

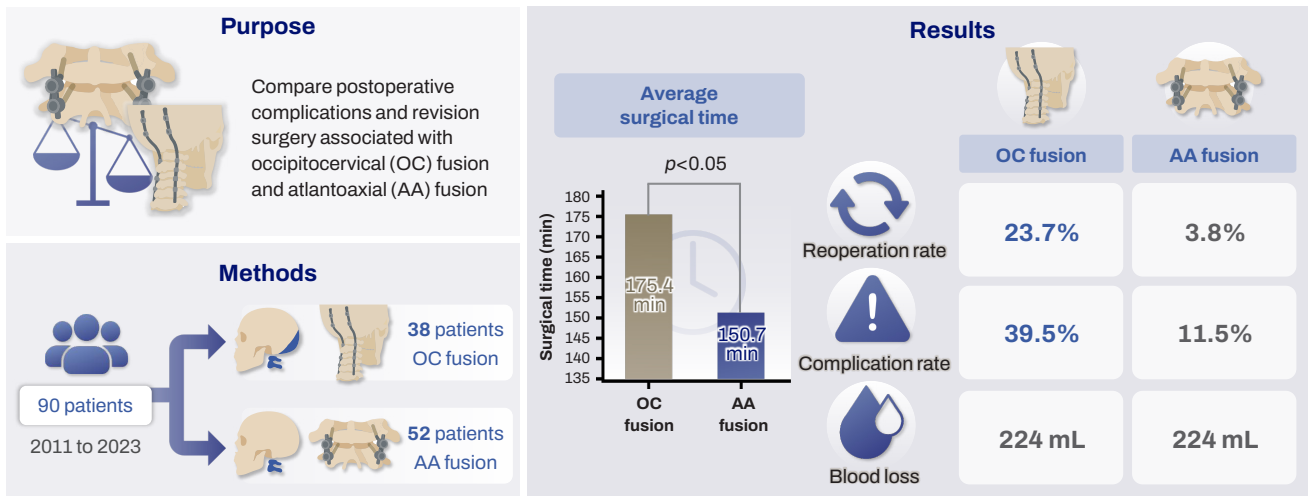
More postoperative complications and revision surgery after occipitocervical fusion than after atlantoaxial fusion: a retrospective multicenter cohort study

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CONCLUSION Although OC fusion is indispensable for certain conditions, particularly basilar invagination, it entails more risk than does AA fusion; the choice of technique thus warrants careful consideration.

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More postoperative complications and revision surgery after occipitocervical fusion than after atlantoaxial fusion: a retrospective multicenter cohort study

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Study Design: A retrospective multicenter cohort study.

Purpose: We sought to determine whether occipitocervical (OC) fusion is followed by more postoperative complications and revision surgery than is atlantoaxial (AA) fusion. We aim to compare postoperative complications and revision surgery associated with OC fusion and AA fusion.

Overview of Literature: OC and AA fusion are established techniques for restoring upper cervical stability. However, the outcomes of the two methods have not been compared.

Methods: This study included 90 patients who underwent upper spinal fusion surgery for mechanical instability, performed by three surgeons in two hospitals from 2011 to 2023; OC fusion was indicated for irreducible AA subluxation, os odontoideum, and severe upper C1 fracture. Of the patients, 38 (mean age, 58.7 years) underwent OC fusion, and 52 (mean age, 62.8 years) underwent AA fusion. To evaluate surgical outcomes, we documented surgical time, intraoperative blood loss, postoperative complications, and the rate of revision surgery. Radiographs were obtained to identify screw malposition, rod breakage, and nonunion. To compare the outcomes of the two techniques, we used the Mann-Whitney *U* test for continuous variables and the chi-square or Fisher's exact test for dichotomous variables.

Results: OC fusion took significantly longer (175.4 minutes) than AA fusion (150.7 minutes, $p=0.020$) and had a higher complication rate (39.5% vs. 11.5%, $p<0.0001$). The reoperation rate was 23.7% (9/38) after OC fusion and 3.8% (2/52) after AA fusion; the difference was statistically significant ($p=0.0073$). Average amounts of blood loss were 224 mL during OC fusion and 224 mL during AA fusion; the difference was not significant ($p=0.947$).

