C7 decancellation closing wedge osteotomy for the correction of fixed cervico-thoracic kyphosis

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Abstract Our objective is to report on the clinical and radiological outcome following a decancellation closing wedge osteotomy for the correction of fixed cervico-thoracic kyphosis in patients with ankylosing spondylitis. The only treatment available for severe fixed flexion deformity of the cervical spine in these patients is an extension osteotomy. Traditionally an anterior opening, posterior closing wedge osteotomy is performed with or without internal fixation. We describe a decancellation *closing* wedge osteotomy of C7 accompanied by secure segmental internal fixation. Eight patients operated between 1990 and 2003 with mean age of 54 years and minimum follow up of 2 years were retrospectively evaluated. Restoration of normal forward gaze was achieved in all patients. No patient suffered spinal cord injury or permanent nerve root palsy. There was no loss of correction or pseudarthrosis at final follow up. C7 decancellation closing wedge osteotomy supplemented with secure segmental internal fixation in experienced hands

provides a safe and effective treatment for fixed cervico-thoracic kyphosis in patients with ankylosing spondylitis.

Keywords Cervico-thoracic kyphosis · Cervical osteotomy · Segmental fixation · Ankylosing spondylitis

Introduction

Severe fixed flexion deformity of the cervical spine in patients with ankylosing spondylitis can cause significant psychological and functional disability [7]. Apart from being painful, it can cause marked limitation of the forward gaze, interfere with chewing, swallowing and skin care under the chin.

Advances in the medical treatment including anti-TNF medication, may slow or prevent development of spinal deformity in spondyloarthropathies [1]. Prevention of these deformities by early recognition of the disease process and adequate medical treatment should still be the main aim of the medical profession [13].

In patients with radiologically incomplete ankylosed spines, closed correction of cervico-thoracic deformity with traction and subsequent fusion without osteotomy may be appropriate [8]. However, in patients with advanced disease causing a fixed deformity, the only treatment available is a corrective extension osteotomy [7, 9].

Anterior opening and posterior closing wedge osteotomy in the cervical spine for the correction of a kyphotic deformity has been previously described [5–7, 9, 12, 13, 15] (Fig. 1). We present our experience with a decancellation *closing* wedge osteotomy at C7

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Fig. 1 Planned resection lateral view for traditional anterior opening/posterior closing wedge osteotomy (*left*). Lateral view after closure of osteotomy (*right*)

supplemented by secure segmental internal fixation (Fig. 2).

Materials and methods

Eight patients who underwent decancellation closing wedge osteotomy at C7 for fixed cervico-thoracic kyphosis between 1990 and 2003 (six male and two female), were retrospectively evaluated. Among these, seven patients underwent the above procedure between 1997 and 2003, while one patient underwent this procedure in 1990. The mean age was 54 years (range 35–74 years). The minimum follow up was 2 years (range 2–3 years). All patients had a significant chin-

on-chest deformity with marked restriction of forward gaze (Figs. 3, 4). Three patients had previously undergone a lumbar osteotomy and two patients previously underwent total hip replacements. One patient underwent a staged procedure that involved an initial thoracic osteotomy followed by combined lumbar and cervical osteotomy 3 weeks later. Five patients had ankylosing spondylitis and three patients had associated psoriatic spondyloarthropathy. Two patients had a previous T1 fracture resulting in a pseudarthrosis.

Clinical outcome was assessed by patient completed questionnaire at each follow up appointment. The patient was asked to grade the outcome as: (1) excellent, (2) good, (3) satisfactory, (4) no change, (5) unsatisfactory, and (6) poor. Clinical photographs were taken

Fig. 2 Planned resection lateral view for closing wedge osteotomy (*left*). Lateral view after closure of osteotomy (*right*)

Fig. 3 Fifty seven-year-old male underwent initial lumbar osteotomy for the correction of thoraco-lumbar kyphotic deformity followed by cervical osteotomy for the correction of fixed cervico-thoracic kyphotic deformity. Figure 3a: pre-operative lateral standing clinical photograph. **b** Post lumbar osteotomy lateral standing photograph. **c** Post cervical osteotomy lateral standing photograph

pre-operatively and at final follow up. The Chin Brow Vertical Angle (CBVA) was measured using clinical photographs.

