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Thoracic outlet syndrome due to hyperextension-hyperflexion cervical injury

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Summary

Posttraumatic brachial plexus entrapment in fibrotic scarring tissue is taken into consideration as the cause of complaints for patients who suffered a hyperextension-hyperflexion cervical injury. All 54 patients included in this analysis where symptom-free before the accident and subsequently complained for pain, paresthesia and slight weakness in the arm. In 14 neurological signs of brachial plexus entrapment were observed. Electroneurophysiological, summary index testing was positive for a brachial plexus involvement in all cases. Conservative measures, comprising physical therapy and vasoactive drugs were applied for a period of 6 to 12 (mean 8.4) months; surgical procedure of neurolysis was then proposed in 39 cases to solve the problem. Thirty-two patients were operated on. Twenty of these had a neat improvement on a 6-month to 1-year follow-up. Seven patients had refused surgery; of these 6 patients had clinical worsening at the same follow-up period while 1 remained unchanged. All patients with clinical symptoms not reversed after some time post-injury should be investigated for a possible brachial plexus entrapment.

Keywords: Brachail plexus; entrapment; thoracic outlet; hyperflexion; hyperextension; whiplash injury.

Introduction

Posttraumatic thoracic outlet syndrome, i.e. brachial plexus entrapment in fibrotic scarring tissue, may be the physical basis for prolonged complaints of patients who suffered hyperextension-hyperflexion, non structural cervical injury due to vehicular, slow-speed, rear-end accidents. The mechanisms of traction and distortion of cervical bony, ligamentous, and nerve structures have changed since safety systems have improved.

Patients and methods

Patient population included those patients who had suffered mild car accidents mostly rear-end crash. Included in the analysis were only patients who reported no other injuries. Concomitant head injury, back injury or arm injury were factors for exclusion of the patient from this analytic study. Our data were taken from a careful patient examination as well as from emergency unit documentation. Patients who suffered neck pain and stiffness or had symptoms of brachial plexus entrapment prior to injury were excluded from the study as well as patients whose MRI or/and CT scans revealed disc herniations which could be responsible, even if partially, for the symptoms presented. Patients with postural factors and anatomic anomalies seen on radiological investigation were also excluded from the study.

All patients included in the analysis underwent an X-ray of the cervical spine and possibly MRI or CT scan, as well as electrodiagnostic testing by summary index for the upper extremities on both sides. The time gap between injury and the moment patients came to our attention was 10 months (2 to 27 months). There were 31 female and 23 male patients. Age range was between 19 and 57 years with an average of 36.5 years. There was no significant difference in age between the male and female group.

The brachial plexus entrapment was seen on the right side in 13 patients, on the left in 9 patients and in 2 patients the entrapment was seen bilaterally.

The superior trunk alone was affected in 5 patients, the inferior trunk in 3 patients while 8 patients all three trunks were involvedt. Other combinations of trunk involvement were superior and middle in 4 patients and superior and inferior in 4 cases. Middle trunk was never affected alone.

Results

Clinical symptoms

All patients complained of neck pain and stiffness. Seventeen complained also of headache alone or in association with shoulder and/or arm pain. Twenty-seven patients referred shoulder pain associated with neck pain and/or headache. Arm pain was present in 10 patients. Most of the patients whose neurophysiologic findings indicated primary superior trunk involvement had pain in the suprascapular nerve territory on the affected side. Tingling in arm and hand augmented during sleep was frequently reported. Dizziness was present in 8 patients while one had also blurred vision.

Neurological findings

All patients showed tenderness and various degrees of muscular stiffness in the supraclavicular region as well as reduced motion amplitude of the neck in all directions. The Adson and "signe du plateau" test was positive in all patients. In 39 patients there were signs of neurological disturbances while 15 patients were free from any neurological sign to be correlated with a brachial plexus entrapment. When present, neurological findings were almost always slight and depended largely on the brachial plexus trunk affected. If just the superior trunk was involved, the most common finding was hypoesthesia of the skin covering the deltoid muscle and in the interscapular region. There was a decrease of strength in the supraspinatus muscle. When also the middle trunk was involved, hypoesthesia of the skin on the outer side of the forearm and a slight decrease of strength in the triceps muscle and the extensor communis of the fingers was seen. When the inferior trunk was affected, the most common neurological finding was a slight decrease of force in the hypothenar muscle group and interossei muscles as well as mild hypesthesia of the ulnar side of the hand, the inner side of the forearm and, occasionally, of the arm. When more than one trunk was involved various degrees of combination of the aforementioned signs was observed.