Conclusions: Although OC fusion is indispensable for certain conditions, particularly basilar invagination, it entails more risk than does AA fusion; the choice of technique thus warrants careful consideration.

Keywords: Occipitocervical fusion; Atlantoaxial fusion; Upper cervical instability; Surgical complication; Reoperation

Introduction

The occipitocervical (OC) junction, one of the most complex and mobile regions of the spine, consists of two important joints: the occipitocervical (OC) joint and the atlantoaxial (AA) joint [1]. Flexion, extension, and rotation are significant at these joints: primarily, at the C0–C1 level, angles of flexion and extension average 23°–25°, and in the atlantoaxial joint, the average rotation is approximately 23°–39°, and angles of flexion and extension average 10°–20° [2]. These joints are prone to injury, degenerative changes, and instability as a result of various causes, such as trauma (e.g., Jefferson's and hangman's fracture), infection, tumors, congenital anomalies, and inflammatory diseases (e.g., rheumatoid arthritis and osteoarthritis) [3]. Instability usually results in axial pain, with or without radiculopathy, and in focal sensorimotor deficit, respiratory disturbances,

and myelopathy [4,5].

OC and AA fusion are established techniques for treating upper cervical instability [5,6]. Cervical instability has a bimodal distribution, affecting young and elderly patients. Each patient's clinical and radiological findings should be evaluated individually to alleviate the symptoms and determine the best surgical treatment with the lowest risk of complications. Surgical management with OC fusion or AA fusion has been shown to yield better results than do conservative treatment options [7–9]; however, even with the proper understanding of the pathological process and detailed knowledge of anatomy, these operations may lead to undesired and serious complications [10,11]. According to previous reports, patients who underwent OC fusion are prone to a more significant number of complications and more need for revision surgery than patients who underwent AA fusion [12]. In this retrospective study, we compared surgical outcomes of OC and AA fusion with

regard to operative time, average amount of blood loss, postoperative complications, and rate of revision surgery.

Materials and Methods

This research was approved by the ethics committee of Okayama Rosai Hospital (approval no., 421). The necessary informed consent forms were duly signed and obtained from all the patients involved in the study. The cohort of this multicenter retrospective analysis consisted of patients who underwent OC and AA fusion for mechanical instability of various causes at Okayama Rosai Hospital and Okayama University Hospital between 2011 and 2023. The operations were performed by three surgeons in two hospitals. We included patients with (1) severe mechanical instability of the upper cervical spine; (2) severe myelopathy and axial neck pain, with or without radiculopathy, confirmed by radiological findings; and (3) failure of more than 3 months' worth of conservative treatment or recurrent symptoms. We excluded patients with less than 1 year of follow-up and those lacking postoperative computed tomographic and magnetic resonance imaging studies. Surgical time, intraoperative blood loss, and postoperative complications were documented to assess surgical outcomes. Radiographs were obtained to identify screw malposition, rod breakage, and nonunion.

To analyze ordinal scale data, we used the Mann-Whitney *U* test, and to evaluate data for continuous variables, we used the independent-samples *t*-test. To determine the presence of nonrandom associations between the two categorical variables, we used the chi-square or Fisher's exact test to compare nominal scale data. In addition, we documented Frankel grades (regarding neurological outcomes) before and after both procedures. We meticulously performed all statistical calculations by using GraphPad Prism ver. 6.0 (GraphPad Software, Boston, MA, USA). A *p*-value of <0.05 indicated statistical significance; this threshold guided the identification of meaningful differences and associations within the study findings.

Results

Patient demographics

Ninety patients were included in this study. The average age of those who underwent OC fusion was 58.6 years, and the average age of those undergoing AA fusion was 68.1 years; these two averages did not differ significantly ($p=0.449$). The OC group included 18 men and

20 women, and the AA group included 28 men and 24 women; these gender distributions also did not differ significantly. The procedures were performed for anterior atlantoaxial subluxation in 48 patients, upper cervical fracture in 16, os odontoideum in eight, C2 pseudotumor in seven, basilar impression in three, metastatic tumor in seven, and other diagnoses in one (Table 1).

