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INTRADISCAL MEASUREMENTS OF pH IN PATIENTS WITH LUMBAR RHIZOPATHIES

By

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Mixter & Barr's (1934) report of herniated discs causing sciatica, opened up a new surgical field. Since then many thousands of patients have been relieved from sciatica by the removal of a prolapsed or herniated discs and the excellent results obtained by this procedure have been verified by numerous authors (*Friberg & Hirsch* 1946, *Senning & Sjöqvist* 1947, *Waris* 1948, *Knutsson & Wiberg* 1958, *Sparup* 1960).

In some of the cases with lumbar rhizopathies and clinical symptoms simulating those of sciatica, no herniated discs have been found at surgery and the results reported have been less good (*Friberg & Hirsch* 1946, *Senning & Sjöqvist* 1947, *Gottschalk & Höjgaard* 1962, *Hirsch & Nachemson* 1963).

Such negative explorations made it necessary to use more refined preoperative diagnostic procedures such as water-soluble contrast myelography (*Arnell* 1949, *Knutsson* 1951), electro-myography (*Shea & Woods* 1955, *Knutsson* 1951), intraosseous venography (*Schobinger, Krueger & Sobel* 1961, *Amsler & Wilber* 1967) and discography (*Hirsch* 1948, *Lindblom* 1948, *Fernström* 1960). Thorough neurologic examinations have been made and correlated with operative findings (*Norlén* 1944, *de Morsier* 1967).

Despite all these clinical investigations, almost all reports on disc surgery include a number of cases where explorations revealed no disc prolapses. In a number of these cases, however, surgery showed connective tissue reactions around the nerve-root, such as adhesions and fibrous scars, sometimes in connection with a rupture of the disc. Also in

patients with disc hernia connective reactions can sometimes be seen around the nerve-root (*Hirsch* 1958). In some breeds of dogs, such a reaction caused by the herniated disc tissue is always severe and has been shown to be clinically important (*Hansen* 1951, 1952, *Olsson* 1951).

The pain elicited by the prolapsed disc has been said to depend not only on the actual mechanical pressure but also on an inflammatory reaction of the nerve-root proper. This reaction has been thought to be caused by the degenerated disc tissue (*Lindahl* 1966).

Kelly (1956) mentioned that the theory of mechanical pressure did not fit in with a number of clinical experimental and physiological facts, a view recently supported by *Ogienko* (1967). *Smyth & Wright* (1958), however, maintained that the pressure on the nerve-root was sufficient by itself to cause sciatica but much more so if the nerve-root was hypersensitized by disc herniation. They also postulated that the postoperative reaction with fibrosis around a sensitized nerve-root alone could cause pain.

Herniated lumbar discs can exist in patients after recovery from a period of sciatica (*Friberg & Hirsch* 1949, *Friberg & Hulth* 1951, *Gol, Andrews & Manicom* 1966).

Histological investigations of biopsy specimens of nerve-roots have been made by *Lindahl & Rexed* (1951), who showed that in seven out of ten cases operated upon for lumbar rhizopathy, inflammatory reactions (neuritis) were found in the nerve-roots.

As early as 1942 *Lewis* suggested that the pain associated with tissue damage is due to the locally occurrence of abnormal chemical substances.

A low pH has been found in tissue from painful tumors but not in painless tumors, where the pH is normal (*Revici, Stoopan, Frenk & Ravich* 1949), and on the basis of their experimental work on human subjects they thought local chemical changes to be an important factor in the production of pain. They also suggested that better pain control at the level of the abnormal focus requires better knowledge of the abnormal metabolic factors responsible for the release of the substances that alter the local pH.

A reduced pH has been observed in anoxic skeletal muscle and can also result from formation of acid metabolites during heavy muscle exercise (*Frunder* 1949). In an investigation on experimentally produced skin pain *Lindahl* (1961) showed that among the various substances tested, only the hydrogen ion had such pain producing pre-

perties that it might reasonably be regarded as a chemical mediator of skin pain, *i.e.*, an elevated hydrogen ion concentration of the same magnitude as that often seen in the body in different conditions could produce pain.

