Mihir R. Bapat
Vinod J. Lahiri
N. S. Harshavardhan
Umesh S. Metkar
Kshitij C. Chaudhary

Role of transarticular screw fixation in tuberculous atlanto-axial instability

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Abstract Prospective study of 27 consecutive cases of tuberculous atlanto-axial instability operated between 1998 and 2003. Early surgical stabilization of tuberculous atlanto-axial instability has gained popularity. This is largely due to success of chemotherapy in rapid control of infection. Although selective atlanto-axial fusion techniques are advocated in other indications, their role in tuberculosis remains confined to atlanto-axial wiring techniques that are mechanically unsound. The role of three-point rigid fixation using transarticular screws (TAS) remains unclear. The objectives of this study are: (1) To define the role of transarticular screws in tuberculous atlanto-axial instability based on radiological criteria. (2) To attempt to separate patients that can be treated by selective atlanto-axial fixation as against the standard occipito-cervical fusion (OCF). (3) Compare the clinical and radiological outcome parameters between the two groups. Twenty-seven consecutive patients of tuberculous atlanto-axial instability were operated between 1998 and 2003. The pattern of articular surface destruction and the reducibility of the atlanto-axial complex were assessed on plain radiographs and MRI. The reduc-

ibility of the C1–C2 joint was graded as reducible, partially reducible and irreducible. Pattern of the C1–C2 articular mass destruction was grouped as minimal, moderate and severe. The patients were divided into two surgical groups based on radiological findings and were treated with TAS ($n=11$) and OCF ($n=16$) fusion. The three-point fixation provided by the TAS allowed early brace free mobilization by 3 months with fusion rate of 100%. Fusion occurred in 83.16% in the OCF group. Implant failure occurred in two patients who underwent OCF. The patient satisfaction rate in the TAS group and the OCF group was 90.90 and 62.50%, respectively. Results in 27 consecutive patients demonstrate improved patient fusion and satisfaction rates in the TAS group. Judicious selection of patients for TAS fixation is possible with relatively few complications in tuberculosis of the atlanto-axial complex. This, however, requires a thorough understanding of the MRI pattern of involvement of the atlanto-axial complex that is difficult in non-endemic areas.

Keywords Atlanto-axial tuberculosis · Atlanto-axial instability · Segmental fixation

M. R. Bapat (✉) · V. J. Lahiri
N. S. Harshavardhan · U. S. Metkar
K. C. Chaudhary
Orthopaedics, King Edward Memorial
Hospital, Mumbai, Maharashtra, India
E-mail: mrbkemh@netscape.net
Tel.: +91-22-26590851
Fax: +91-22-26590851

Introduction

Traditionally treatment of atlanto-axial tuberculosis has been based on the severity of destruction and the reducibility of the atlanto-axial complex. Occipito-cervical (OC) fusion has been the treatment of choice in cases of severe osteo-ligamentous disruptions. Atlanto-axial segmental wiring techniques are advocated for segmental fixation in minimal disease [2, 3, 16, 17]. Although other rigid segmental atlanto-axial fixation techniques, like the transarticular screws, have gained acceptance in other clinical situations, their role in tuberculous instability of the atlanto-axial complex are unclear [6, 9, 14, 18–20].

Aims and objectives

1. To define the role of trans-articular screws (TAS) in tuberculous atlanto-axial instability based on radiological criteria.
2. To attempt to identify patients that can be treated by selective atlanto-axial fixation as against the standard occipito-cervical fusion (OCF).
3. Compare the clinical and radiological outcome parameters between the two groups.

Material and methods

Study design

Twenty-seven consecutive patients of tuberculous atlanto-axial instability were treated in a single spine unit at the King Edward Memorial Hospital from 1998 to 2003 and followed-up prospectively for an average period of 24 months.

Diagnosis

Tuberculosis was diagnosed on the basis of progressive worsening of neck pain and stiffness with or without signs of compressive myelopathy, elevated erythrocyte sedimentation rate, lymphocytosis and characteristic radiological and magnetic resonance imaging features indicative of tuberculous infection. All patients had one or more constitutional symptoms, viz. significant weight loss, diminished appetite and rise of temperature in the evenings. India being an endemic country, the characteristic clinical, hematological and radiological findings were considered diagnostic of tuberculosis. The diagnosis was uncertain in two cases of mild disease. Trans-oral aspiration of the retropharyngeal abscess confirmed the diagnosis in these patients.

