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Cervical osteotomy in ankylosing spondylitis: evaluation of new developments

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Abstract *Objectives:* Cervical osteotomy can be performed on patients with cervical kyphosis due to ankylosing spondylitis. This study reviews the role of two new developments in cervical osteotomy surgery: internal fixation and transcranial electrical stimulated motor evoked potential monitoring (TES-MEP). *Methods:* From 1999 to 2004, 16 patients underwent a C7-osteotomy with internal fixation. In 11 patients, cervical osteotomy was performed in a sitting position with halo-cast immobilization (group S), five patients underwent surgery in prone position with Mayfield clamp fixation (group P). In group P, longer fusion towards T4-T6 could be obtained that created a more stable fixation. Therefore, post-operative immobilization protocol of group P was simplified from halo-cast to cervical orthosis. *Results:* Consolidation was obtained in all patients without loss of correction. Post-operative chin-brow to vertical angle measured 5° (range 0–15). TES-MEP was successfully performed during all surgical proce-

dures. In total, nine neurological events were registered. Additional surgical intervention resulted in recovery of amplitudes in six of nine events. In two patients spontaneous recovery took place. One patient showed no recovery of amplitudes despite surgical intervention and a partial C6 spinal cord lesion occurred. *Conclusion:* We conclude that C7 osteotomy with internal fixation has been shown to be a reliable and stable technique. When surgery is performed the in prone position, distal fixation can be optimally obtained allowing post-operative treatment by cervical orthosis instead of a halo-cast. TES-MEP monitoring has been shown to be a reliable neuromonitoring technique with high clinical relevancy during cervical osteotomy because it allows timely intervention before occurrence of permanent cord damage in a large proportion of the patients.

Keywords Ankylosing spondylitis · Cervical spine osteotomy · Instrumentation · Neuromonitoring · TES-MEP

Objectives

Ankylosing spondylitis is a rheumatic autoimmune disease in which the ossification of ligament and joints results in fusion of the spinal column. Involvement of the cervical spine may lead to flexion deformities and severe “chin on chest” deformities (Fig. 1). The development

of a rigid spine in ankylosing spondylitis is often combined with a flexion contracture of the hips. The cervical kyphosis therefore cannot be compensated by extending the hips resulting in restriction of the horizontal gaze. This restriction is socially very disabling and also can cause pain and sometimes complicates eating and breathing.

Fig. 1 **a** Pre-operative photograph of a patient with a cervical kyphosis due to ankylosing spondylitis. Notice an increased chin-brow to vertical angle and a horizontal gaze impairment. **b** Post-operative photograph of the same patient after a C7 correction osteotomy. Notice the reduction of the CBV angle and the correction of the horizontal gaze compared to the pre-operative photograph. Note the change in compensatory knee flexion and improved general balance.

The surgical technique to reduce the cervical-thoracic kyphosis angle is a cervical correction osteotomy as first published in 1977 by Simmons [16]. Considering the patient group with a rheumatic disease and associated comorbidity, this is a potentially hazardous procedure. Surgery was performed in a sitting position under local anesthesia allowing continuous neurologic monitoring. Halo casting was used to maintain the correct position; no internal fixation was performed. McMaster [10] published a second case series in 1997 describing the technique of a C7–T1 cervical osteotomy under generalized anesthesia in a prone position without internal fixation in 12 patients and with internal fixation in three patients.

Due to new developments in internal fixation techniques and in evoked potential neuromonitoring methods, the surgical possibilities for cervical osteotomy are increasing. However, the benefits and results of the new possibilities on this difficult and potentially hazardous procedure have not been reviewed.

In this study, the results are reviewed for a series of 16 patients from one operative team. New aspects were the consistent use of internal fixation and continuous motor

evoked potential monitoring of arms and legs. The aim of this study is to report these new intra-operative developments and to evaluate their role.

Patients and methods (Table 1, Fig. 1a, b)

The data was reviewed for 16 patients, 14 males and two females, who underwent a cervical osteotomy between 1999 and 2004. All patients suffered from ankylosing spondylitis. Pre-operatively, one patient was diagnosed with poly-neuropathical abnormalities of sensory and motor deficit of both feet. Six patients had suffered from earlier cervical fractures.