Radiological outcome was assessed using standing lateral radiographs preoperatively, 3 months postoperatively and at final follow up. The preoperative cervico-thoracic kyphosis and postoperative lordosis was measured by the angle formed between the lines drawn connecting the posterior cortices of lower cervical and upper thoracic vertebrae. Complications including neurological deficit, loss of correction, implant failure and revision surgery were recorded.

Senior Author's current recommended surgical technique

The aim of the cervical osteotomy is to: (1) correct chin on chest deformity, and (2) improve forward gaze of the patient. Sagittal imbalance must be corrected *first* before performing the cervical osteotomy.

Pre-operative planning involves:

1. Standing lateral radiographs and clinical photographs to measure: (a) Chin Brow Vertical Angle (CBVA) and cervical kyphosis to assess the degree of gaze angle correction required, and (b) the C7 sagittal plumb line to confirm that no sagittal imbalance existed.

2. Magnetic resonance imaging (MRI) to rule-out cranial-cervical stenosis and confirm the vertebral artery enters the cervical spine through the transverse foramen of the sixth cervical vertebrae. Magnetic resonance angiography (MRA) if available also helps to confirm the position and flow of the vertebral artery.
3. Computer tomography (CT) scan to assess: (a) skeletal anatomy and degree of calcification of the anterior longitudinal ligament, (b) the degree of C1/C2 ankylosis (this is the last segment to fuse in ankylosing spondylitis, hence this can cause difficulty in assessing the amount of neck extension required during the corrective manoeuvre), (c) for the presence of previous fracture with or without pseudarthrosis, and (d) the dimensions of vertebral bodies, pedicles and cervical lateral masses.

Surgical technique

The patient is intubated via an awake fibre-optic endotracheal intubation. After general anaesthesia is induced, a carbon-fibre halo is applied. The spinal cord is monitored using somato-sensory evoked potentials (SSEPs) and motor-evoked potentials (MEPs). The patient is positioned prone with the head immobilised using a Douro attachment to hold the halo ring firmly

◀ **Fig. 4** Fifty nine-year-old male with psoriatic arthropathy had C7/T1 fracture leading to fixed cervico-thoracic kyphosis. He had normal sagittal balance. **a** Pre-operative lateral standing clinical photograph. **b** Post cervical osteotomy standing lateral clinical photograph illustrating good correction achieved. **c** Pre-operative lateral whole spine radiograph illustrating that the deformity is at the cervico-thoracic junction. **d** Post operative lateral whole spine radiograph illustrating the correction achieved. **e** Post cervical osteotomy cervico-thoracic lateral radiograph

to the table. Transparent drapes are used, as this allows visualisation of the patient during the corrective manoeuvre.

The lower cervical and upper thoracic spine is exposed via a standard posterior midline approach. The procedure can be described in four stages as follows:

Stage 1: (Insertion of screws)

After identification of the levels with image intensifier, top loading lateral mass screws are inserted into C4, C5 and C6 followed by pedicle screws into T2, T3 and T4.

