaneous and surrounding ecchymosis or the time of ambulation. (Table 2)

Clinical outcomes

Compared to preoperative values, all patients demonstrated significant reduction in VASSNP ($P < 0.05$) during follow-up. (Table 2) There were no statistically significant differences in postoperative VASSNP between the two groups. There were 4 ASIA grade D patients in group A and 6 ASIA grade D patients in group B before surgery. All patients in this study achieved ASIA grade E 3 months after surgery. (Table 2)

Radiological outcomes

The CSA of paravertebral tissue before surgery was $1765.5 \pm 192.8 \text{ mm}^2$ in Group A and $1711.1 \pm 154.7 \text{ mm}^2$ in Group B. Three days postoperatively, the CSA was $2242.5 \pm 251.9 \text{ mm}^2$ in Group A and $2184.8 \pm 204.0 \text{ mm}^2$ in

Variable	Group A(<i>n</i> = 40)	Group B(<i>n</i> = 68)	<i>P</i>
Operative time, minutes	87.5 ± 18.5	91.8 ± 18.7	0.244
Blood loss, ml	41.0 ± 5.5	40.7 ± 5.5	0.756
Analgesic (parecoxib sodium), mg	2.0 ± 8.8	1.8 ± 8.3	0.890
Ecchymosis, no. (%)	2(5.0)	3(4.4)	>0.999
Timing of ambulation, days	2.1 ± 0.4	2.0 ± 0.4	0.937
Drainage volume, ml	/	39.0 ± 7.0	
ASIA Grade, D/E (Grade E %)			
Preoperative	4/36(90.0)	6/62(91.2)	>0.999
3 months	0/40(100.0)	0/68(100.0)	>0.999
VASSNP			
Preoperative	4.3 ± 0.8	4.2 ± 0.7	0.844
3 days	2.8 ± 0.8	3.0 ± 0.8	0.313
7 days	1.1 ± 0.5	1.2 ± 0.5	0.362
3 months	0.1 ± 0.3	0.2 ± 0.4	0.608

Table 2. Comparison of clinical outcomes between the two groups. Data expressed as mean ± standard deviation unless otherwise indicated. There were no significant differences found in the independent samples t-test, chi-square test or fisher's exact test for the data.

Variable	Group A(<i>n</i> = 40)	Group B(<i>n</i> = 68)	<i>P</i>
Pre. CSA, mm ²	1765.5 ± 192.8	1711.1 ± 154.7	0.111
Post. CSA, mm ²	2242.5 ± 251.9	2184.8 ± 204.0	0.196
The edema coefficient (%)	27.0 ± 2.9	27.7 ± 4.2	0.339
Bone fusion time, no. (%)			0.700
3 months	33(82.5)	58(85.3)	
6 months	40(100.0)	68(100.0)	

Table 3. Comparison of radiological outcomes between the two groups. Data expressed as mean ± standard deviation unless otherwise indicated. There were no significant differences found in the independent samples t-test, chi-square test or fisher's exact test for the data.

Group B. The edema coefficient was similar between the two groups. (*P* > 0.05) (Table 3) The fusion rates at 3 months after operation were 82.5% in Group A and 85.3% in Group B; All patients in two groups achieved solid bone fusion at 6 months after operation. The fusion rates at 3 and 6 months after operation were comparable between the two groups. (Table 3)

Discussion

This study analyzed 108 patients with a new odontoid fracture who underwent posterior atlantoaxial fixation via intermuscular approach. The results indicated that the utilization of drainage tube did not have a significant impact on postoperative recovery outcomes.