It is thus possible that the pain arising from the disc hernia could be due not only to the mechanical pressure, but also to an increased hydrogen ion concentration secondary to an inflammatory reaction to mechanical irritation or to the extrusion of disc tissue. It might also be possible that leakage of acid metabolites through a rupture in the dorsal longitudinal ligament and in the annulus could elicit a similar reaction around the nerve-roots and irritate them as well as the free nerve-endings found in the ligament and in the outer part of the annulus (*Hirsch, Ingelmark & Miller 1963, Jackson, Winkelmann & Bicker 1967*). The possibility of such a course of events was discussed already in 1959 by *Hirsch*.

The present study was performed to find out whether pH-measurements in lumbar discs could help to explain some of the clinically obscure rhizopathies in the lumbar region. Measurement of the hydrogen ion concentration of prolapsed discs might also be of interest in the discussion whether the causal mechanism of the pain in disc hernia, is mechanical or chemical.

METHODS

The pH-electrode, especially constructed for this study, was of needle type with a length of 145 mm (Figure 1) and a diameter of 1.2 mm. The electrode consisted of purest antimony and as reference a calomel electrode was used, which was placed together with the patient's finger in a solution of physiological saline. A similar arrangement has been described by *Bates (1964)* and used by among others *Carter, Rector Jr., Campion & Seldin (1967)*. Recording was made from Radiometer pH Meter 25-25SE-27. The pH-electrode was calibrated with different standard buffer solutions immediately after reading the pH inside the disc, and the values noted there were corrected according to the calibration-curves obtained.

The electrode was sterilized to Diglutaraldehyl 2.5 per cent for at least 2 hours before use.

At operations for lumbar rhizopathy with the routine surgical technique (*Hirsch*

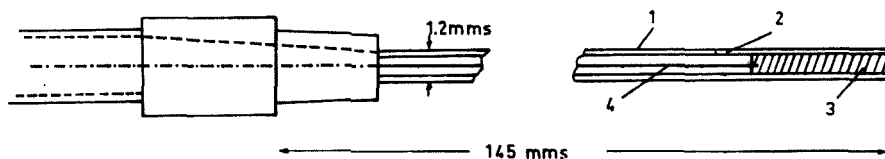


Figure 1. Schematic drawing of the needle type antimony pH-electrode used.

1. Stainless steel—silver-plated, 2. Silica, 3. Antimony, 4. Iron.

& Nachemson 1963) the nucleus pulposus of the explored interspaces was reached, after retracting the nerve-root medially, by inserting a larger needle (diameter 2.1 mm, length 140 mm) with a pointed mandrin which then was extracted. The electrode was then inserted. When measuring in two discs, two of these larger needles were inserted and the electrode was moved from one disc to the other.

The length of the electrode was necessary in order to use it in unanaesthetized subjects. On two occasions pH readings were made one day prior to surgery (cases 4 and 5) and the electrode was inserted into the nucleus with the help of an image intensifier, using the posterolateral approach.

At surgery care was always taken to obtain a dry field before the disc was entered at least 1.0 cm in depth. Measurement of pH was taken after two minutes in order to achieve stable conditions. When removed careful examination invariably confirmed that no visible blood had been in contact with the electrode.

In several discs the electrode was relocated at a distance of 1–1.5 cm within the nucleus, and also towards the prolapse, but no difference in pH was observed.

MATERIAL

The present material consisted of measurements from one or two disc levels in 30 patients operated on for lumbar rhizopathy. In addition in one measurement was made during surgical correction for scoliosis. Two patients were measured both unanaesthetized prior to surgery and during surgery in order to check that anaesthesia did not influence the pH-values. Of the patients with sciatica, 10 had two discs measured and 20 one disc only. Of these discs, there were 22 with prolapses, 4 with scars and adhesions only, and 14 appeared normal.

