STUDIES ON THE PATHOLOGY OF LOW BACK PAIN

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It is now about thirty years since Schmorl (1929) described structural changes in intervertebral discs and in intervertebral bodies observed at necropsy. Disc surgery during the last twenty-five years has shown that there is a high incidence of disc ruptures in patients with low back pain and sciatica, and there is a wide belief that low back pain originates in the discs. Although it can be well understood and accepted that structural disc changes may lead to circumscribed local disc sequestrations, causing mechanical pressure on lumbar nerve roots, the underlying mechanism of low back pain is still not known.

Since 1940 a number of investigations have been done in Sweden in order to correlate the clinical picture of low back pain with structural changes in lumbar intervertebral discs.

CLINICAL FEATURES OF LOW BACK PAIN

The clinical diagnosis of "low back pain" covers a number of different symptoms. Mostly it is comprised of pains and tiredness in the lumbar area of the back. Although many diseases can give rise to referred pain in the back, most of those who complain of back pain are young or middle-aged people with no abnormality elsewhere in the body than in the spine or the surrounding tissues.

In order to establish a basis for further discussions 15,000 cases of backache were classified (Friberg and Hirsch 1946). All were in patients examined at the orthopaedic department of the Medical School in Stockholm from 1936 to 1946, and 9,500 of the patients had been radiographed. It was found that the symptoms began in the late twenties, and that the highest incidence was between the ages of thirty to fifty years. The incidence was equal in men and women. On plain radiography roughly half the patients showed narrowed interspaces, bony sclerosis and osteophytes, indicating disc degeneration in the lumbar spine. Forty-eight per cent of these degenerative changes occurred in the fourth lumbar disc and in 75 per cent either the fourth or the fifth disc was involved. In 15 per cent instability between the lower lumbar vertebrae was the only radiographic sign of disc change.

Seventy-four per cent of the men were engaged in physical work. This proportion corresponds roughly with the country's proportion of labourers. There was no evidence that heavy physical work was the direct cause of disc changes.

In order to estimate the incidence of low back pain in Sweden, Hult (1954) made an extensive study in different areas of the country among men of different professions. About 2,000 people were questioned, examined and radiographed. The incidence of low back pain was 65 per cent. There was no significant difference in the incidence among heavy manual labourers and other groups, but it was found that when those employed in physical work were affected they had to stay off work much longer.

Of those with acute pain 20 per cent blamed an injury. Another 20 per cent stated that the pain began while they were carrying heavy objects or were subjected to some kind of mechanical stress. The remaining 60 per cent were unable to ascribe any cause.

In addition to these studies Friberg and Hirsch (loc. cit.) examined twenty-five patients between twenty-five and forty years of age with acute back pain, with regard to involvement of
other parts of the body. In none of these patients was anything found that could be said to be a causative factor.

ANATOMICAL STUDIES OF LUMBAR DISCS

Since clinical experience suggested that lumbar intervertebral discs might develop structural changes that would account for low back pain it became obvious that we would have to re-examine the anatomical appearance of the discs. For this work we have since 1946 collected hundreds of necropsy specimens of the spinal column from persons of all ages. Most of the studies have been on subjects aged between twenty and fifty years. The lumbar spine was dissected out with the sacrum within a few hours of death and fixed in a vice to permit radiographic studies in flexion and extension in the fresh state. After fixation in formalin the intervertebral discs were cut through horizontally and examined grossly and microscopically. It was concluded (Friberg and Hirsch 1949) that the nucleus shows regressive changes quite early. With increasing age the water content in the nucleus decreases, the fibrous structure increases, and the delimitation from the annulus becomes less marked.

It was difficult to decide when a disc should be classified as pathological. It became obvious that the term degeneration as a clinically reliable statement could be accepted only when ruptures were seen in the annulus. The type and localisation of the ruptures are different at different levels of the lumbar spine. In the two lowest discs the degenerative changes occur mainly posteriorly. They have a characteristic configuration. The rupture of the annular fibres often starts from the inner side of the annulus and extends from the centre of the disc posteriorly or postero-laterally, being surrounded by smaller ruptures undermining the whole posterior area of the disc. When enough collagen bundles are broken the fibrous construction of the annulus loses its concentric shape, some fibres retract and tissue from central parts of the disc seems to squeeze or replace annulus areas. Parts of the disc then become necrotic, disintegrate, and become partly replaced by connective tissue, but the whole disc is never totally changed. Even in completely degenerate discs there are always remnants left of the former structure.