Radiological findings

All patients had an X-ray of the cervical spine taken immediately after the injury. Forty-five patients presented a straightening of the cervical vertebral column. None of the patients had an inversion of the curve, while 9 patients had a normal X-ray exam. MRI and/or CT scanning was performed in 48 patients. In 39 patients the scanning was negative for disc disease and/or other traumatic or degenerative problems that could explain the symptomatology. In 9 patients a disc herniation was found which did not correspond to the level of radicular symptoms or could not explain completely the radicular symptoms. Six patients had no CT or MRI imaging exams as their neurological signs clearly indicated the presence of a brachial plexus entrapment.

Neurophysiological findings

Electrodiagnostic testing was performed by using the summary index test proposed by Robinson *et al.* evaluating the summary results of nerve conduction studies and not the single tests.

Electrophysiological tests were of the F wave type from median and ulnar nerves, SSEP (N9) from median and ulnar nerves, motor and sensory nerve conduction studies from median, ulnar and medial antebrachial cutaneus nerves and electromyography.

The summary indexing of these paramethers in all the patients were positive for TOS.

A control study (submitted for revision) was done with patients affected by true neurological TOS and with normal control group. The results showed no difference between the true and whiplash groups while the control group of patients showed normal parameters.

Treatment

Before coming to our attention, all patients had already received some conservative treatment addressed to the cervical spine. The majority of patients had been treated by cervical dressing for a period from 1 week to 1 month and various modalities of physical therapy, postural corrections as well as analgesic and muscular relaxation drugs. Many patients were submitted to laser and ultrasound treatment of cervical paravertebral musculature. Our local medical treatment consisted for all patients of vasoactive (Naftidrofurile) and local anaesthetics (Bupivacaine) injected directly in the laterocervical area, either in the loose connective tissue or in the scalene muscles. These treatment modalities led to significant, lasting improvement in 15 cases.

Consequently, surgery was proposed in 39 patients. Seven patients refused surgery, while 32 were operated on. A supraclavicular approach allowed neurolysis of the offended nerve trunks. Occasionally, scalenotomy or other soft tissue removal was performed when found to be interfering with the nerve trunks. The intraoperative finding was that of a moderate to dense scar tissue surrounding completely the offended nerve trunks at the point of their exit from the interscalenic space. The primary superior trunk was rarely involved, while the middle trunk was frequently concerned. The subclavian artery was frequently observed to be hardly adherent to the middle trunk, as the scar tissue had formed a sheet around both structures incorporating them. Sometimes the different anatomical components where hardly distinguishable before neurolysis. This situation engendered a neurovascular conflict. The inferior trunk was frequently in touch either with the

ventral margin of the subclavian artery, or with the ventral aspect of the middle trunk.

Follow-up

Of the 7 patients not operated on, 6 worsened at a six month to one year follow-up, while one patient remained unchanged. The worsening generally involved a decrease in muscular strength, increase of pain and tingling in the radicular territory as well as arousing of unspecific disturbances such as dizziness and face pain.

In the operated group, 24 patients at the six month to one year follow-up showed a neat improvement. A longer time interval from injury to surgery entailed a reduced quality of result. Time was needed for the nerve trunk to regain its normal function. The improvement primarily concerned the dysfunction signs of the neck and more proximal segments of the upper extremity while the distal parts improved later. In the two patients who had suffered dizziness preoperatively, the problem solved after surgery. The one patient that remained unchanged after surgery had a repeated electromyography three months later, but no improvement with regard to the preoperative examination was observed.

Pathophysiological mechanism

When a car is hit from behind, the body, supported by the seatback and seatbelt, accelerates while the head, not supported, remains still. Thus the head actually is pushed backwards and the neck becomes hyperextended [4]. The headrest limits excessive movements and so prevents structural damage to the column but it permits enough movement to induce the stretching of the neck muscles and brachial plexus trunks.

The suspected pathophysiological mechanism is based on the fact that at the moment of the traumatic event two different, yet interrelated, events take place:

1) sudden and forceful anterior contraction of neck muscles due to their sudden and intense stretching
2) lenghtening of brachial plexus trunks to adjust to neck movement

The sliding capacity of the nerve trunks inside the interscalenic space becomes limited due to muscular contraction and, consequently, two different types of nerve injury develop:

1) compression injury due to forceful muscular contraction (continued contraction)
2) traction injury due to limited mobility of nerve trunks at compression site.

