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Advanced Peripheral Nerve Surgery and Minimal Invasive Spinal Surgery

Edited by
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Preface

On behalf of the Committee for Peripheral Nerve Surgery of the World Federation of Neurosurgical Societies, and sponsored by EU.N.I., European Neurosurgical Institute, the Third Course on peripheral Nerve Microsurgery and on Minimally Invasive Treatments for Spinal Diseases was held in Treviso, February 9–11, 2004.

In the course, which was also supported by the European Association of Neurosurgical Societies (EANS), the Latin-American Federation of Neurosurgery, and the Italian Neurosurgical Society, the different minimally invasive techniques were analyzed which are presently used in order to minimize bone demolition, scarring, and risk of recurrence. The results of intradiscal techniques were compared with those of miscrodiscectomy, and new methods were discussed in face of problems such as epidural fibrotisation, microinstability, osteoporotic or neoplastic or postraumatic vertebral lesions. The different minimally invasive methods were discussed with participation of specialists from different countries. At the same time peripheral nerve problems were discussed and differential diagnosis problems highlighted.

As in past years, the course included conferment of the Hanno Millesi Award. This prize was conceived by the Committee of Peripheral Nerve Surgery of the World Federation of Neurosurgical Societies in honor of this Father of Surgery in the field. The prize consists of a financial support to a young researcher to help him going ahead with his studies on new perspectives in the field of nerve biology and surgery. The prize is financed by EU.N.I., European Neurosurgical Institute, and is assigned upon evaluation of the best paper presented.

This year Prof. Millesi, Dr. Giocoli, and members of the commission awarded Dr. A. Gravvanis and coworkers from the General State Hospital of Athens, Department of Plastic Surgery and Microsurgery & Burn Center of Hellenic Pasteur Institute, Greece. Dr A. Gravvanis presented the paper "The effect of genetically modified Schwann cells in end-to-side nerve grafting". The concept investigated by him is whether collateral nerve regeneration is feasible through silicone tubes, as previously he had demonstrated in rat models that Schwann cell lining of tubes improves significantly the regeneration rate and fiber maturation, but Schwann cell lining of tubes did not ensure collateral nerve regeneration in all cases. Hence the aim of the study was to improve these results by lining the silicone tubes with genetically modified Schwann cells with increased motility.

We are especially grateful to Acta Neurochirurgica for having dedicated this Special Issue to the Course in Treviso. In this volume we present papers on peripheral nerve surgery and on spinal surgery in order to underline the relevance of a common understanding of the clinical problems, in order to obtain a more perfect differential diagnosis between problems so closely related but so different in their management.

Alberto Alexandre, *Albino Bricolo*, and *Hanno Millesi*

Foreword

"This Special Issue of Acta Neurochirurgica is dedicated to the publication of the papers which were presented in the IIIrd Course on minimally invasive neurosurgery, held in Treviso under the organisation of the Committee for Peripheral Nerve Surgery of the WFNS. Discussion has moved through new trends on peripheral nerve surgery, and pain treatments, which are a challenging interdisciplinary matter for many professionals. Moreover analysis of differential diagnosis with spinal degenerative diseases has called the attention of participants. This Committee of the WFNS has increased his activities through the years, and symposia have been organized by it, in different continents. But the one in Treviso remains each year a regular recurring appointment open to interdisciplinary discussion and to the presentation of new trends and points of view.

Certainly Neurosurgery is a continuously evolving world, and each and everyone of us is compelled to critically consider the techniques he is employing and to analyze the results he is obtaining. There are diseases whose physiopathology is not yet clearly understood, and the mechanism of generation of such a difficult and complicate matter as pain remains under several aspects a dilemma. The discussion over these conditions involves interdisciplinary cooperation.

This is why similar meetings, during which we feel to be conducted through a careful analysis of new techniques and reconsideration of routinary trends, are useful and welcome. The participation of such a large group of experienced and outstanding professionals has made these days of great concern for all participants.