All the patients with lumbar rhizopathies had a previous long enough history of sciatica warranting surgery. The pertinent clinical findings are summarized in Table 1. In all these patients myelography performed preoperatively with water-soluble contrast either showed a distinct disc hernia or a short nerve-root sleeve suggestive of disc hernia (Arnell 1949, Knutsson 1951). In some cases, as seen from Table 1, the myelographic findings were somewhat uncertain and the reporting radiologist could not state whether the myelographic defect was due to reactive changes such as fibrosis and adhesions or a small disc hernia. In these patients, the history and clinical findings were severe enough to indicate surgery.

After the performance of measurements, surgery was proceeded in the ordinary way, *i.e.*, disc hernias were removed or scars excised.

In some patients the myelogram was uncertain at more than one level and in these cases, which are given in the table, also a second level was explored and measured. In three of the cases the exploration was entirely negative (Nos. 1, 9, 28).

Another three patients had previously been operated upon (Nos. 23, 27, 30).

At each exploration the surgeon noted the amount of connective tissue around the nerve-root; he found either none (0), some (+) or a large amount (+++). In the instances where no scars were found, the epidural space was filled with fat and the nerve-root was not adherent to the posterior part of the disc. In the patients where some scar tissue was found, the space was devoid of epidural fat (as described by Hirsch 1958) and some fibrous tissue was seen around the nerve-root, which was nevertheless relatively easy to free from the disc. In the group classified as having

abundant scars and adhesions, the root was clearly bound down to the disc by dense fibrous adhesions and there were absolutely no free fat in the actual space.

The routine roentgenograms were scrutinized for degenerative changes and graded according to *Knutsson* (1940, 1942).

RESULTS

The data obtained in 31 patients are given in Table 1. It is seen that the pH in these patients varied between 5.7 and 7.5. In those 22 discs where a prolaps was found the pH varied between 6.6 and 7.5 (mean 7.0). For this group paired correlation coefficients were evaluated between pH, age of the patient, preoperative duration of sciatica, Lasegue's sign, degenerative changes on X-ray, amount of connective tissue reaction around the nerve-root and subjective impression of pain on the day prior to surgery.

As statistically significant correlations were found between pH and degeneration ($r = -0.41^*$), between pH and pain ($r = -0.46^*$), between Lasegue's sign and pain ($r = -0.46^*$) and between age and degeneration ($r = -0.52^{**}$).

The most significant correlation was found between pH and the amount of connective tissue reaction found around the nerve-root ($r = -0.77^{***}$).

As seen from Table 2, the values in the group where no reaction was found are significantly higher than those where such a reaction was seen ($t_{\text{diff.}} = -5.4$).

When the pH values of all prolapses were taken together and compared with the negative explorations (Table 3), no statistical difference was demonstrable. Compared with the pH values of those four cases where an abundance of scar tissue and adhesions was the only findings, the difference was definitely significant ($t_{\text{diff.}} = -6.8$).

There was no correlation in this material between pH and the duration of pain prior to surgery or the age of the patient.

DISCUSSION

Intravital pH-measurements have demonstrated variations from pH 5.7 to 7.5 inside lumbar discs. In the same individual the difference between two adjacent levels did not exceed pH 0.5, and in most instances it was much the same. Most of the prolapsed discs showed values above pH 7.0. In those who also showed some connective tissue reaction around the nerve-root the values were significantly lower (Table 2).

Table

Patient no.	Sex	Age (years)	Preop. duration of sciatica (months)	Immediate preop. impression of pain (+, +, +, +, +)	Neurologic deficit	Lasègue's sign (degrees)	Disc involved
1	♂	42	12	++	—	70°	L4 - L5 L5 - S1
2	♀	46	—	—	—	—	L3 - L4
3	♀	46	2	+++	+	10°	L4 - L5
4	♂	37	2	+++	+	20°	L4 - L5
5	♂	43	3	+	+	60°	L4 - L5
6	♂	42	5	++	+	60°	L4 - L5 L5 - S1
7	♂	54	2	+++	+	60°	L5 - S1
8	♂	54	3	+++	+	60°	L4 - L5 L5 - S1
9	♂	55	4 (24)	++	+	90°	L4 - L5 L5 - S1
10	♀	50	4	++	+	80°	L4 - L5
11	♀	36	4	++	+	60°	L5 - S1
12	♂	41	6	+	+	60°	L5 - S1
13	♂	52	1	+++	+	20°	L5 - S1
14	♂	40	10	++	+	50°	L4 - L5 L5 - S1