Stage II: (C7 decancellation)

A posteriorly based wedge is resected (Fig. 2). This includes the whole of the lamina of C7, the inferior part of C6 lamina and the superior part of T1 lamina. The lateral masses of C6 should be preserved for the insertion of screws. The osteotomy is extended laterally to decompress the C8 nerve roots thoroughly. The fused C7–T1 facet joints and lateral walls of the C7 pedicles are removed with a high-speed burr and Kerrison rongeur. The medial walls of the C7 pedicles are kept intact at this stage; which not only helps to protect the dura but also prevents bleeding from the epidural vessels. Surface haemostatic agents and cottonoids are used to decrease bleeding. Using straight and curved fine curettes, the C7 vertebral body is decancellation via the pedicles. This is performed as far forward as the anterior longitudinal ligament and medially until it communicates with the contralateral side. Fluoroscopic imaging may be utilised to check the position of the curettes. It is the intention to use the retained anterior longitudinal ligament as the hinge to *close* the osteotomy (Fig. 2). All bone debris is thoroughly washed out. The lateral cortical walls of the C7 vertebrae are then resected in a ‘V’ shaped manner using a Leksell rongeur as far as the anterior cortex. The medial walls of the pedicles are now removed with a fine bone nibbler and a L shaped bone punch used to

push the posterior cortex of the vertebral body into the decancellised space. Larger fragments of bone are gently removed from the vertebral body and the decancellised vertebral space is thoroughly washed out. Utmost care is exercised to avoid retraction of the cervical spinal cord. At this stage the C8 and T1 nerve roots are then re-examined to ensure that they are freely mobile.

Stage III: (Application of the rods)

Upon completion of the wedge resection, the surgeon prepares two tapered titanium rods (3.5–6.0 mm) (Synthes, Switzerland) by cutting to the appropriate length and contouring into the corrected lordosis intended for the cervico-thoracic junction. The ‘cervical’ part of the rod is then connected to the lateral mass screws on each side. The taper should be positioned just above the cervico-thoracic junction, as this offers superior biomechanical strength. The ‘thoracic’ part of the rod is kept free at this stage.

Stage IV: (Closure of osteotomy)

The surgeon then de-scrubs, goes to the head of the table and firmly grasps the halo. An un-scrubbed assistant then unclamps the halo and the surgeon, with elbows tucked next to his trunk slowly extends the neck to the desired position and holds the halo firmly. The Halo is then reclamped in that position. The surgeon continues to support the halo. During this important stage the scrubbed assistant closely monitors changes in the dura, nerve roots and ensures that the residual posterior elements of C6 and T1 vertebrae do not impinge on the posterior dura as the neck is extended. It is sometimes possible to see crinkling of the posterior dura mater at this stage as the tension is taken of this structure. As this is a *shortening* procedure of the spine this should not cause neurological deficit provided the undercutting of the lamina has been performed adequately. Great care is taken to prevent *translation* at this point. The scrubbed assistant then connects the ‘thoracic’ part of the rods to the thoracic pedicle screws. All screws are tightened and crosslinks applied at the cranial and caudal extent of the instrumentation to increase the rotational stability of the construct. Decortication is performed from C4 to T3. Local bone graft plus bone graft harvested from the posterior iliac crest is then laid down posterolaterally. A deep drain is placed and the wound closed in layers. The patient is recovered and when comfortable immobilised in a Halo jacket for a total of 3 months.

Results

All patients reported restoration of normal forward gaze. Subjective outcome was excellent in three patients and good in five patients. There was no significant neurological deficit in any patient. Three patients reported mild sensory radiculopathy in the C8 dermatome lasting 2–4 weeks. Two patients had deep infections that were successfully treated with debridement and intravenous antibiotics.

The mean blood loss was 2,400 mls (range 1,000–3,200 mls). The mean operative time after anaesthesia and positioning of the patient was five hours (range 3–6 h and 30 min).

One patient (Table 1—patient 2) had preoperative cervico-thoracic kyphosis of 40° and CBVA of 108°. He underwent staged thoracic, lumbar and cervical osteotomy during the same admission to correct his sagittal balance and forward gaze. His postoperative cervico-thoracic kyphosis was 20° and CBVA was 16°. In the remaining seven patients, the mean preoperative cervico-thoracic kyphosis of 15° (range 10°–30°) was corrected to a lordosis of –41° (range –18° to –50°) achieving mean total correction of 57° (Table 1). The mean CBVA in these seven patients improved from 41° (range 16°–60°) to 6° (range –7° to 18°) (Table 1). There was no pseudarthrosis or loss of cervico-thoracic correction at final follow-up. One patient developed a 50% anterior subluxation of C7 on T1, which later united.