The special event of the attribution of the Hanno Millesi Award, conceived and offered by EU.N.I. to the WFNS, has further increased the interest of the appointment. An important paper on nerve regeneration stimulated by genetically modified Schwann cells, by Andreas Gravvanis has been awarded this year. This paper is in the line of the research awarded last year, the big progress that came from Fausto Viterbo who in Butucatu could demonstrate nerve regeneration by terminolateral anastomosis. We, who initiated the Committee of peripheral nerve surgery, are proud to observe that great attention is paid to young researchers."

Madjid Samii, M.D., Ph.D.
PastPresident of the WFNS
President of INI

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Neurolysis: Is it beneficial or harmful?

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Summary

The term internal neurolysis means removal of fibrotic tissue inside a nerve trunk. Unfortunately the term was used for procedures with complete isolation of fascicles with all consequences like damage of links between the fascicle and impairment of blood supply. The conclusion based on some negative experiences that all surgery within a nerve trunk has to be avoided cannot be accepted.

Neurolysis within a nerve trunk, id est within the epineurium, is a step-wise procedure to decompress fascicles from a constricting fibrosis. It stops immediately if this aim is achieved or continues with resection and reconstruction if an irreparable damage is present. It is better to use terms that describe exactly what was done and abandon the ill-defined term "internal neurolysis".

Fibrosis of the paraneurium remains outside the epineurium but causes the same consequences as fibrosis of the epineurium.

Keywords: Neurolysis; internal; nerve trunk.

Introduction

Neurolysis outside of the nerve itself is a common and frequently very successful procedure in order to remove an external compression like a bony fragment, scar tissue or a foreign body. A second very important indication is to liberate a nerve from adhesions and provide the possibility of passive motion for adaptation to the different position of an extremity.

The nerve itself must be intact if a good result is to be expected.

If the nerve is damaged and fibrosis of the different connective tissue layers has developed, external decompression alone is not able to produce functional recovery. It was therefore discussed for long (Babcock 1907, 1927, Lehmann 1936, John B. Murphy 1916) whether in such a case surgery within the nerve (internal neurolysis) to remove the fibrotic tissue which causes compression of the fascicles could solve the problem. The rather crude surgical techniques of those days might however have caused more damage than benefit.

An excellent survey of the historical development is given in the book of Susan Mackinnon and Lee Dellon (1988) on page 131 and 132.

Consequently, when microsurgical techniques became available, surgeons applied these techniques to operate within the nerve, convinced that the atraumatic procedure would minimize the surgical trauma. Without much hesitation fascicles were isolated, connections between the fascicles destroyed, and the circulation within the nerve impaired.

Curtis and Eversman (1973) applied internal neurolysis to all cases of carpal tunnel syndrome based on electromyographic criterias in regard to the severity of the case rather than on the local situation.

In the following years cases were observed in whom – after an internal neurolysis – a pain syndrome developed and internal neurolysis was condemned.

I have personally studied this problem intensively since 1975 and provided definitions and criterias to be followed to avoid problems. The results were summarized in 1995 (Millesi 1995).

Many surgeons are still afraid to enter a nerve trunk.

At a recent meeting I was asked whether I still do internal neurolysis or whether I have abandoned this procedure. My answer was that I still do surgery within a nerve trunk as I always did but I suggest to abandon the term "Internal Neurolysis".

For this reason I think it is necessary to outline again my approach to surgery within the nerve. In recent years fibrosis of the paraneurium has gained more and more significance especially in cases of brachial plexus lesions.

Therefore some information about this tissue is included in this paper.

Connective tissue components of a nerve trunk:

Endoneurium

The endoneural space is filled with a very delicate connective tissue framework, which is vulnerable and may become collagenized. We called this situation a fibrosis of type C. The involved fascicle are shrunken and hard. Regeneration is not possible in such an environment.

These fascicles have to be resected and the defect bridged by nerve grafts.