Legen. changes on X-ray (0,+,++, +++)	Preop. myelographic findings	Operative findings	Amount of granulation tissue, scars adhesions visible at explor. (0,+,+++)	Intra- discal pH	Comments
0	neg.	neg.	0	7.4	pH of venous blood also measured at explor. (7.3)
0	neg.	neg.	0	7.3	
0	---	neg.	0	7.5	
++	prolapse	prolapse covered by lig.	0	6.9	Scoliosis, measured during Harrington correction. Disc not explor.
+	adhesions or prolapse?	free prolapse	+	6.6	Measured 1 day preop. at L4-L5 level under local anest. pH = 6.7
+	adhesions or prolapse?	prolapse covered by lig.	+	6.8	
+	prolapse?	neg.	0	6.8	Measured 1 day preop. at L4-L5 level under local anest. pH = 6.7
+	prolapse	free prolapse	0	7.1	
+++	prolapse?	nerve-root in dense scar	+++	6.2	
++	prolapse	free prolapse	0	7.0	
+	neg.	neg.	0	7.3	
+	neg.?	neg.	+	6.8	
++	neg.	neg.	0	6.9	
++	prolapse	free prolapse	0	7.0	
+	prolapse?	free prolapse	+	6.7	
++	prolapse	free prolapse	0	7.1	
++	prolapse	free prolapse	+	6.9	
+	prolapse	small prolapse covered by lig.	+	6.9	
+	uncertain	neg.	0	7.4	

Table

Patient no.	Sex	Age (years)	Preop. duration of sciatica (months)	Immediate preop. impression of pain (+, + +, + + +)	Neurologic deficit	Lasègue's sign (degrees)	Disc involved
15	♂	45	2	++	+	40°	L5 - S1
16	♂	57	4	+++	+	45°	L4 - L5
17	♂	27	2 (10)	+++	+	30°	L4 - L5
18	♀	39	2	+++	+	40°	L5 - S1
19	♂	52	6	+	+	neg.	L4 - L5
20	♂	42	4	+	+	50°	L4 - L5
21	♂	40	5	+	+	40°	L5 - S1
22	♂	46	1 (6)	+++	+	40°	L5 - S1
23	♂	24	4 (15)	+++	+	30°	L4 - L5 L5 - S1
24	♂	48	7	+++	+	20°	L4 - L5 L5 - S1
25	♂	37	4	++	+	30°	L5 - S1
26	♀	45	6	+	—	30°	L5 - S1
27	♂	38	3	++	+	30°	L4 - L5
28	♀	65	6	++	—	60°	L3 - L4 L4 - L5
29	♀	42	4	+++	+	40°	L4 - L5
30	♂	51	5	+	+	80°	L4 - L5 L5 - S1
31	♂	57	5	+	+	50°	L4 - L5 L5 - S1

1 (cont.)

Degen. changes on X-ray (0,+,++, +++)	Preop. myelographic findings	Operative findings	Amount of granulation tissue, scars adhesions visible at explor. (0,+,+++)	Intra- discal pH	Comments
0	prolapse	free prolapse	0	7.5	
+	prolapse uncertain	adhesions	+++	6.0	
+	fibrous tissue?	adhesions	+++	5.7	
+	prolapse uncertain, small	free prolapse	+	6.7	
0	prolapse	neg.	0	7.0	
+	prolapse	free prolapse	+	7.1	
+	prolapse	free prolapse	0	7.0	
0	prolapse	free prolapse	+	6.6	
0	adhesions or prolapse	adhesions	+++	6.3	{ operated upon at this level 6 mths. prev.
+	uncertain	neg.	0	6.8	
++	prolapse	free prolapse	+	6.6	
+	neg.	neg.	0	7.1	
0	prolapse	prolapse covered by lig.	0	7.4	
0	prolapse?	free prolapse	0	7.4	
+	adhesions or prolapse	free prolapse	0	7.4	operated upon at this level 3 yrs prev.
++	protusion or prolapse	neg.	0	7.2	{ unusual deform. arthritis of the facet-joint at this level
+++	protusion	neg.	0	7.2	
++	prolapse	free prolapse	+	6.8	
+	prolapse	prolapse	0	7.4	
+	neg.	neg.	0	7.2	operated upon at this level 3 yrs prev.
++	prolapse	free prolapse	+	6.7	
+++	neg.	neg.	0	7.0	