Among the 500 discs first examined eleven prolapses were found, all in the two lowest interspaces. The discs all showed the same structural changes that were found in other examples of disc degeneration. It thus became clear that a prolapse is a part of the general degeneration of a disc.

Comparison of the degenerative changes in discs with the radiographic appearance showed that a normal radiograph may be consistent with considerable degenerative changes. When on the other hand a radiograph showed a narrowed interspace, sclerosis or osteophytes, the corresponding disc was severely damaged.

After the age of fifty, structural changes are increasingly more common, as are radiographic signs of degeneration, whereas from a clinical point of view the frequency of backache is decreasing. If, therefore, pathological changes in the discs are the cause of low back pain, not all structural changes may give rise to pain. From the macroscopic appearance of the discs it seems clear that it is during the early stages of deterioration, when the discs still have a certain amount of function, that they may cause trouble. When the discs are completely destroyed there is no longer any movement between the vertebrae, and that area of the spine is stable and does not seem to cause pain.

HISTOLOGICAL CHANGES

All the lumbar disc specimens were examined microscopically. Some of them were also studied with the electron microscope (Hirsch, Paulson, Sylvén and Snellman 1952). In the nucleus there is very little structure to be seen with the microscope. The cells are few and other structures are covered by intercellular substances.
In the lower discs fissures and ruptures occur early, beginning mostly at the border between the nucleus and the cartilaginous plates and extending towards the centre of the nucleus. The nucleus is becoming more compact, with diminished stainability, the collagenous structure being visible. These dry necrotic areas can often be seen as early as the third decade.

Under the electron microscope the nucleus in children and young persons shows numerous collagen fibres running in all directions. It is a porous system, the space between the fibres varying. The collagen fibres have the same appearance as in other connective tissues, but they are surrounded by chondromucoid elements, probably chondroitin-sulphuric acids. By fermentative treatment of the specimens the chondroitin-sulphuric components could be eliminated, whereby purified collagen fibres could be seen. In specimens from elderly persons many of the nuclear fibres were uncovered, illustrating structural changes down to the molecular level. It is thus obvious that the nucleus is not a watery gel but is composed of highly organised material.

The annulus is known as a structure where dense fibres are running in different directions. The fibres are grouped in bundles. Some extend from one cartilaginous plate to the other, and some cross from vertebra to vertebra. They take an oblique course, the construction of which we were not able to record.

In the electron microscope the collagen fibres appeared as true collagen structures to which chondromucoid material was attached, although less than in the nucleus. The bundles were twisted and kept together by thin structural elements of chondroitin nature.

As early as twenty years of age the annular fibres seemed to loosen up. Areas were found where the structure was no longer so compact. In these places the stainability changed, indicating biochemical disorder. In the middle of the third decade histochemical as well as structural changes were common in the lower lumbar discs.

Both in front of and behind the annular fibres the long ligaments are to be seen. In man these elements were thin connective tissues. There is a discussion among many investigators whether and how these ligaments are attached to the outer border of the discs. It was our impression that they were closely connected to the annulus and thus took a definite part in the function of the disc. There was a marked difference in the metachromatic reaction. The smaller chondromucoid content of the ligaments suggested that they might be less elastic than the annulus. Structural changes in the annulus might therefore mechanically affect the close relationship between the two anatomical elements.