Perineurium

The perineurium surrounds the endoneural space and delineates it to the outside world. Fibrosis of the perineurium I have seen in cases of direct damage e.g. by injection of a toxic substance into the nerve. A perineuriotomy may be considered but I think it is the better solution to resect the involved fascicles and bridge the defect by nerve grafts.

Epineurium

This is the connective tissue which envelopes the fascicles and extends between the fascicles. It contains the vessels, provides space for movement of the fascicles within the nerve trunk and surrounds all the fascicles of a nerve trunk. Consequently we have to distinguish between an interfascicular (internal) and an epifascicular (external) epineurium. This is not specialized connective tissue like the endoneurium or the perineurium. It reacts easily against a traumatic damage of different kind with fibrosis. The fibrotic tissue shrinks and the fascicles within this tissue are compressed.

If the interfascicular tissue is involved (fibrosis of type B), it is more difficult to achieve decompression. If however the epifascicular epineurium alone is shrunken, the whole nerve is compressed like a too tight stocking (fibrosis of type A). The shrinkage of the epineurium is mainly directed in transverse direction.

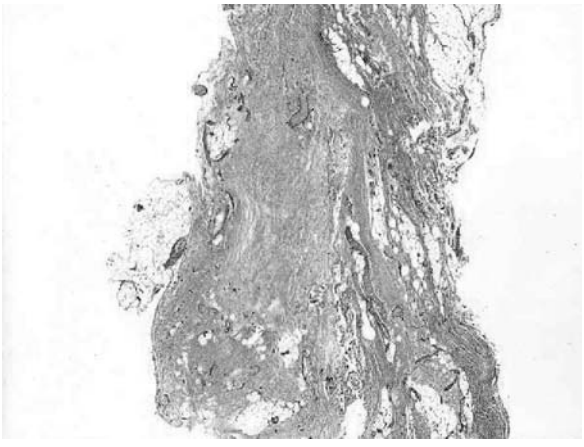

Fig. 2. Histologic section of a thickened fibrotic segment from a patient with a brachial plexus lesion. HE,Magn.:20x

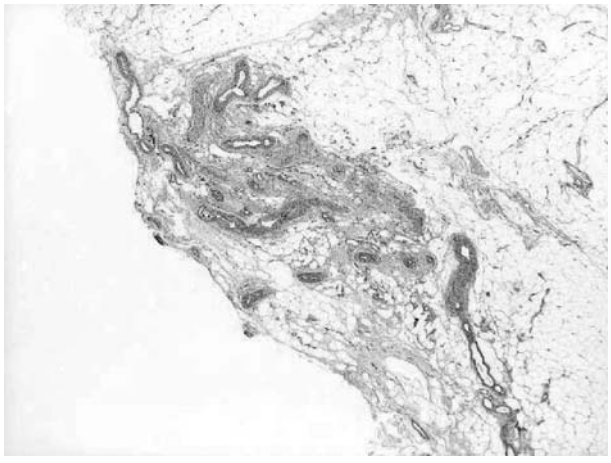

Fig. 1. Histological section of normal paraneurium. HE.Magn.:20x. Loose connective tissue with many vessels and fat lobules

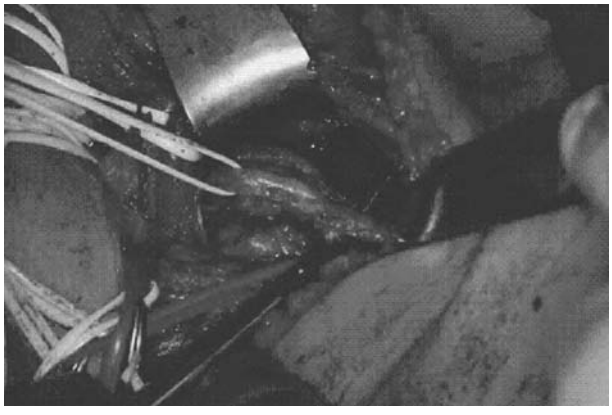

Fig. 3. Traumatic brachial plexus lesion. One of the structures of the brachial plexus with intact epineurium surrounded by a thick layer of fibrotic paraneurium. Paraneuriotomy has already been performed

Fibrosis of the paraneurium forms a subgroup of fibrosis of type A. We use the term fibrosis of type A*.