Those four discs that were surrounded by more severe connective tissue reaction had a very low pH ($\bar{m}$ 6.1).

It is possible that inflammatory reactions from outside might influence the pH inside the disc, but it is more likely that the elevated hydrogen ion concentration found in some of the cases, the probable result of one or several of the chemical processes that occur in discs, cause the connective tissue reactions by leakage through ruptures in the annulus.

Table 2. Discs with prolapses.

	No connective tissue reaction around the nerve-root	Some connective reaction reaction around the nerve-root
No.	11	11
pH mean	7.2	6.8
range	6.9-7.3	6.6-7.1
T-statistics	$\leftarrow \dots t_{\text{diff.}} = -5.4 \dots \rightarrow$	

Table 3. Comparison between pH-values and visible pathology.

	Discs with prolapses	Discs with no visible pathologic changes	Discs with much scars and adhesions around the nerve-root
No. of cases	22	14	4
pH mean	7.0	7.1	6.1
range	6.6-7.5	6.8-7.4	5.7-6.3
T-statistics	$\leftarrow t_{\text{diff.}} = -0.86 \rightarrow$		
	$\leftarrow \dots \dots \dots t_{\text{diff.}} = -5.8 \dots \rightarrow$		

van den Hooff's (1964) histochemical investigation showed that the area of histologic degeneration in the annulus fibrosus contained a considerable amount of acid mucopolysaccharides (positive Alcian-Blue-stain). According to *Mathews & Glagov* (1966), mechanical factors may give rise to alterations in connective tissues and increase the acid mucopolysaccharide content, especially kerato-sulphate.

Dahmén (1966), who also used histo-chemical methods, showed that the annulus fibrosus from healthy discs contained mostly neutral mucopolysaccharides, while prolapsed discs contained more acid muco-

polysaccharides. *Delarue, Mignot, Payen & Roussel* (1955) demonstrated changes in the histo-chemical reaction in degenerated connective tissues with lowering of the pH values and concluded that this was due to the increase in acid mucopolysaccharides.

Investigations into chemical changes occurring in the nucleus pulposus and annulus fibrosus have been carried out by among others *Hirsch, Paulson, Sylvén & Snellman* 1952, *Sylvén, Paulson, Hirsch & Snellman* 1951, *Gardell & Rastgeldi* 1954, *Gardell & Hansen* 1959, *Hansen* 1959, *Davidson & Small* 1963, *Taylor & Little* 1965, *Dickson, Happey, Pearson, Naylor & Turner* 1967, while other workers have tried to compare chemical findings of disc hernias with the "normal" disc aging (*Davidson & Woodhall* 1959, *Mitchell, Hendry & Billewicz* 1961, *Rodighero, Greco & Bertolin* 1964, *Lyons, Jones, Quinn & Sprunt* 1966).

Hirsch, Paulson, Sylvén & Snellman (1952) showed an increase with age of the collagen/polysaccharide ratio in the human disc, while *Hallén* (1960) showed an increase in the ratio kerato-sulphate to chondroitine sulphate with a lowering of the total amount of polysaccharides. The increase in collagen/polysaccharide ratio found by *Hirsch et al.* might thus be due to the decrease in the polysaccharides with advancing. According to *Buddecke & Sziegoleit* (1964), the chief acid mucopolysaccharides present in the human intervertebral discs are chondroitine 4-sulphate, chondroitine 6-sulphate, keratan sulphate and hyaluronic acid.