The indication for surgical intervention was a fixed cervical kyphosis impairing the horizontal gaze function and restricting activities of daily living (ADL). During pre-operative clinical examination this impairment is expressed by the chin-brow to vertical angle (CBV). The CBV angle measures the angle between the line from chin to brow and the vertical axis of a standing patient. Good extension of the patients' knees is essential during this measurement to obtain valid values. The average

pre-operative chin brow angle measured 42° (range 30–70). Average age in this group of patients was 50.8 years (range 23–82).

Pre and post-operative radiological evaluation was performed on the lateral cervical X-rays. Pre-operatively, the intervertebral fusion due to ankylosing spondylitis is determined. The Cobb-angle of the cervical kyphosis was measured when possible, however in most patients it could not be obtained due to over-projection of chest, scapula and jaw.

The surgical data and TES-MEP data were gathered during the operations. The results of the TES-MEP monitoring were used to register and evaluate neurological events.

At post-operative follow-up the CBV angle and neurological impairment were determined. On the lateral cervical X-ray, consolidation of the osteotomy was assessed and the Cobb angle was measured. Successful fusion was noted when consolidation was seen in the corrected extended cervical spine, defined as bone fusion seen on the lateral X-ray. This can be difficult to assess in patients with ankylosing spondylitis. When the X-ray is not conclusive, clinical assessment contribute in determining consolidation. After 3 to 6 months, consolidation can be assumed when a radiograph can confirm an identical position of the instrumentation and the clinical assessment shows a patient without pain and a clinically unchanged extended cervical spine.

Technique

Surgical technique

The cervical spine was exposed between occiput and T3 or lower. The level of C7/T1 was identified. Lateral mass screws are placed bilaterally at C3, C4 and C5. At the T1 pedicle, and if needed and possible, at more distal levels, pedicle screws were placed bilaterally (Cervifix/low structure USS, Synthes, Switzerland). Excision of the spinous process at C6 and C7 and a laminectomy at C7 were performed. The bilateral foramen of the C7 and C8 nerves was fully exposed at both sides. The osteotomy was performed as described by Simmons [16]. Due to the soft bone, mostly a curette or rongeur, sometimes an osteotome is used. The corrective extension maneuver was made and the osteotomy was closed according to pre-operative planning. No intra-operative X-rays are performed. Clinically, the extension maneuver and the position of the head are closely observed through the transparent drapes. One surgeon performs the extension maneuver by holding on to the clamp or halo. Then the cervical and thoracic screws were attached to contoured rods in the corrected position and bone grafts were placed posterior over the laminae. Due to the correction, the laminae of C6 and T1 are almost in contact.

The results of the TES-MEP monitoring were carefully registered. When the neuromonitoring amplitudes remained stable, the internal fixation rods were fixed. Whenever decrease in amplitude occurred (below 20% of reference value) [8], potential causes of the amplitude decrease were detected following a three step protocol. First, decreases due to technical causes were detected and repaired. Second, optimization and stabilization of any hemodynamical changes was performed. Third, when the TES-MEP amplitudes remain low, the preceding surgical maneuver was considered to be the cause of the amplitude decrease and a significant warning for impending neurologic deficits. Therefore, if possible the last surgical maneuver was corrected or reversed, for example reducing the correction or replacing a pedicle screw.

In this study, the first 11 patients underwent the cervical osteotomy in a sitting position (group S). In these patients a halo-cast was applied pre-operatively and continued after surgery until consolidation of the osteotomy. In a sitting position, stabilizing the obtained correction by internal instrumentation is technically difficult, as the rods have to be contoured to the new shape of the extreme lordosis. The halo-cast severely limits the maneuver area and subsequently impedes the distal fixation procedure.

To overcome these technical problems, the technique was modified to a procedure performed in a prone position using the Mayfield clamp to fixate the head. This position was used in the last five patients (group P). In the absence of a halo-cast, the application of the internal instrumentation was earlier to achieve. Therefore good distal fixation could be performed and extended distally to level T6 or lower. Because a more stable fixation was obtained by the longer instrumentation, this group was treated post-operatively with a stiff cervical orthosis until bony fusion of the osteotomy was shown.