Study group

There were 17 male and 10 female patients between 10 and 47 years of age. Seventeen patients had received anti-tubercular drug treatment prior to admission for varying periods between 10 days to 6 months. One patient had received Syre's head-halter traction, while two patients had been given skeletal traction using the Gardner-Wells tongs, for less than 2 weeks. All patients were graded using Ranawat's scoring system for pain. Twenty-six patients reported moderate to severe pain and required increasing doses of non-steroidal anti-inflammatory drugs (Table 1).

Neurological scoring

Thirteen patients had myelopathy and were graded as per the Nurick's grading system. One patient had left hypoglossal nerve paresis of 5 weeks duration. No patient presented with respiratory distress. One patient had dysphagia due to pressure from a large retropharyngeal abscess that was aspirated to improve his symptoms. Seven patients presented with severe pain and were incidentally detected to have exaggerated deep tendon reflexes and Babinski's sign (Nurick's grade 1). Two patients reported clumsiness of grip and gait (Nurick's grade 2), while one patient had non-functional grip strength (Nurick's grade 3; Table 2).

Pre-operative imaging

Preliminary radiographs included an open mouth and a lateral radiograph of the cranio-vertebral junction. Following supervised skeletal traction using Gardner-Well's tongs lateral radiographs were obtained at first and second week. The extent of realignment was assessed on the lateral and the open mouth radiographs in traction. A dedicated magnetic resonance imaging (MRI) of the cranio-vertebral junction was carried out with the aim to study the status of the articular masses of the atlas and the axis for transarticular screw fixation.

The atlanto-axial instability and vertical instability was judged on the lateral radiographs. Atlanto-dens interval of more than 8 mm was observed in all cases (range 8–16 mm). A vertical migration was considered significant if the dens was located 4 mm above the McGregor's line ($n = 16$). Rotatory dislocation was seen on the open mouth radiograph in three patients of severe atlanto-axial disease. Improvement in the rotatory alignment was observed in one patient after supervised skeletal traction.

A retropharyngeal abscess of a varying size was seen in all cases with variable amount of erosion of the odontoid and the anterior arch of atlas.

Table 1 Ranawat's pain score

Pre-operative treatment

All patients were instituted on four-drug anti-tubercular therapy comprising of isoniazid, rifampicin, pyrazinamide and ethambutol. A pre-operative skeletal traction using Gardner-Wells tongs was applied for a maximum period of 2 weeks to attempt a reduction of atlanto-axial complex. The traction was applied irrespective of the mobility of the atlanto-dens complex on the preliminary radiographs and prior treatment received. The reduc-

ibility was assessed with lateral radiographs through traction at seventh and fourteenth day, respectively.

Radiological classification

Reducibility of the atlanto-axial joint

Reducibility under traction was categorized as reducible, partially reducible and irreducible depending on the

Table 2 Nurick's score

Table 3 Reducibility grades

Radiological pattern	ADI (mms)	SAC (mms)	Patients (n=27)	RS	VI
Reducible	<5	>15	6	0	0
Partially reducible	5–8	12–15	19	0	6
Irreducible	>8	<12	2	3	10

ADI Atlanto-dens interval, SAC Space available for cord, RS Rotatory subluxation, VI Vertical instability

atlanto-dens interval (ADI) and the space available for the cord (SAC; Table 3). A reduced atlanto-axial joint had ADI of less than 5 mm and SAC more than 16 mm on the lateral radiograph. A partially reduced C1–C2 joint showed an ADI between 5 and 8 mm, and SAC between 12 and 15 mm. In these patients no rotatory subluxation was noticed after reduction. In an irreducible atlanto-axial dislocation, no change in the ADI and the SAC was observed even after supervised traction (Fig. 1).