Naylor (1962) demonstrated an absolute decrease of polysaccharide in the nucleus of discs which have prolapsed, compared with that in age-matched normal discs. *Mitchell, Hendry & Billewicz* (1961), on the other hand, showed that the polysaccharide content of the intact nucleus increases to reach a maximum in the age group 30–40 and then declines to reach its lowest value late in life, whilst there is a constant gradual increase in collagen content with age.

Lyons, Jones, Quinn & Sprunt (1966) also noted changes in the proteinpolysaccharide fractions of the nucleus pulposus with a decrease in polysaccharide content in both aging and prolapses, and they thought that the chemical changes observed could suppress such parameters as the water-binding capacity and the elasticity of the disc tissue and make it more friable and thus more predisposed to mechanical failure with subsequent extrusion of the nucleus pulposus with its decreased viscosity. The ability of the disc to bind the cations should also be materially lower because of the loss of anionic sites in the molecule.

The use of chondrolytic enzymes to accelerate the degenerative process beyond the stage when the lumbar discs give rise to symptoms was suggested by *Hirsch* (1959).

Chymopapain is an enzyme that has the ability to disrupt the mucopolysaccharide/protein complex of the disc, and *Smith & Brown* (1967) reported good clinical results from injection of this enzyme into the lumbar discs of patients with low back pain and sciatica. These authors also reported a temporary increase in urinary acid mucopolysaccharide excretion after "chemo-nucleolysis". The increase was found largely to be due to the chondroitine sulphate C fraction. They believed this substance to consist of absorption products from the displaced disc material.

If proteolytic enzymes should act on the protein/polysaccharide complex, an elevated hydrogen ion concentration could occur owing to an increase in free amino acids (*Gardell* 1968). Since all connective contain such enzymes in the lysosomes, this could also happen inside the disc. *Tateiwa* (1967), using an amino-acid analyser, found a significant increase of thyrosin and phenyl-alanine in lumbar discs removed at surgery, compared with that in age-matched autopsy discs.

The morphological events of discs degeneration have been described by, among others, *Saunders & Inman* (1940) and *Hirsch & Schajowicz* (1952). The first-mentioned authors demonstrated an increasing amount of necrotic tissue inside the disc and the latter authors could demonstrate some attempts at reparation by granulation tissue via ruptures in the annulus fibrosus. In this poorly vascularized area the anaerobic metabolism of the remaining fibroblasts and other cells may, perhaps, some times increase the lactic acid concentration and thus lower the pH.

On the basis of the above investigations *Feffer* (1963), in patients suffering from acute low back pain or lumbar rhizopathies, postulated acute inflammatory processes triggered off by some substances from the nucleus pulposus. He also reported good results by intradiscal hydrocortisone injections. Others, such as *Inman* (1962), *Heidrich* (1964), and *Sakharov, Zotova & Bodatchiov* (1967), instilled hydrocortisone epidurally or gave ACTH by intravenous drip (*Naylor* 1962) to such patients.

In this connection the inflammatory process caused by an autoimmune response to disc tissue in rabbits should be mentioned (*Bo-bechko & Hirsch* 1965).

As previously mentioned, there has been some discussion (*Kelly*

1956, *Smyth & Wright* 1958, *Lindahl* 1966) as to whether the pain arising from disc hernias is entirely mechanical, as was primarily thought by *Mixter & Barr* (1934).

We also know that in a number of patients with lumbar rhizopathies no disc hernia can be found. It is thus possible that chemical irritation or inflammatory changes around a nerve-root can be initiated by a leakage of acid constituents from within the disc or from the disc hernia proper, pressing on the nerve-root. The results obtained in this study seem to support this possibility in some cases of lumbar rhizopathy. In most cases of disc prolapse, however, the measured pH-values were around neutral or above, and in these the mechanical pressure theory seems to be able to explain the sciatica. In three patients in this material (cases 1, 9, 28) the surgeon was unable to find any visible pathologic changes around the nerve-roots or on the disc. In the explored discs of these patients the pH varied between 6.8 and 7.4.