Comparison of surgical results

A comparison of the surgical outcomes of the two groups revealed differences in surgical time and average amount of blood loss. On average, OC fusion took 175.4 minutes, which was significantly longer than the average of 150.7 minutes for AA fusion ($p=0.021$) (Fig. 1). For patients

Table 1. Characteristics of occipitocervical and atlantoaxial fusion groups

Characteristic	Occipitocervical fusion	Atlantoaxial fusion	<i>p</i> -value
Age (yr)	58.6±25.6	68.1±23.7	0.449
Gender			0.669
Male	18	28	
Female	20	24	
Diagnosis			
Anterior atlantoaxial subluxation	19	29	
Upper cervical fracture	5	11	
Os odontoideum	3	5	
C2 pseudotumor	2	5	
Vertical subluxation/basilar impression	3	0	
Metastatic tumor	6	1	
Others	0	1	

Values are presented as mean±standard deviation or number.

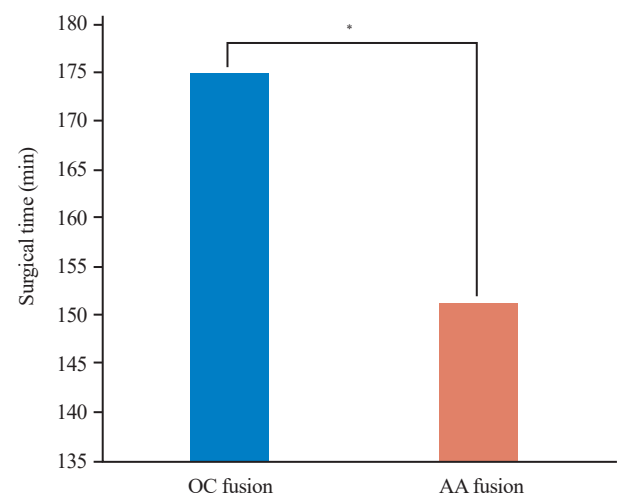


Fig. 1. Average surgical time of two groups. The surgical time of occipitocervical (OC) fusion was statistically longer than that of atlantoaxial (AA) fusions. $p<0.05$.

undergoing OC fusion, the average amount of blood loss was 223.5 mL for AA fusion and 223.9 mL for OC fusion (Table 2). The difference was not significant ($p=0.947$).

Comparison of perioperative complications

The total rate of complications after OC fusion (39.5%) was significantly higher than that after AA fusion (11.5%, $p<0.0001$). Surgical site infection (SSI), the most common complication, occurred in three patients after AA fusion and in five after OC fusion. All cases of deep-layer SSI necessitated reintervention. With regard to implant-related complications, one case of implant malposition was identified after AA fusion ($p>0.999$). Rod breakage occurred in four patients after OC fusion and in one patient after AA fusion ($p=0.154$). Screw loosening was observed in three patients after OC fusion ($p=0.266$), and adjacent segmental disorder was noted in one patient after OC fusion ($p=0.409$). In addition, intraoperative complications included one C2 nerve injury, one case of dysphagia, and one cerebrospinal fluid leak, all during OC fusion.

The reoperation rates were 23.6% (9/38) after OC fusion and 3.8% (2/52) after AA fusion; the difference between the two rates was statistically significant ($p=0.0073$). Among patients who underwent AA fusion, the only indication for reoperation was deep SSI. In contrast, among those who underwent OC fusion, five patients underwent reoperation for deep SSI, three for screw loosening, and one for dysphagia (Table 2).

Table 2. Surgical results and complications of occipitocervical and atlantoaxial fusion groups

Variable	Occipitocervical fusion (n=38)	Atlantoaxial fusion (n=52)	p-value
Surgical time (min)	175.4±223.5	150.7±44.4	0.0203*
Blood loss (mL)	223.5±220.6	223.9±275.6	0.947
Revision surgery	9	2	0.0073**
Major complication			
Total	15	6	<0.0001**
Deep surgical site infection	5	3	0.263
Implant breakage	4	1	0.154
Screw loosening	3	0	0.266
Implant malposition	0	1	>0.999
C2 nerve injury	0	1	>0.999
Cerebrospinal fluid leakage	1	0	0.409
Adjacent segment disease	1	0	0.409
Dysphagia	1	0	0.409

Values are presented as mean±standard deviation or number. * $p<0.05$. ** $p<0.01$.