The literatures have not provided sufficient evidence to support the routine utilization of closed suction wound drainage in orthopedic surgery, including spine surgery¹. Kajetan et al.¹⁸ conducted a survey among German spine surgeons with online questionnaires and found no definitive indications for the utilization of drainage tubes in spine surgery. Factors influencing the decision to use a drain in spine surgery included size of wound, type of surgery, hemostasis at the end of procedure and patients' coagulation function. Based on a previous retrospective study, Liu et al.¹⁹ concluded that it is safe and feasible for patients with anterior cervical spine surgery not to place drainage tube after surgery when meticulous intraoperative procedures are followed and strict postoperative assessment of drainage volume is conducted. Patients without drainage tube experienced significantly reduced perioperative bed rest and hospital stay durations, as well as decreased pain levels and psychological stress, leading to higher satisfaction rates. Hung et al.²⁰ reported no significant benefit of utilizing drainage tube in the prevention of postoperative epidural hematomas or reduction of infections following minimally invasive lumbar spine surgery; instead, it resulted in heightened levels of postoperative pain, anxiety, and discomfort. The posterior atlantoaxial fixation via intermuscular approach preserved the tension band of extensor muscles while minimizing detachment of the posterior cervical muscles. We previously found that the intermuscular approach could reduce the postoperative drainage volume and the extent of paravertebral tissue edema compared to open approach²¹. For the cases of reducible atlantoaxial dislocation treated with atlantoaxial intra-articular cage fusion by unilateral intermuscular approach and contralateral conventional open approach. The drainage was 19.0 ± 5.7 ml in the intermuscular approach side and 44.0 ± 7.0 ml in the open approach side. The postoperative cross-sectional area of the paravertebral tissue was 1188.1 ± 49.8 mm² in the

intermuscular approach side and $1333.5 \pm 55.0 \text{ mm}^2$ in the open approach side²¹. Due to its inherent advantages of minimal postoperative drainage, less degree of postoperative soft tissue edema and fewer dead spaces, this intermuscular approach technique theoretically carries a low risk of postoperative hematoma formation. In our surgical protocol, meticulous hemostasis was performed for soft tissue bleeding before closing the incision. In group B, the drainage volume on each side of the spine did not exceed 25 ml. Despite the patients in Group A not being equipped with the closed suction drainage, there were no cases developing postoperative bleeding-induced neurological injury. Therefore, we believe that the intermuscular approach technique without drainage tube placement is safe and feasible.

In comparison to open approaches, the posterior atlantoaxial fixation via intermuscular approach results in reduced iatrogenic soft tissue damage. The analysis of cervical spine MRI images from patients included in this study concluded that, in the short-term postoperative period, there was no significant exacerbation of paravertebral tissue edema among patients without drainage tube compared to those with drainage tub. Multiple studies have consistently demonstrated that spinal minimally invasive surgery exhibits superior performance compared to conventional open surgery in terms of reducing intraoperative bleeding and postoperative drainage^{22,23}. In our study, the mean intraoperative blood loss in all patients and the mean postoperative drainage volume in group B were less than 50 ml. Due to the minor iatrogenic tissue injury during the operation, the postoperative VASSNP is significantly reduced in both groups and additional analgesics are not required. Furthermore, there was no differences in terms of the additional analgesic consumption within one week postoperatively, the number of cases with subcutaneous and surrounding ecchymosis.

As a muscle-sparing technique, intermuscular approach effectively reduces the occurrence of approach-related complications. However, it is important to note that the surgical method has a narrower surgical field compared to traditional spine surgeries and lacks commonly observed anatomical landmarks. Consequently, there is an inherent risk of accidental injury to VA and venous plexus. Preoperative CTA should be down to exclude aberrant VA. During operation, attention should be paid to prevent injury to the venous plexus and C2 nerve root and its branches located in the anatomical space between the SEM and suboccipital muscles²⁴. Finally, meticulous hemostasis should be performed for soft tissue bleeding before closing the incision.

Conclusion

The posterior atlantoaxial fixation via intermuscular approach technique does not necessitate postoperative drainage tube placement if there is no accidental vascular injury or excessive muscle bleeding occurs intraoperatively.

Data availability

The datasets used and analysed in the study available from the corresponding author on reasonable request.

Received: 22 September 2024; Accepted: 25 December 2024

Published online: 02 January 2025

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Acknowledgements

This study is supported by Naval Medical University Research Foundation (NO. 2021MS14).

Author contributions

Zhenji Xu: data analysis, writing and reviewing. Ji Wu: data analysis, writing original draft, table and image production. Yong Li: investigation, formal analysis, software. Haibin Wang: data acquisition. Fei Chen: data acquisition. Bin Ni: data interpretation. Xuhua Lu: project administration, supervision. Qunfeng Guo: data interpretation, project administration, operation, funding acquisition.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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