In four patients with pH values around 6.0 there were obvious signs of inflammatory reaction around the nerve-roots. Preoperatively it might be possible, with pH-measurements, to differentiate these cases from true prolapses, due to the very high hydrogen ion concentration found in these discs. Even with the preoperative use of water-soluble contrast myelograms they cannot with certainty be distinguished from prolapses (*Hirsch & Nachemson* 1963, *Fahrenkrug, Gottschalk & Højgaard* 1964).

Actually, the two cases (Nos. 4 and 5) where the pH was measured one day before surgery, the determination was made partly because the radiologist could not state whether the defect found was due to adhesions or to a prolapse. In both cases the preoperative pH value suggested a disc-prolapse, which was confirmed at exploration.

In cases with low pH values it is likely that chemical changes inside the disc can liberate acid substances, which can explain the pain syndromes. Experiments on the hydrogen ion concentration necessary to evoke pain at different locations inside the human body support this (*Revici, Stooepen, Frenk & Ravich* 1949, *Menkin* 1956, *Lindahl* 1961).

Some evidence in support of this line of thought was produced by the observation in this material of a significant correlation between pH and subjective impression of pain prior to surgery ($r = -0.46^*$). *i.e.* the lower the pH of the disc the more severe the subjective impression of pain.

The pain sometimes persisting after removal of herniated discs has been discussed in terms of fibrous tissue reaction around the nerve-

root (*Smyth & Wright 1958, Inman 1962, Nachemson 1965, 1966*). In the three cases re-explored in this material two had no such reaction visible and the discs had a pH of 7.4 and 7.2, respectively. The third patient (No. 23) showed an intradiscal pH of 6.3 and had a severe connective tissue reaction around the nerve-root.

Chemically, no satisfactory explanation for these low pH values is available. The proteolytic enzymes found in the lysosomes of connective tissue might liberate "acid" amino acids from the protein/poly-saccharide complex of the disc. The anaerobic metabolism of the aging discs might also give rise to an elevated hydrogen ion concentration by an increased concentration of lactic acid.

From a chemical point of view it is possible, but not very probable, that an increase in "free" acid mucopolysaccharides will give rise to the lowered pH found in some of the discs.

Further investigations into the chemistry of lumbar discs are obviously necessary for a better understanding of the cause of the increased hydrogen ion concentration found in some discs.

S U M M A R Y

In 40 lumbar discs in 30 patients with rhizopathy the pH was determined during surgery by a specially constructed antimony pH-electrode of needle type.

In 22 discs where a prolapse was found the pH varied between 7.5 and 6.6 ($\bar{m}$ 7.0). There was a significant negative correlation between pH and disc degeneration, preoperative pain, and most significantly, the amount of connective tissue reaction around the nerve-root. When the pH value was below 7.0 in these discs there were also signs of some inflammatory reaction around the nerve-root. Hardly any such reaction was seen in discs with pH 7.0 or above. In two unanaesthetized patients the pH was also measured on the day before surgery, and the following day at surgery, with equal results. In four cases where exploration revealed that the nerve-roots were covered by dense fibrous scars and adhesions the hydrogen ion concentration inside these discs was significantly higher ($\bar{m}$ pH 6.1) than in the 14 "negative" discs ($\bar{m}$ pH 7.1) and the 22 prolapsed discs ($\bar{m}$ pH 7.0).

The various possible chemical explanations for the high hydrogen ion concentration are outlined on the basis of previous studies on the chemistry of the lumbar discs.

It is possible that acid metabolites inside the disc can leak through

ruptures in the annulus and cause some inflammatory reaction around the nerve-root. In four cases of very high hydrogen ion concentration the nerve-root was completely embedded in a dense fibrous scar. In these cases the pH was as low as, or lower than, that known to produce pain in human tissues. This was not the case, however, in most of the prolapsed discs.

RESUME

Cette étude a porté sur 40 disques lombaires de 30 sujets atteints de rhizopathie chez lesquels le pH a été mesuré avec une électrode d'antimoine de type pointu.