Changes in Frankel grade after surgery

Preoperatively, no cases in either group were classified as grade A or B. Grade C function was observed in eight cases before AA fusion and in seven before OC fusion. Grade D function was identified in 26 cases before AA fusion and in 18 before OC fusion. Grade E function was present in 18 cases before AA fusion and in 11 before OC fusion (Table 3).

The Frankel grade improved postoperatively in 34.2% (13/38) of patients who underwent OC fusion and in 36.5% (19/52) of those who underwent AA fusion. No deterioration occurred after either procedure. The changes in Frankel grade after both AA and OC fusion did not differ significantly ($p=0.822$) (Table 3).

Discussion

Occipitocervical fixation has evolved significantly, with advancements in surgical techniques aimed at improving stability at the craniocervical junction while reducing complications and enhancing outcomes [13]. Initially, surgical interventions at the craniocervical junction were limited by the anatomical complexities and significant risks involved. In the early 20th century, Foerster introduced the concept of fusion with grafts [14], but patients required a minimum of 12 weeks of traction; this led to early investigations into techniques involving wires and bone grafts to stabilize the craniocervical region [14]. These early materials, although semirigid, were often plagued by complications such as nonunion and hardware failure.

The advent of modern internal fixation systems, particularly the introduction of occipital plates and screw-rod systems, provided more rigid stabilization, resulting in better outcomes and reduced complications. In

Table 3. Frankel grade of occipitocervical and atlantoaxial fusion groups

Variable	Occipitocervical fusion (n=38)	Atlantoaxial fusion (n=52)	p value
Preoperative Frankel grade			0.879
A or B	0	0	
C	7	8	
D	19	26	
E	12	18	
Postoperative change of Frankel grade			0.822
No change	25	33	
Improvement	13	19	

Values are presented as number.

the first significant advancement in AA fixation, Gallie in 1939 introduced a sublaminar wire fixation method, which remained a standard approach for decades. As biomechanical understanding improved, with Goel's pioneering and with Magerl's introduction of transarticular screw fixation in 1987, stability and outcomes of AA fusion procedures were enhanced [15,16]. Although underlying pathological conditions often dictate the surgical approach, a critical decision is whether to perform OC fusion or AA fusion [3]. Comparing the outcomes of these procedures is crucial [17] because both aim to treat cervical instability that results from changes related to rheumatoid arthritis, basilar invagination, trauma, degenerative disorders, tumors, and infection [18,19] (Table 4).

Our results indicate that OC fusion is associated with longer operative times than AA fusion ($p=0.0203$), probably because it is more invasive. The complication rate was also higher after OC fusion than after AA fusion, as was the reoperation rate ($p<0.0001$). These findings are consistent with those of Tian et al. [20], who reported a higher revision rate after OC fusion (11.3%) than after AA fusion (5.2%) in a retrospective

cohort study. Zileli and Akinturk [19] reported similar findings in 67 (52%) of 128 patients who underwent OC fusion.

According to the literature, the rate of reoperations after OC fixation is high because of implant-related complications, craniocervical malalignment, or infection. In addition, the anatomical complexity of the craniocervical junction and the presence of comorbid conditions, such as rheumatoid arthritis or cerebral palsy, may contribute to the significantly higher rates of screw loosening and infection after OC fusion than after AA fusion ($p=0.00073$). In our study, revision surgeries were indicated for deep SSI and rod breakage/screw loosening after AA fusion and for deep SSI and rod breakage and screw loosening/pullout after OC fusion (Fig. 2).

With regard to patients' quality of life, the most prevalent complication reported to be associated with OC fusion is dysphagia. In our sample, only one patient had dysphagia (Fig. 3). This proportion was not statistically significant ($p=0.409$); according to the literature, however, such incidence have ranged from 10% to 25% during long-term follow-up. The incidence of dyspha-