Grading of articular surface destruction

The area of the lateral masses of the atlas and the axis eroded due to disease were evaluated on lateral and

open mouth radiographs and MRI. The articular outline seen on the plain radiographs (open mouth and lateral) helped in gross evaluation of the C1–C2 articulation and planning the trajectory of the TA screw. The axial T1 and T2 weighted MRI images of the lateral masses of C1 and C2 were then assessed. Sequential images allowed evaluation of the extent of erosion of the articular surfaces of the atlas and the axis. The articular surfaces were divided by four quadrants (anterior, posterior, medial and lateral). The trajectory of the trans-articular screw was planned depending on the specific quadrant of the articular surfaces eroded. The size of the C2 pedicle was noted to decide upon the size of the screw to be used. The articular surface erosion was grouped as minimal ($n=2$), moderate ($n=13$) and severe ($n=12$) depending upon the extent of destruction. Moderate erosions were subdivided into two types. In subtype A ($n=9$), the erosion of the articular surface involved the antero-lateral and the postero-lateral quadrants, whereas the central and the medial portion of the articular surface was available for passage of the transarticular screws. In subtype B ($n=4$), the erosions encroached onto the central and the medial portion of the articular surfaces. In these patients transarticular screw fixation was not considered feasible. In patients with severe disease ($n=12$) the contour of the articular surface was difficult

Fig. 1 Reducibility criteria for atlanto-axial dislocation

to judge due to severe destruction and malalignment of the atlanto-axial complex (Fig. 2)

Surgical plan for management

The patients were broadly categorized into two groups. In 11 patients with an acceptable realignment of the atlanto-axial complex with minimal or moderate subtype A erosion of the articular surfaces, segmental atlanto-axial fixation using transarticular screws and modified Gallie's fusion was performed (Figs. 3, 4). Patients with moderate subtype B erosion or severe atlanto-axial disease were treated with OCF ($n=16$; Figs. 5, 6).

In one patient of the transarticular screw fixation group, the posterior arch of C1 was found impinging on the cord and was excised. The stand-alone screw fixation was protected with a rigid occipito-cervical orthosis for 3 months. In another patient, unequal affection of the articular masses permitted the passage of the transarticular screw on the left side only and this was augmented with modified Gallie's fusion. In all cases an attempt was made to denude the articular cartilage of the C1-C2 joint and achieve fusion using cancellous autogenous bone graft harvested from the posterior iliac crest.

The occipito-cervical fixation was performed using a Hartshill rectangle in 16 patients. The caudal level of fixation was C2 in seven patients and C3 in nine patients. In 12 patients with severe disease and in one patient with moderate subtype B erosion the posterior impingement was relieved by excision of the posterior C1 arch. The remaining three patients with moderate type B erosion presented with myelopathy and the author preferred to

excise the posterior arch of atlas although a significant impingement was not observed. A cortico-cancellous autogenous strut graft was placed between the occiput and the lamina of C2. In all these cases, an attempt was made to prepare the atlanto-axial joint for fusion in the manner similar to the transarticular screw fixation group. In the two patients with an irreducible atlanto-axial dislocation, a second stage anterior trans-oral debridement was necessary to relieve the residual supra-axial stenosis (Table 4).

Post-operative protocol

All patients were mobilized with an occipito-cervical orthosis 5 days after surgery. The anti-tubercular chemotherapy was continued for a minimum period of 12 months. The follow-up radiographs were obtained at 6 weeks and at 3, 6, 9, 12 months. The lateral mass fusion was assessed on open mouth radiographs, while the posterior fusion was judged on lateral radiographs. Facetal fusion was complete if bridging trabeculae (haziness) were seen crossing the joint surface. Unilateral facet fusion together with posterior fusion was noted as complete fusion.

Guarded cervical spine flexion-extension movements were resumed at 6 weeks irrespective of complete fusion. The patient was asked to chart subjectively the improvement in the flexion-extension range of movement at each follow-up as; less than 50%, or more than 50% of the normal pre-illness range. Rotations were permitted only after fusion was noticed on the radiograph. Post-operative pain score and neurological grading was carried out at each follow-up. At 24 months, the patients were asked to subjectively judge

Fig. 2 Articular surface erosion pattern and zone for trans articular screw

Fig. 3 Minimal erosion

Fig. 4 Moderate subtype A erosion

Fig. 5 Moderate subtype B erosion

Moderate Subtype B Erosion

Fig. 6 Severe erosion

Severe Erosion

Table 4 Surgical protocol

MINIMAL EROSIONS	Para-articular soft tissue abscess with normal contours of the articular surfaces	n = 2
MODERATE SUBTYPE A EROSIONS	Erosion of the antero-lateral and postero-lateral quadrants with the central and the medial portion of the articular surface intact.	n = 9
MODERATE SUBTYPE B EROSIONS	Erosion encroaching the central and medial portion of the articular surface	n = 4
SEVERE EROSIONS	Severe articular surface destruction with loss of contour. Significant occipito-atlantal or subaxial disease	n = 12

the limitations imposed by the surgery and the satisfaction experienced. This was documented as poor, fair, good and excellent.