Neuromonitoring by TES-MEP

Intra-operative neuromonitoring was performed by transcranial electrical motor evoked potential (TES-MEP) monitoring in all patients. The responses were elicited by transcranial electrical stimulation using a custom-made stimulator, the Neuro-guard (JS-Center, Bedum, The Netherlands).

Two needle electrodes were inserted subcutaneously at 2 cm posterior from Cz (the anode). The cathode, a Velcro ground strip electrode, was immersed in saline and placed on the forehead. Electrode impedance calibration was performed pre-operatively. Multipulse stimulation was used at supramaximal level in a train of 4–7 pulses, with a pulse width of 100 µs and interpulse interval of 2 ms. The supramaximal level was determined before surgery and generally measured between

150 V and 250 V. Double train stimulation was used with a intertrain interval of 20–25 ms to increase amplitudes in five patients [6].

The evoked muscle responses were recorded at four bilateral muscle groups with surface electrodes. As surgery was performed at C7, the responses measured at the trapezius muscle (C2–C4) could be considered a reference site to which responses from below the operative level could be compared. Of the other three bilateral monitoring sites, two monitoring sites are selected at the upper extremity and one on the leg. Possible monitoring sites were: the forearm extensors, the muscle abductor digiti V, the muscle abductor pollicis brevis, the anterior tibial muscle, the quadriceps muscle, and the hamstrings.

Sudden decreases in amplitudes were registered, and the tendency of the overall curves was followed closely. Whenever response amplitude decreased, possible technical failure, systemic changes (blood pressure, heart rate, and body temperature) and recent surgical action were documented. Decreases below 20% of the pre-operative reference values were defined as significant changes of amplitude and were reported to the surgeon as a possible neurological event when other causes as technical failure or systemic changes had been ruled out [8].

Anesthetic techniques

Intubation in patients with a rigid cervical kyphosis is difficult because of restricted access to the oral cavity. Therefore all patients were intubated with oral tracheal fiber optic intubation technique.

Because of the use of TES-MEP monitoring during surgery, a strict anesthetic protocol was required as muscle relaxants decrease the monitored muscle responses. Patients were orally premeditated with midazolam (0.1 mg/kg) 1 h before general anesthesia. No muscle relaxants were given that would influence the muscle responses. General anesthesia was induced with a bolus dose of propofol (2 mg/kg) and remifentanyl (1 µg/kg). If relaxation was necessary for smooth intubation, atracurium (0.4 mg/kg) was given once

(1/2: 15–30 min). During the first 30 min, anesthesia was maintained by propofol (4 mg/kg/h) by continuous infusion. Thereafter, the dose was lowered to 2 mg/kg/h). Continuous infusion of remifentanyl began at 15 µg/kg/h and was titrated according to pain responses. Bolus application of remifentanyl and propofol was avoided because of its influences on the TES-MEP responses. Thirty minutes before the end of the operation, morphine was given and remifentanyl was stopped 20 min thereafter. Patients were ventilated with a gas mixture of O₂ and N₂O in the ratio 1:2.

Results

Surgical procedure (Table 2, Fig. 2a, b)

The anesthetic and TES-MEP monitoring preparation time took 90–160 min (average 126 min). The average blood loss was 940 ml (range 150–2650 ml) and the average time of surgery measured 194 min. (range 135–270 min). The patients, operated in a sitting position, wore a halo-cast post-operatively for 8–16 weeks. The patients operated in the prone position wore a stiff cervical orthosis for 12–16 weeks.

Post-operative results and complications (Table 2)

The surgical procedure was completed in all patients. The post-operative CBV angle measured approximately

Table 1 Co-morbidity or previous surgery of 16 patients undergoing a C7 correction osteotomy

Comorbidity/previous surgery	Number of patients
Previous lumbar osteotomy	6
Previous cervical fractures	6
Crohn's disease/colitis	5
Total hip arthroplasty	3 (all bilateral)
Chronic obstructive pulmonary disease	2
Cardiovascular disease	2
Vasculitis	2
Insuline dependent diabetes mellites	1

Fig. 2 **a** Pre-operative X-ray of the cervical spine with a rigid cervical spine due to ankylosing spondylitis. **b** Post-operative X-ray of the same cervical spine after a C7 osteotomy with internal fixation.