Paraneurium

It was mentioned above that the nerve has to be able to move passively in order to adapt to the movements of an extremity. The nerve needs also space to change its diameter. In full extension the nerve is extended and stretched and has a smaller diameter as compared to full flexion when the nerve becomes shorter with the same volume and has a larger diameter. This space has to be available for proper function. It is filled by a loose connective tissue, which extends between the epineurium and the surrounding tissue. If we isolate a nerve, we do it in this space and within this tissue. If we harvest a nerve as a graft, this is also done in this space and one part of this tissue remains always on the surface of the nerve.

This tissue is usually not described in textbooks. In cadaver dissections it is not impressive and may be overlooked. Since it is fixed to the epineurium and it contributes to the pathology (see below) it should be listed as part of the connective tissue frame work of a peripheral nerve.

This tissue was extensively described by Johannes Lang (1965) and called ''conjunctiva nervorum''. Van Beek and Kleinert (1977) referred to it as ''adventitia''. In the atlas of micro morphology by Krstic it is well described and called ''paraneurium''. On my question Krstic could not tell from where he had this term and who used it for the first time. I think this term is easier to handle than the two other terms. It corresponds to the term ''paratenon'' of tendons.

Therefore I shall continue to use paraneurium.

Surgical procedures to deal with a connective tissue problem of a peripheral nerve:

It was already mentioned that an *exploration* of a peripheral nerve is performed in the paraneurial space.

If there are adhesions and the paraneurial space is obliterated, an *external neurolysis* has to be done and everything compressing the nerve from outside has to be removed. At the end of this procedure the surface of the nerve (the epifascicular epineurium) should look normal and the nerve should give a soft impression by palpation.

If the surface of the nerve is irregular and the nerve is indurated, something more has to be done. This is the point when ''internal neurolysis'' comes into consideration. Doing nothing would mean neglect the possibility of significant improvement. It would be wrong to start with an interfascicular dissection coming from the sane tissue proximally and distally and to isolate the fascicles.

As a first step a longitudinal incision across the thickened tissue on the surface of the nerve has to be performed until fascicles are seen. This is an *epifascicular epineuriotomy*. Very often one will see the fascicles expand since the compression has subsided. In this case a fibrosis of type A is diagnosed and the surgery can be finished.

If, however, the decompression is incomplete and fibrous tissue can be seen extending between the fascicles into the depth, the epifascicular epineurium is removed all around the nerve to decompress fascicles which are located in a distance from the epineuriotomy. This would be an *epifascicular epineuriectomy*.

If there is more fibrous tissue between the fascicles and not all the fascicles can be decompressed by the last step, one continues with an *interfascicular epineuriectomy*.

The surgery is limited to those segments which have already developed fibrosis. In no case is it extended into normal tissues.

In these two cases the diagnosis would be: Fibrosis of Type B.

If the fascicles themselves were indurated the surgeon has to assume a fibrosis of type C. A neurolysis procedure cannot influence this condition. A more aggressive approach has to be elected: *Resection and nerve grafting*.

The same is true if the fascicular pattern has been lost. This would be a lesion of degree IV according to Sunderland.

One sees that the goal of neurolysis is to achieve decompression of compressed fascicular tissue. The surgical activity stops immediately if this goal is achieved or continues with resection and reconstruction if the damage is too far advanced. In no case are fascicles isolated and deprived from the blood supply.

The pathology of the paraneurium.