Results

All patients were discharged from regular follow-up after 2 years and were asked to follow-up once a year. The minimum follow-up to assess completeness of fusion was 2 years (2–4 years)

Pain score

All patients had complete relief of pain and occipital headache. Two patients showed incomplete OCF but were asymptomatic. Resolution of pain occurred within 3 months in 22 patients (81.48%). In five patients pain improved gradually over 6–12 months (Table 1).

Neurological improvement

Twenty-two patients (81.48%) improved by one Nurick grade, while five patients (18.51%) remained static. Amongst the five cases that did not improve, two had irreducible AAD and required a second stage anterior debridement. No patient deteriorated. Hypoglossal nerve paresis improved in the first month after surgery with no residual deficit (Table 2).

Fusion

Complete posterior fusion was seen at 24 months in all but two cases (92.59%) of OCF. Sixteen out of 27 patients (59.25%) showed fusion as early as 3 months. In the transarticular screw fixation group, 8 out of 11 patients (72.72%) fused completely by 3 months and the fusion was complete in all patients as early as 9 months. In the transarticular screw fixation group, facet fusion occurred bilaterally in 8 out of 11 cases (72.72%), uni-

Table 5 Chart showing the number of patients showing fusion *TAS* Trans-articular screw, *OCF* Occipito-cervical fusion, *P* posterior fusion, *BF* Bilateral facet fusion, *UF* Unilateral facet fusion, *NF* Uncertain fusion

laterally in two cases (18.18%) and was uncertain in one patient (9.09%). In the OCF group, three patients (18.75%) fused by 3 months and seven (43.75%) by 9 months (Table 5). In two patients, the fusion was incomplete at 24 months. Wire breakage was seen in one patient but this did not interfere with fusion. Incomplete fusion was not associated with pain.

Range of movement and patient satisfaction

Ten out of 11 patients (90.90%) with segmental fixation subjectively graded the cervical spine flexion-extension movement as slightly more than 50% of the pre-illness status and were satisfied with the outcome of treatment. The remaining one patient reported incomplete neurological recovery as cause for poor outcome.

All 16 patients with OCF complained of significant restriction of spinal movements and only 12 patients (75%) were satisfied with the outcome. Rotations were restricted in both groups at 24 months. However, the combined restriction of flexion-extension and rotations produced significant disability in the OC group.

Complications

Superficial occipital sore occurred in four (25%) cases of OCF. Dural puncture during drilling of the skull occurred in one patient. Delayed wound healing was seen in one patient. There were no deep wound infections. Breakage of a single occipital wire was seen in one patient. This, however, did not interfere with OCF. In the transarticular screw fixation group, three patients had delayed wound healing. In one patient, a post-operative sinus formed that healed without complications after

3 months of anti-tubercular chemotherapy. There were no cases of implant failure or loosening. There was no vascular injury or neural injury.

Discussion

A spurt in the incidence of musculoskeletal tuberculosis has rekindled interest in the atlanto-axial disease. Although rare, atlanto-axial tuberculosis is an extremely disabling condition with potentially catastrophic complications. The disease begins as an infective synovitis of the atlanto-dental and atlanto-axial joints and continues unabated to destroy the osseoligamentous stability of the atlanto-axial complex and the occipito-cervical junction. In the pre-instability phase, anti-tubercular chemotherapy rapidly controls infection and affects a cure. This is the only definitive indication for conservative management [3, 15, 17, 27]. As instability ensues, the atlanto-axial complex settles into malaligned positions that include a combination of sagittal, vertical and rotatory deformity. Cord injury can be immediate due to acute compression by abscess, sequestra or osseous impingement. Traction and external orthosis help to realign the atlanto-axial and may alleviate pain and prevent spinal cord dysfunction. However, it is uncertain whether sufficient stability can be restored and late deformities can be prevented. Furthermore, it is difficult to predict the duration required for this reparative process to be complete. There is sufficient evidence now that the cord suffers repetitive microtrauma due to dynamic compression in a mal-aligned or unstable cranio-vertebral junction [1–3, 16, 25–28]. The indications for early intervention would therefore include progressive or non-improving neurological dysfunction, uncontrollable severe instability and early disease where stability is not restored after 6–8 weeks of conservative treatment [3, 17]. In endemic countries, it is not uncommon for the patients to present late with moderate to severe disease and a fixed mal-aligned atlanto-axial complex. A seemingly fixed atlanto-axial complex can be realigned into an acceptable position with supervised skeletal traction (92.59% in this series [25]).