Table 2 Post-operative surgical outcome in 16 patients undergoing a C7 correction osteotomy

Nr	Age	position	Level	Surgical cause of TES-MEP depression < 20%	Subsequent surgical actions	Recovery of TES-MEP depression	Complications
1	33	Sitting	C4–T2	1. Pedicle screw misplacement 2. During extension procedure	1. Replacement screw 2. Reduction of obtained correction	Yes	Transient C8 paraesthesia
2	23	Sitting	C6–T1	During correction procedure	Reduction of obtained correction	Yes	Viral meningitis
3	64	Sitting	C4–T1	–	–	–	Transient C8 paresthesia
4	56	Sitting	C4–T2	–	–	–	–
5	82	Sitting	C3–T3	During correction procedure	Reduction of obtained correction	No	C6 partial spinal cord lesion. Second surgery without recovery
6	30	Sitting	C2–T2	–	–	–	Cardiac arrest and resuscitation 4 days post-operatively, resulting in severe post anoxic encephalopathy
7	41	Sitting	C4–T2	During correction procedure	Reduction of obtained correction	Yes	–
8	45	Sitting	C4–T3	–	–	–	Transient C8 paresthesia
9	56	Sitting	C3–T2	–	–	–	Transient C8 paresthesia
10	74	Sitting	C3–T1	–	–	–	Transient C8 paresthesia
11	46	Sitting	C4–T2	–	–	–	Second surgery for prominent tender part of T1 spinal proces
12	47	Prone	C3–T6	During correction procedure	Reduction of obtained correction	Yes	Transient C8 paresthesia
13	62	Prone	C3–T4	–	–	–	Transient C8 paresthesia, wound infection
14	64	Prone	C4–T4	During correction procedure	Immediate spontaneous recovery	Yes	Wound infection (readmitted for debridement), transient C8 paresthesia
15	46	Prone	C3–T6	–	–	–	Transient paresthesia right leg
16	44	Prone	C3–T5	1. During laminectomy C7 2. During correction procedure	1. 30 min wait with corticosteroids 2. Reduction of obtained correction	Yes	Fist post-operative days reduced strength in upper extremities (4/5) with full recovery

5° (range 0–15°); an average correction of 38° (range 25–65). All patients had a minimum post-operative follow-up period of 1 year. In all patients consolidation was obtained within 4 months. The average acquired cervical lordosis measured by Cobb's angle was 33.5°.

Two severe complications occurred in this case series both in group S treated with a Halo-cast. One 82 year old patient with pre-operative myelopathy developed a C6 spinal cord lesion that was registered by TES-MEP monitoring, but it could not be reversed either intra-operatively or by a secondary anterior decompression surgery performed the same day. The result was a C6 right/C7 left motor and partial sensory deficit with no evidence of late recovery. One patient died 6 weeks post-operatively, after a cardiac arrest 4 days post-operatively resulting in a post-anoxic encephalopathy. Other post-operative complications were: viral meningitis (1), wound infection (2), temporary C8-paresthesia/arm pain (9). Two patients underwent additional surgery. In one patient, a debridement of the wound was performed 1 month after the cervical osteotomy, because of a wound infection. In addition antibiotics were subscribed

and he was discharged after 17 days when the wound had healed. Another patient was readmitted 6 months post-operatively for resection of a prominent tender part of a spinous proces at T1.