So far the paraneurium has not even been mentioned. The reason for that is the following:

The cause which initiates the pathologic changes involves at first the paraneurium if it acts from outside. Very soon the epifascicular epineurium is involved as well and the two layers fuse. The surgeon does not see the paraneurium but only the thickened epineurium.

This is one of the reasons why the paraneurium did not attract attention.

All cases of fibrosis of type A include a fibrosis of the paraneurium.

In a large casuistic, especially in brachial plexus cases, one can meet patients who have an isolated fibrosis of the paraneurium with intact epifascicular epineurium. Shrinkage of this tissue can produce a loss of function and in contrast to the epifascicular epineurium a contracture in longitudinal direction. It is treated in similar fashion:

Paraneuriotomy as a first step and
Paraneuriectomy as a second step.

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TOS pathophysiology and clinical features

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Summary

The authors present 280 patients operated on for thoracic outlet syndrome (TOS). In a first group of patients anatomical variants were the striking findings. The underlying factor for TOS development is therefore a well defined structural condition and its pathogenetic mechanism is known to be a nerve fibre compression.

In a second group there was no specific salient finding but a postural deviation. The unique pathological features were adhesions of the brachial plexus to the scalenus muscle. Consequently its pathogenetic mechanism is generally recognized as nerve fibre distraction.

In all patients neurological, vascular and myofascial pain symptoms were observed before the operation. Neurological and vascular pain disappeared after surgery, while the myofascial pain remained.

The authors believe that especially in the second, larger group of patients enhancement of the pain-immobility-fibrosis loop is the central pathogenetic factor on which surgical therapy is successful, and that myofascial hemisyndrome – probably arising from a longstanding postural deviation – is not a TOS dependent symptom. In TOS, therefore, there is a pain loop that cannot be resolved by surgical therapy alone.

The connection between myofascial pain syndrome and TOS might explain the many controversial opinions regarding frequency, results and surgical possibilities of this lesion.

Keywords: Thoracic outlet syndrome; myofascial pain; brachial plexus entrapment; trigger point; surgery; posture.

Introduction

The authors present 280 patients operated on for thoracic outlet syndrome (TOS) at the Neurosurgical Department of the University of Milan from 1982 to 1990 and from 1995 to 2000, at the Neurosurgical Department of San Gerardo Hospital of Monza from 1990 to 1995, and at the Neurosurgical Department of the University of Sassari from 2000 to 2003.

Patients were divided into two distinct groups. Fifty-two belonged to a first group where the striking findings from the clinical, diagnostic and pathological points of view were elements described as anatomical variants (cervical ribs, transversal mega-apophysis, fibrous bands, scalenus minimus). The underlying factor for development of TOS is therefore a well defined structural condition, and its pathogenetic mechanism is known to be a neural compression.

The second group of 228 patients was characterized by the absence of diagnostic or intraoperative features mentioned above. The salient finding is not a specific one and could also be observed in the first group, i.e. a postural deviation: tilting or side sliding of the pelvic joint and rotation of the spine. In this group, the unique pathological features were adhesions of the brachial plexus to the scalenus muscle, its pathogenetic mechanism is therefore generally recognized as nerve fibre distraction.

In all 280 patients neurogenic, vascular and myofascial pain symptoms were observed before the operation. Neurogenic and vascular pain disappeared after surgery, while the myofascial pain remained.

The authors believe that especially in the second, larger group of patients, enhancement of the pain-immobility-fibrosis loop is the central pathogenetic factor on which surgical therapy is successful, and that myofascial hemisyndrome, probably arising from a longstanding postural deviation, is not TOS provocated but a TOS independent symptom. In TOS there exists therefore another pain loop that cannot be resolved with surgical therapy alone.

The connection between myofascial pain syndrome (MPS) and TOS may explain the controversial opinions about frequency, results and surgical possibilities.

Materials and methods

Two hundred and eighty patients are reported, 220 females and 60 males, between 27 and 78 years old. 184 patients had surgery on the right side, 96 on the left. 248 patients had follow-up, 196 of them over more than one year.