Discussion

Cervical fixed flexion deformity in patients with ankylosing spondylitis can be a primary deformity or it may be associated with fixed flexion deformity of the hips and or thoracolumbar kyphotic deformity. In which case consideration should be given to a total hip replacement and corrective lumbar osteotomy *before* a cervical osteotomy is considered [13].

Although lumbar osteotomy at the level of cauda equina is relatively safe, cervical osteotomy is extremely hazardous. Urist [15] recommended the C7/T1 junction as the optimum site for corrective osteotomy because: (a) the spinal canal is relatively wide, (b) the cervical cord and eighth nerve root have good flexibility in this region, (c) damage to the C8 nerve root is less detrimental to the hand function than damage to the other nerve roots, and (d) the vertebral artery is less likely to kink when the neck is extended.

Urist [15] and Simmons [13] performed surgery under local anaesthesia with the patient in the *sitting*

Table 1 Table illustrating correction achieved by decancellation closing wedge cervical osteotomy in each patient

Patient number	Pre op C7/T1 kyphosis (degrees)	Post op C7/T1 Lordosis (degrees)	Correction achieved (degrees)	Pre op CBVA (degrees)	Post op CBVA (degrees)	Correction achieved (degrees)
1	10	−40	50	28	−4	32
2	40	20	20	108 ^a	16 ^a	92 ^a
3	12	−50	62	60	10	50
4	30	−18	48	16	0	16
5	10	−50	60	56	18	38
6	10	−50	60	34	−7	41
7	10	−50	60	40	12	28
8	26	−34	60	51	13	38

^a Includes correction achieved due to staged thoracic, lumbar and cervical osteotomy during the same admission

CBVA Chin brow vertical angle

position, as this avoids potentially hazardous endotracheal intubation and also allows continuous subjective intraoperative monitoring of the spinal cord and nerves. There are a number of disadvantages however with this technique: (1) at the point of correction the patient is given a brief anaesthetic thereby losing subjective spinal cord monitoring, (2) lack of airway control in the event of sudden emergencies, (3) risk of air embolism, and (4) difficulty in managing hypotension. Due to the advances in fibre optic intubation and somatosensory and motor evoked potential monitoring, general anaesthesia is now favoured by the patient, surgeon and the anaesthetist [5, 7, 9].

In the thoracolumbar region, three types of spinal osteotomies have been described for the correction of deformity in the ankylosing spondylitis [16]: (1) opening wedge osteotomy, (2) polysegmental osteotomy, and (3) closing wedge osteotomy.

An *opening* wedge osteotomy is performed with the posterior longitudinal ligament acting as a hinge, leading to fracture of the anterior longitudinal ligament. This differs from the technique of a closing wedge osteotomy where the hinge is based at the anterior longitudinal ligament [11, 14, 17] thus leading to controlled correction of the osteotomy. The sharp lordotic angle and elongation of anterior column by an opening wedge osteotomy was associated with serious vascular and neurological complications [16]. In the cervical spine this can cause stretching of anterior structures including trachea and oesophagus. Furthermore subluxation caused by rupture of posterior longitudinal ligament was associated with high incidence of non-union, neurological complications and even death [2].

Polysegmental osteotomy maybe associated with lower risks. However the correction achieved is often insufficient especially when the intervertebral discs are

calcified [16]. This technique has not been described in the cervical spine.

Theoretically, a closing wedge osteotomy is superior to the other two techniques in terms of safety and efficacy because there is no stretch of anterior structures and rapid fusion can occur across the two cancellous surfaces with minimal loss of correction [16]. In this technique the disc status is not important. However it is technically difficult. Due to extensive improvements in the intraoperative spinal cord monitoring and spinal instrumentation system, the technical difficulties have been minimised.