Moreover, it is well known that an intense and sudden muscular contraction leaves the muscles in a state of a prolonged contracture with development of myofascial syndrome and trigger points [6, 11]. These present clinically with stiffness, pain and, on palpation, the presence of hard muscular strings. This post-traumatic, time-lasting contraction may eventually play a secondary role in a prolonged compression of the nerve trunks [3].

Discussion

Olsson has studied the anatomical details of the nerve structures which may be the base for fibrotisation processes. The epineurium is similar to other connective tissue rich parts in the body, and its extracellular fluid is free to diffuse. The walls of the endoneurium are entirely covered by a basal lamina which surrounds the outer plasma membrane surface of the Schwann cells, the endoneurial vessels and the perineurial cells apparently forming a stabilizing structure.

Endoneurial fluid circulation depends on two major forces, net hydrostatic pressure and net osmotic pressure. The lack of lymphatics in nerve fascicles might render the removal of endoneurial fluid difficult. Also clearing of intrafascicular oedema occurring in many neuropathies is a rather slow process.

The frequent occurrence of anastomosis between the intrinsic (intrafascicular) and the extrinsic (nutrient arteries and epineurial vessels) system combined with a vascular organization in the form of plexA are of great importance for the oxygen supply. Experiments by staining have revealed the existence of a blood-nerve barrier in the fascicles. This barrier is composed of two components, the endoneurial vessels and the perineurium and is not as efficient as the blood-brain barrier. Perineurium creates a fluid environment around the nerve fibres of optimal composition for transmission of electrical impulses. Peripheral ganglia are surrounded by a perineurium with the same structural and functional features. It has thus a role in the homeostasis of the intraganglionic compartment. Nerve damage due to an injury may be further aggravated by oedema increasing endoneurial pressure which might compromise blood flow in the fascicles. Fibrosis, either at the site of the primary injury or in the distal part undergoing Wallerian degeneration may

so be marked that axonal regeneration and nerve repair are interfered with. The events provoked by an injury possibly induce a chronic compression of nerve trunks which interferes with their adequate blood supply. This initially induces changes in the small vessels of the endo- and perineurium and, consequently, changes in permeability of perineurium with swelling and oedema formation [5]. Early and late oedema of the vasogenic type is associated with elevated endoneurial fluid pressure and microcirculatory disturbances. Proliferation of fibroblasts, changes in the composition of the matrix and collagen formation may result in endoneurial fibrosis at the site of the lesion and distal to it.

If fibrosis is not solved, thinning of the myelin sheath is observed [1, 9]. The hypothesis is also that ischemia primarily affects the orthograde and retrograde axonal transport, which is very susceptible to oxygen deprivation and whose inadequate function interferes with adequate nerve conduction [1]. The process becomes selfmaintaining and, if not interrupted, deteriorates even if the muscles relax [1, 7]. During surgery fibrotic scar tissue enveloping the nerve trunks was found, and the site of greatest scarring was lateral and posterior to the anterior scalene muscle. This is in conformity with the statement that the maximal swelling and oedema formation is situated at the edges of the compression site [9]. Depending on the myelin and/or axonal derangement, the clinical expression of entrapment may present as pain and paresthetic disturbance or it may, in more severe situations, consist in muscle wasting and fibrillation potentials in the wasted muscles [2, 8, 10]. This pathological sequence of entrapment is well known to surgeons involved in peripheral nerve surgery and was described in 1964 by Weisl and Osborne [12]. The process of entrapment is a progressive one, and if persisting for time after injury, it will reach a point were the changes become irreversible [1].

Not all individuals develop this problem. It may be related to the anatomical conformation and pretraumatic posture and working habits. The brachial plexus, probably, becomes injured just in those patients who have some anatomical variations and/or have daily working and posture attitudes with a faint equilibrium of the nerve trunks in the thoracic outlet and in whom the cervical injury comes to disrupt this homeostatic equilibrium.

We suppose that, if diagnosis is made in time, a conservative approach by postural training, revascularization, appropriate drug application and other physiotherapeutic and pharmacological measures addressed to brachial plexus treatment, could solve this problem in many cases.

The surgical treatment to be performed is a small supraclavicular incision. External neurolysis is needed in the great majority of cases. Large exposures are not indicated because of increased scar formation which might compromise the result of surgery. Anyway, the surgical performance (neurolysis, scalenotomy, Sibson's ligament resection etc.) is highly variable from patient to patient and must be suited as to perform just the minimally indispensable surgical act.

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