Traditionally, surgical management of the atlanto-axial disease has focussed on atlanto-axial wiring for the early disease and OCF for severe destruction [1, 2, 7, 8, 16, 26–28, 31]. Segmental atlanto-axial wiring is mechanically unsound and requires support with rigid occipito-cervical orthosis until radiological fusion is seen [9, 12, 20, 23]. The use of rigid atlanto-axial fixation techniques like transarticular screws have allayed concerns regarding implant failure and instability recurrence associated with wiring techniques [6, 10, 14, 18, 19]. Although transarticular screws are used in other clinical situations, their role in tuberculous atlanto-axial instability is unclear. On the contrary to pyogenic organisms,

adherence and biofilm formation of *M. tuberculosis* on implant surface are less likely, and it can provide the basis of successful instrumentation in spine tuberculosis [13].

It is imperative to judge the reducibility and the pattern of erosion of the articular surfaces of the atlanto-axial joint to plan the trajectory of the transarticular screws in a partially destroyed joint [4, 5, 15].

In the present study, the reducibility of the atlanto-axial complex was graded as reducible, partially reducible and irreducible. In a partially reduced C1–C2 joint, the mal-alignment of the C1 and C2 articular surfaces was minimal providing adequate surface area for safe passage of TAS. Minimal forward translation of the atlas over the axis also reduced the inclination of the TAS thereby reducing the technical difficulty posed by soft tissues during passage of trans-articular guide wires. In this position, the ADI and the SAC are optimal to avoid compromise of the neural elements. The atlanto-axial joint being a synovial joint, the anterolateral and the posterolateral surface of the lateral masses in contact with the infected synovium demonstrate early erosions. The central and the medial portion of the articular surface are unaffected until late in the disease process (early and moderate type A erosion in the present study). Hence, transarticular fixation of the atlanto-axial complex can be performed in these cases. However, rigid segmental fixation is not possible when the medial portion of the articular surface is encroached upon by the infective pannus. This can be appreciated by assessing the sequential T1 and T2 images of the atlanto-axial complex. In the present study, the MRI was assessed by each author separately and the inter-observer variation was found in only one case (3.70%). However, there has been no discrepancy between the pre-operative radiological assessment and intra-operative findings. Considerable experience is required to interpret the MRI finding in tuberculosis, as it is often difficult to differ-

entiate between reactive bone edema and infective erosion. This may validate the need to assess the severity of the osseous lesion with a CT scan. In the present study, CT scan was performed in the first seven cases. The assessment of the articular contour in both imaging modalities was found similar by the author (M.B.). Hence, the CT scan was not used in the remaining cases. Out of the 27 cases in the present study, 11 patients (40.74%) were amenable to transarticular screw fixation augmented with a modified Gallie's fusion. The fusion rates and the patient satisfaction rates were significantly higher in this group than the remaining 16 patients with severe disease who underwent an OCF. Comparison between the two surgical groups with the differing grades of disease sounds incorrect. However, the author wishes to emphasize that a large proportion of these patients with moderate erosion of the articular surface would otherwise undergo OCF. The main drawback of the current study is the relatively small number of patients in each surgical group. The author has therefore tried only one method of segmental fixation. However, other fixation modality, viz. atlanto-axial plating techniques can be used [11, 20]. Similar patterns of erosion are likely to be encountered in inflammatory and tumorous affections of the cranio-vertebral junction where segmental atlanto-axial fixation can be attempted. In one case the author preferred a unilateral facet fixation due to severe destruction of one of the facet joint [10, 21, 29, 30].

Conclusion

Defining the pattern of erosion of the articular surfaces of the atlas and the axis helps to salvage patients for rigid segmental fixation of the atlanto-axial complex. Sparing the occiput improves the fusion rate, allows early restoration of movements and improves patient satisfaction.

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