TES-MEP neuromonitoring (Table 2, Fig. 3)

In all 16 patients TES-MEP monitoring was performed successfully. In two patients reference monitoring of the trapezius muscle could not be performed. Monitoring was completed using the remaining six muscle sites. The transcranial elicited trapezius muscle response could not be performed because of two reasons. First, from direct stimulation of the high cervical roots (C2–C4) by extracranially conducted TES currents along the scalp, muscle responses (M-response) interfered with the intracranially elicited MEP response. Secondly, interference from extinction of large stimulation artifact occurred when the halo-cast forced to more medial placement of the EMG electrodes over the trapezius muscles. The Mayo-clamp used in group P, permitted more lateral

Fig. 3 Time plots of the TES-MEP amplitudes for four bilateral muscle groups in patient 12 (Table 2). Time marks (*X*-axis) indicates 15 min. At each time plot, the amplitude is given as a percentage from the reference point that was set just before cervical correction (line **R**). Immediately after the correction (line **C**) a change in amplitudes is registered, with a decrease below 20% of both anterior tibial muscles and the right hand muscles. After intervention (line **I**) by reducing the achieved correction amplitude recovery is seen.

placement of the electrodes, which resulted in a marked reduction of these artifacts.

In seven patients, the TES-MEP monitoring was undisturbed with amplitudes of all muscles sites above 20% of reference values. Of these patients, post-operative clinical neurological examination showed no motor changes.

During two surgical procedures, technical disturbances caused a transient decrease of muscle responses. An accidental disconnection of the recording sites (1) and stimulation electrodes (1) occurred during the extension procedure. After replacing the electrodes the amplitude values turned to normal. No additional surgical event occurred and no post-operative deficit was noted.

In seven patients (44%), nine surgical related neurological events were monitored. In all these patients, a decrease of amplitude below 20% or reference value was

measured during or immediately after the correction extension maneuver. In one patient an immediate spontaneous recovery was seen. In the six other patients, the surgeons responded to the amplitude decrease by reducing the correction of the cervical spine. In five of the six patients, the TES-MEP responses recovered and no post-operative neurological lesions were diagnosed.

In one 82-year-old patient, the responses did not return to the original values, which resulted in permanent neurological damage as described above.

In two patients, besides a neurological event during the correction, a second episode of amplitude decrease was registered. In one patient this was due to a misplaced thoracic pedicle screw. Immediately after the registration of the amplitudes decrease, the pedicle screw was replaced and the TES-MEP amplitudes turned to its original value. In the second patient a decrease in amplitudes occurred while performing the laminectomy of C7. No evident surgical cause could be found, a subclinical myelopathy due a severe kyphosis was proposed as the cause for the event. The surgeons decided to wait for spontaneous recovery while a high dose of corticosteroids was given. After waiting for 30 min the amplitudes returned to values above 20% of reference and the procedure was continued. On the second day, post-operative, neurological examination showed a

strength of 4/5* in all muscles in both arms, and both legs showed no impairment 5/5*. The deficit had fully recovered by 3 months.

(* = Neurological classification according to Medical Research Council)

Discussion

New aspects of this study are the consistent use of internal fixation and TES-MEP monitoring during cervical osteotomy.

The use of internal fixation has been reported in previous case-reports [2, 10, 11, 12]. Posterior and combined anterior-posterior procedures have been described. To our knowledge no case-series have been reported with the use of internal fixation techniques in cervical osteotomy. In this study, internal fixation was consistently performed after the extension correction as described by Simmons. A clinically good correction was obtained; there was no translation or loss of correction; all patients fused.

Earlier publications on C7 correction osteotomy performed without internal fixation report the occurrence of pseudarthrosis and translation [10, 16]. These complications did not occur in this study. Most likely, internal instrumentation has created an optimal biomechanical stable and reliable fixation facilitating consolidation in the corrected position. However, distal fixation proved technically difficult to perform on a sitting patient wearing a halo-cast. Therefore during this study period, it was decided to change the intra-operative position. In the following five patients, an identical surgical procedure was performed in a prone position, the patients' head being fixed with a Mayfield clamp.

This technique has three advantages compared to the sitting procedure. First, without the halo-cast limiting the working space, the distal fixation could be extended easily to mid-thoracic level. The acquired longer fixation is considered more stable, because a longer moment arm is created to counteract the high junctional forces of the rigid spine of patients with ankylosing spondylitis. Furthermore, a longer multilevel fixation improves stability considering the osteoporosis associated with ankylosing spondylitis.

Second, because of the long fusion thus acquired, post-operative halo-cast treatment is not required. In this study, a cervical orthosis proved to provide sufficient support during the post-operative consolidation period. Third, the clinically important intra-operative TES-MEP reference value of the trapezius muscle could be more easily monitored in the prone position without a halo-cast.