Halo-jacket *without* internal fixation after osteotomy has been found to be inadequate for immobilisation [7, 9], hence the addition of internal fixation can prevent displacement and loss of correction postoperatively. Although Shimizu et al [12] and Mc Master [7] initially used sub-laminar wires, due to the ankylosis of posterior bony elements and possibility of tearing underlying adherent dura, they are no longer used. Lateral mass and thoracic pedicle screws with rods have been used more recently [4, 9].

High incidence of post-operative superficial and deep wound infection has been reported in the literature following deformity correction in patients with ankylosing spondylitis [16]. In our series, two patients developed deep infections, which were successfully treated by debridement and intravenous antibiotics. Due to the small number of patients investigated, this might not be the true reflection of the infection rate. However, we believe that this group of patients are more prone to infection by virtue of the fact that they are immunocompromised due to their underlying disease and that they are usually taking anti-inflammatory and other disease modifying medications.

Proper positioning of the patient is important. Postoperative blindness has been reported due to the

increased eyeball pressure during the operation [3]. Application of a halo preoperatively helps to: (1) immobilise the head with a Douro attachment to the table, thus avoiding the use of facial padding thereby reducing eyeball pressure and the incidence of postoperative facial oedema, (2) controlled correction of the deformity after the osteotomy, and (3) postoperative immobilisation in a halo jacket. The reverse Trendelenburg position of the table helps to reduce the bleeding, but can increase the incidence of venous air embolism and hence we kept the table horizontal to the ground. This also helps to estimate the amount of correction by allowing the patient's face to be parallel to the floor after correction of the deformity. Simmons [13] recommended that slight under correction of the deformity is desirable as opposed to overcorrection because this would achieve good compromise between looking ahead for walking and being able to work at a desk.

The use of intra-operative spinal cord monitoring is also extremely important in this group of patients [4]. In our series, the first three procedures were carried out with SSEP monitoring alone, whilst the remainder of the operations were carried out with combined SSEP/MEP monitoring [10]. Although Stagnara 'wake-up' test has been the gold standard for assessment of neurological status during spinal deformity surgery, timely completion of an intraoperative wake-up test can be difficult in an already technically demanding and hazardous cervical osteotomy operation. Furthermore the critical time window for reversal of a deficit can be lost while waiting for the patient to recover consciousness. Hence we strongly recommend the use of intraoperative spinal cord monitoring.

We believe intra-operative bleeding is mainly due to the bleeding from the epidural vessels, rather than the cancellous vertebral body and hence retaining the medial walls of the pedicles until the last stage helps to decrease bleeding. Generous use of surface haemostatic agents and packing with cottonoids also helps to reduce the amount of bleeding.

Leaving behind the pedicular remnants, as can happen in an opening wedge osteotomy, may lead to kinking of the nerve roots with resultant radiculopathy when the osteotomy is closed. The pedicles are completely removed in decancellation closing wedge osteotomy; therefore the incidence of postoperative radiculopathy is extremely low. Intraoperative sagittal translation and postoperative loss of correction is associated with anterior defects inherent with an opening wedge osteotomy and is less likely to occur with a decancellation closing wedge osteotomy [16]. The use of segmental internal fixation also helps to

provide immediate spinal stability maintaining correction until bony union.

Conclusions

Cervico-thoracic osteotomy continues to be challenging and hazardous, but successful surgery can be immensely beneficial to the patient. Adapting the decancellation closing wedge osteotomy commonly used in the lumbar spine for use in the cervical spine has produced gratifying results in this series of cervical osteotomy for fixed cervico-thoracic kyphosis patients. Greater control in closing the osteotomy, greater area of contact between cancellous surfaces and the concept of shortening the neuro-axis has definite advantages over the standard opening wedge osteotomy originally described by Urist and Simmons [13, 15]

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