When ruptures in the annular fibres occurred close to the outer border of the disc a connective tissue reaction occurred in the annulus area. Vessels grew in from the long ligaments, and in the lower lumbar discs from the posterior ligament. These foreign elements appeared as vascular granulation tissue. Our specimens were reviewed to determine the frequency of granulation tissue reactions at different disc levels at different ages. It was found that in the lower lumbar discs the ingrowth of vessels into the posterior part of the disc was common between the ages of thirty and fifty—that is, when low back pain shows the highest incidence. Hirsch and Schajowicz (1952) believed that although nerve elements were not known to be present in discs it might well be possible that they could enter together with the vessels into the annulus. If so, a granulation tissue reaction might explain why some discs became sensitive to stress and painful. Nevertheless every method used failed to demonstrate the presence of nerve fibres.

My present impression is that a connective tissue reaction is a part of the phenomenon of advanced ruptures through the annulus in young adults, when backache is common. So long as the tear stays within the annulus healing cannot occur because of the lack of vascular supply. When an area where repair is possible is reached an attempt is made. The granulation tissue becomes converted into a scar, which is often found in disc lesions in the elderly. The same reaction is found in older people in the upper lumbar region, where low back pain is less frequent.
PHYSIOLOGICAL AND BIOCHEMICAL STUDIES

In 1950, when the data now presented were discussed, it could be stated from the clinical, anatomical and microscopical investigations that mechanical stress factors alone might not be the underlying mechanism for the deterioration of lumbar discs. Since intervertebral discs from about the age of fifteen have no vascular supply they might become more sensitive to metabolic disturbances than other connective tissues. It was thought that biochemical analyses might add some information about the disintegration during early youth in an avascular tissue. These studies were made by Hirsch, Paulson, Sylvén and Snellman (1952).

First the diffusion rate of various substances through the nucleus was recorded. Fresh necropsy specimens were placed in specially made covers, and the diffusion rates were calculated by means of interferometric light microscope. It was found that the rate was low and that only molecules of a certain shape were able to enter. It was supposed that the nucleus must be very sensitive to metabolic disturbances.

The chemical components of the nucleus were investigated and found to be protein, polysaccharides and water. The relationship between these elements was then studied at different ages. It could be confirmed that with increasing age the water content decreased. It was also found that with increasing age the protein component in the nucleus increased, whereas the mucopolysaccharides decreased or remained constant. It seemed to us that the change in the water content was because the structural elements were undergoing a decrease in water-binding capacity during ageing. The relationship between protein and mucopolysaccharides might explain this.

Metabolic disorders are shown already at the age of twenty and increase with ageing. This indicates a change in the mechanical state of intervertebral discs.

COMPARATIVE STUDIES ON DISC DEGENERATION IN ANIMALS AND MAN

It is often considered that backache is due to posture, and that mechanical factors in human beings will put much greater stress on the lower lumbar area than elsewhere. It is also supposed that when a spine is acting in the wrong way or if a person is forced to work in a bad position his discs will suffer. Anatomical variations in the construction of the spine, such as congenital anomalies, are also considered to increase the liability to back trouble.

Although some of these suggestions seem to be valid our clinical observations did not show a considerable increase in anatomical variations in those with backache; nor did bad posture or heavy work seem to be significantly more frequent.

It is believed that dogs and cows suffer backache and that degenerative changes in their discs are common. In Sweden Hansen (1952) found that, in some breeds of dog—such as dachshunds, pekines and bulldogs—belonging to the chondrodystrophic types, degeneration and prolapse of the discs are common. The structural changes are very like those in man. The incidence of disc degeneration is high in the middle region and somewhat less in the low thoracic region. When prolapse occurs it may give rise to paraplegia. There may be a profuse connective-tissue reaction under the posterior longitudinal ligaments, the tissue being very like what has been described above as granulation-tissue reaction.

In cows the lumbo-sacral junction is the most mobile part of the spine. It would therefore be expected that if mechanical factors were to affect the discs the structural changes would occur in that area. According to Hansen this is in fact so. In cows the greatest tear is in the posterior ligament, and ruptures and disintegration as well as minor fractures in the posterior edges of the vertebrae occur very early.