The use of TES-MEP monitoring in the arms and legs was a new standard procedure for all cervical

osteotomies. Originally, Simmons [16] described the osteotomy technique under local anesthesia for continuous clinical monitoring. McMaster [10] performed the cervical osteotomy with the use of somato sensory evoked potential (SSEP) monitoring. In case-reports the use of SSEP during cervical osteotomy is also reported [2, 10, 11] SSEP monitoring has proved to be of great value but not always 100% accurate. Cases have been reported of undetected post-operative neurological deficit during SSEP monitoring [1, 9, 18].

TES-MEP has been successfully applied during corrective spinal surgery [3–5, 7, 8, 13–15, 17]. In our opinion the use of TES-MEP has four advantages compared to SSEP. First, TES-MEP directly monitors at the spinal cord and motor roots, the more clinically relevant motor pathways. Second, TES-MEP is highly reliable while no false negative results have been reported. Third, the measurement is instantly available as averaging procedures are not required. Therefore, early surgical correction can be performed when a decrease is noticed, and the results of the correction can be checked immediately. Fourth, multiple muscle sites applied at arm and leg muscles, including special reference sites above the level of surgery, can be monitored thus facilitating the interpretation of the TES-MEP results in difficult cases.

A known disadvantage of TES-MEP is its vulnerability to anesthetics and systemic changes. However using a strict intra-operative anesthetic and monitoring protocol, amplitude decreases of systemic or anesthetic origin can be prevented, recognized and stabilized [8].

In our study, TES-MEP proved to be a reliable monitoring technique during cervical osteotomies. No false negative outcomes were diagnosed. TES-MEP monitoring showed nine neurological events in seven patients illustrating also the high neurological risks of the C7 osteotomy procedure. In order to prevent permanent post-operative neurological deficits additional interventions were applied: adjustment of the obtained surgical correction (6), additional supply of corticosteroids (1) and a pedicle screw change (1). Amplitude recovery after an additional surgical intervention was obtained following six neurological events.

Although monitoring could be performed in all patients, in two patients the responses at the reference site at the trapezius muscle could not be detected. Most likely this was due to the elicitation of cervical motor roots of the trapezius resulting in M-responses or the extinction of large stimulations artifacts from TES.

Nine patients suffered from transient C8 paresthesia. This is most likely due to the compression of nerve roots C8 just at the level of the osteotomy in a corrected extended cervical spine. It is doubtful whether this nerve compression could be prevented by any additional surgical actions. This pure sensory deficit will be undetected using TES-MEP because only the motor pathways are

monitored. However, all deficits were transient and of no great clinical relevance. If SSEP monitoring had been used, these deficits would probably still have been unnoticed as SSEP only monitors the lower extremities using a single stimulation site at the peroneal nerve.

The results of this case-series illustrate the vulnerability of the spinal cord and the high physiological demands on patients undergoing a C7 osteotomy. Considering these complications, it is recommended that a C7 osteotomy to be contra-indicated in patients with accompanying cervical canal stenosis and in the very elderly.

Conclusions

A corrective C7 osteotomy remains a hazardous, high-risk procedure. In this series of 16 patients, two serious complications occurred: one patient with post-operative

spinal cord lesion and one patient with a cardiac arrest and resuscitation resulting in severe post-anoxic encephalopathy. The high neurological risks of spinal cord or nerve root lesions have clearly been illustrated by the TES-MEP outcomes, showing severe amplitude decreases in 7 of 16 patients.

TES-MEP has shown to be of great clinical use in detecting all early neurological events thus allowing immediate surgical correction to prevent permanent neurological damage. We prefer TES-MEP over SSEP and feel it should be strongly recommended in cervical osteotomy procedures.

The authors conclude that internal fixation is of great value in stabilizing a C7 osteotomy. When surgery is performed in a prone position using a Mayfield clamp, a longer fusion can be obtained for a more stable internal fixation. For post-operative treatment after a long cervical internal stabilization, a stiff cervical orthosis is sufficient.

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