Table 4. History of occipitocervical and atlantoaxial fusion technique

Time	Technique	Details
Pre-1950s	External immobilization	Utilized halo rings and tongs for prolonged immobilization [13].
1950s	Wire fixation	Employed in pediatric cases using rib or iliac crest autograft; wiring offered semi-rigid fixation [14].
1970s	Gallie fusion	Introduced sublaminar wiring techniques and structural bone grafting [15].
1980s	Brooks-Jenkins fusion	Involved sublaminar wiring with iliac crest bone graft; provided more excellent stability than Gallie [15].
1990s	Occipital plate fixation	Introduced the use of contoured plates for enhanced occipitocervical stability [16].
2000s	Screw-rod systems	Became the gold standard; involved occipital screws and cervical screws connected by rods [13].
2000s	Advances in instrumentation	Improved techniques with segmental fixation using screws and rods, increasing stability and fusion rates [16].
2010s	Minimally invasive techniques	Development of less invasive approaches, including navigated and endoscopic-assisted procedures [16].

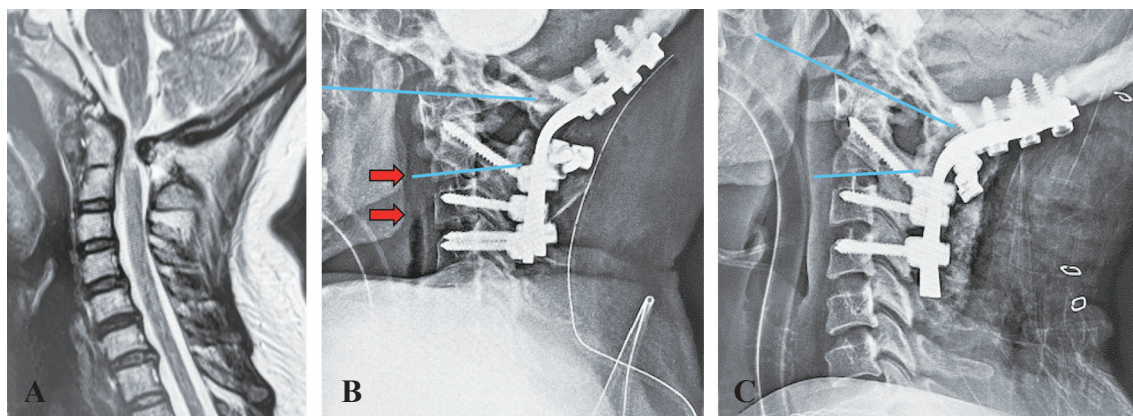


Fig. 2. Case 1: atlantoaxial subluxation, OC2 fusion. (A) Preoperative mid-sagittal T2 weighted magnetic resonance imaging. (B) Postoperative cervical anteroposterior radiogram. (C) Post-operative cervical lateral radiogram. Postoperatively, this patient complained of severe dysphagia. The red arrows indicate retropharyngeal space. Blue angles indicate OC2 angle.

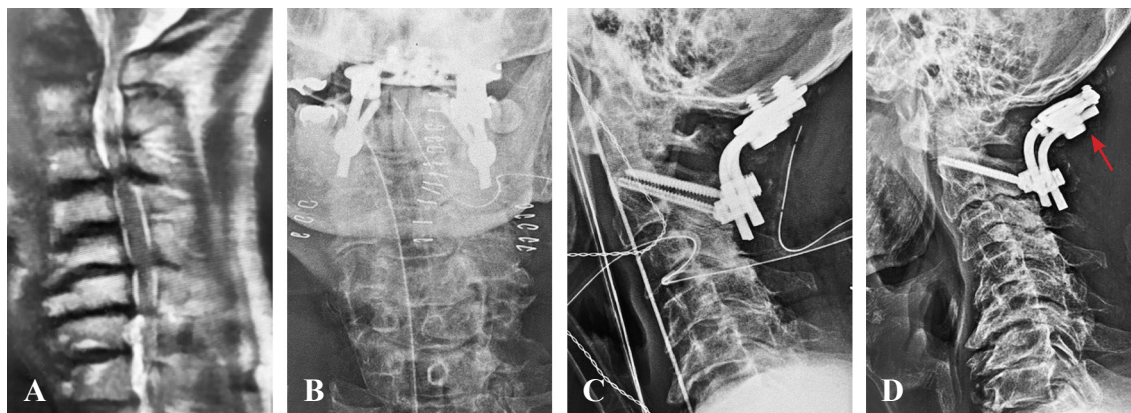


Fig. 3. Case 2: atlantoaxial subluxation, OC2 fusion. (A) Preoperative mid-sagittal T2 weighted magnetic resonance imaging. (B) Postoperative cervical anteroposterior radiogram. (C) Postoperative cervical lateral radiogram. (D) Day-7 postoperative cervical lateral radiogram. The red arrow indicates the occipital screws were back out.

gia was recently reviewed by Singh et al. [21], who also studied the health-related quality of life after OC fusion and return to work and who found that on average, 26% of patients had long-term dysphagia.