Dans 22 disques où on a trouvé vrai prolapsus, le pH a varié de 7.5 à 6.6 (moyenne 7.0). On a aussi trouvé une corrélation négative significative entre le pH et la dégénération du disque, la douleur préopératoire et, notamment, la quantité de tissu conjonctif autour de la racine. Quand la valeur du pH était moins de 7.0 dans ces disques, il y avait aussi des signes d'une réaction inflammatoire autour de la racine.

On n'a vu aucune réaction pareille, quand le pH était 7.0 ou plus. Dans deux cas le pH fut mesuré le jour avant l'opération et aussi au cours de l'opération avec anesthésie totale, sans différence avec anesthésie locale.

Dans 4 cas où la racine se montra entièrement recouverte d'un tissu dense fibrotique et adhérent au disque, le pH dans ces disques était significativement inférieur (moyenne 6.1) que dans les 14 cas d'exploration «négative» (moyenne 7.1) et les 22 cas de prolapsus (moyenne 7.0). Les différentes explications possibles à l'augmentation des ions hydrogènes sont discutées par comparaison avec des recherches antérieures sur la chimie des disques lombaires.

Il est possible que des métabolites acides dans le disque peuvent couler par des ruptures de l'anneau fibreux et causer une réaction inflammatoire autour de la racine. Chez 4 sujets avec une concentration d'ions hydrogènes très augmentée, la racine était complètement entourée d'une cicatrice fibrotique. Dans ces cas, le pH représente moins que la valeur que l'on suppose pouvoir occasioner une douleur dans les tissus humains. Cela n'était pas le cas dans la plupart des prolapsus de disques lombaires.

ZUSAMMENFASSUNG

Bei 30 Patienten mit Wurzelschmerzen wurden in 40 Zwischenwirbelscheiben der pH-Wert mit Hilfe einer spezialkonstruierten nadelförmigen Antimonelektrode gemessen.

In 22 Zwischenwirbelscheiben, bei denen ein Prolaps vorlag, lagen die pH-Werte zwischen 7.5 und 6.6 ($\bar{m}$ 7.0). Es lag eine signifikant negative Korrelation zwischen pH-Werten und Bandscheibendegenerationen, präoperativen Schmerzen und – am meisten signifikant – der Menge von Bindegewebsreaktion im Bereich der Nervenwurzeln vor. Waren die pH-Werte niedriger als 7.0, dann zeigten sich auch gewisse entzündliche Reaktionen um die Nervenwurzeln herum. Derartige Reaktionen wurden kaum bei pH-Werten höher als 7.0 beobachtet. Bei zwei nur örtlich betäubten Patienten wurde der pH-Wert nicht nur während, sondern auch einen Tag vor der Operation bestimmt, wobei die erhaltenen Resultate unverändert waren. Bei vier Fällen, bei denen die Exploration von dickem Narbengewebe umgebene Nervenwurzeln zeigte, lagen signifikant niedriger pH-Werte ($\bar{m}$ 6.1) als in den 14 Bandscheiben mit negativen Befunden ($\bar{m}$ 7.1) und in den 22 prolapierten Bandscheiben ($\bar{m}$ 7.0) vor. Die verschiedenen möglichen chemischen Erklärungen für die erhöhte Wasserstoffionenkonzentration werden angeführt und auf der Grundlage früher veröffentlichter chemischer Untersuchungen der lumbalen Zwischenwirbelscheiben diskutiert.

Es wird als möglich erachtet, dass saure Metaboliten der Bandscheiben durch Rupturen in den Annulus fibrosus austreten und eine gewisse entzündliche Reaktion um die Nervenwurzel herum verursachen können. Bei den 4 Fällen mit sehr niedrigen pH-Werten waren die Nervenwurzeln vollständig von dichten fibrösen Narben umschlossen. In diesen Fällen war der pH-Wert so niedrig oder niedriger als der Wert, der bekannterweise Schmerzreaktion im menschlichen Gewebe hervorrufen kann. Solch stark saures Milieu lag aber nicht bei den Fällen mit Bandscheibenprolaps vor.

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