Of the implant-related complications, which usually occur in the middle to late postoperative period, the most common is distal screw loosening. Our results indicated that the incidence of implant failure, including screw loosening and rod breakage, was higher after OC fusion than after AA fusion ($p=0.154$). Some authors have also proposed ending OC fusion at the level of C3 or even C4 to prevent a higher load on the C2 screw [13]. However, this increases the risk of blood loss, exposure, and longer operation time, which can potentially result in undesirable events such as infection. The results by Wenning and Hoffmann [22] were completely different from ours because the two groups did not differ with regard to revision or infection. Furthermore, in a retrospective study of 799 patients, Winegar et al. [16] noted that the incidence of infection was 30.9% and that of hardware-related failure was 22.3% among those who underwent OC fusion. In another study, Choi et al. [23], who used OC fusion to treat 16 patients with cervicocranial instability that resulted from different pathologic causes, noted a high incidence of infection (13.3%) and hardware-related failure (12.6%).

Despite these risks, OC fusion remains essential for significant OC instability, especially in cases involving congenital malformations or tumor resections. In contrast, AA fusion generally results in fewer complications, is less invasive, and improves clinical outcomes and patient satisfaction. Hu et al. [24] noted that whereas all patients undergoing OC fusion complained of reduced neck mobility, only 4.2% of those undergoing AA fusion reported such issues. Our findings also

indicated that AA fusion was a shorter procedure, the risk of SSI was lower, and mobility was better preserved, which reduced the overall surgical burden on patients. These findings are consistent with those of Yang et al. [12], who retrospectively evaluated 483 OC and 737 AA fusions recorded in a patient database and found that complications such as rod breakage, screw loosening, infection, and revision surgery were also less frequent after AA fusion (26.3%) than after OC fusion (40.9%), which highlights the safety and effectiveness of AA fusion [15]. However, the findings by Yang et al. [12] involved data collected within only 30 days after surgery (a very short follow-up period), and their source, the PearlDiver Database (which is publicly available and is a Health Insurance Portability and Accountability Act-compliant database), contained no information about surgical time or intraoperative blood loss.

The decision-making process remains complex; one of the important goal is the preservation of movement along side stable fixation. Surgeons must carefully evaluate each patient's condition individually to determine the most appropriate surgical approach. OC fusion should be reserved for cases in which AA fusion would not provide sufficient stability, such as when the OC joint is or will become unstable after the patient's underlying pathological processes are addressed.

Limitations of this study included a small sample size, short follow-up periods, and a heterogeneous diagnostic distribution. Further research with larger patient cohorts and extended observation periods is required. In addition, we did not evaluate quality of life, which may significantly affect patient satisfaction and recovery outcomes.

Conclusions

Although OC fusion is indispensable for certain conditions, particularly basilar invagination, it entails more risk of complications and more need for revision surgery than AA fusion. Surgeons must balance the need for OC fusion against these risks to ensure that the chosen surgical intervention aligns with the patient's needs and conditions.

Key Points

- The complication rate was higher after occipitocervical fusion than after atlantoaxial fusion.
- Atlantoaxial fusion was associated with fewer complications than was occipitocervical fusion.
- The rate of revision surgery was higher after occipitocervical fusion than after atlantoaxial fusion.
- Occipitocervical fusion was associated with a higher rate of reoperation than was atlantoaxial fusion.
- The operation time was longer for occipitocervical fusion than for atlantoaxial fusion.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Author Contributions

Conceptualization: MT. Data curation: SA, TK, YO, KS. Formal analysis: KU. Writing—original draft: KU. Writing—review & editing: AOPF, SJE. Supervision: TO. Final approval of the manuscript: all authors.

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