If these observations on animals are compared with what is known in men it seems that degeneration in the low lumbar region is the result of mechanical stress.
MECHANICAL FUNCTION OF LUMBAR DISCS

Although it became more and more obvious that avascular necrosis followed by mechanical stress was the main cause of early degenerative changes in the lower lumbar area, it was still not understood how this would produce pain. Nerve elements do not exist inside a disc, but they are known to be present in the posterior longitudinal ligament. Structural changes and ruptures in the annulus might weaken the posterior part of a disc, and thereafter abnormal movement between the vertebrae and bulging of the posterior area of the disc might stress the sensitive posterior ligament.

It was suspected that if in patients with backache the pressure inside a disc could be raised it would cause pain. We therefore undertook a series of disc puncture experiments. A lumbar puncture needle was introduced transdurally into the posterior area of a lumbar disc under radiographic control. Normal saline was injected. In some discs less than one millilitre could be instilled even with strong pressure on the syringe. In these cases the patient felt no pain. In other discs more than one millilitre could be injected easily, and pain occurred when the pressure was raised. In these cases the patient stated that it was the same pain that he usually had when his backache was present. When the pressure was released the pain disappeared immediately if very little procaine was injected.

It was supposed that the pressure inside the disc had produced stress on the posterior area of the annulus and caused a deformation which affected the posterior ligament with its sensitive nerve elements.

Lindblom (1950), investigating disc puncture and nucleography with a water-soluble contrast medium, found that those discs where pain occurred were really degenerated discs with ruptures of the annulus.

Everything now seemed clear. Degenerated discs could under certain circumstances not tolerate some extra stress that caused pain. If the posterior area was anaesthetised the nerve elements in the posterior ligaments became insensitive and the pain disappeared.

Hirsch and Nachemson (1954) later studied the mechanical tolerance of lumbar discs under normal and pathological conditions. Pressure machines were built and measuring instruments were installed which would allow us to record movements and deformations down to thousandths of a millimetre. Using displacement pick-ups and strain gauges connected to oscillographs incorporating high speed cameras, almost any small movement occurring during a hundredth of a second could be seen.

When a disc with its vertebrae below and above is subjected to pressure it deforms according to a typical curve. The amount of compression is dependent on how much pressure is applied. Most discs will take 300 to 400 kilograms before the breaking point is reached. With 100 kilograms load the total compression in a normal disc is about one millimetre.

If a load is maintained for several minutes a typical time-compression curve will occur where the disc after having reached its main deformation after half a minute tends towards a maximum.

The amount of bulging that occurs in the annulus while the disc is under pressure is very little in normal discs—about 0.5 millimetre for a 100-kilogram load. Degenerated discs deform more; but though the figures are about 100 per cent higher, the amount in millimetres is still not high. A disc with ruptured annular fibres subjected to a load of 100 kilograms would bulge only about one millimetre, which could not be accepted as giving rise to backache.

If a lumbar interspace is subjected to fast-acting shocks from loads falling on the specimen the disc starts to vibrate. These vibrations will die out rapidly during less than a second. Mild or moderate degenerative changes have very little influence on the vibration curves. If an intervertebral disc is loaded, and thus somewhat compressed, the amplitude of the vibrations will be less.
The lumbar discs act as stabilising shock-absorbing tissue elements. Mild or moderate degenerative changes make them less efficient even though their mechanical response does not differ greatly from what can be considered normal.

On both normal and degenerated discs from fresh necropsy specimens, disc punctures were performed while the discs were surrounded by measuring instruments. In neither of these specimens did deformations occur that could be seen on the recording instruments.

These mechanical studies seem to indicate that pain does not occur from the disc because it presses on the posterior ligament.

**MECHANISM OF PAIN**

In order to explain mechanically the pain mechanism we will have to reconsider the posterior structure of a disc. The ligament may be considered as a tape on a rubber tube. If the tube is expanding there may be considerable stress at the junction of the two elements even though the tube has not moved very much. This is because of differences in their physical properties. Normally, if a disc is subjected to mechanical forces there will be a reaction through the entire disc. The nucleus will distribute pressure towards different parts of the annulus, and the annulus will become compressed because its fibres will stretch and bulge. If the nucleus has become dense and necrotic, and has lost part of its water content, it is no longer able to act as a pressure distributor, the entire stress being transferred to the annulus. This might explain why the annulus ruptures. If part of the annulus is out of action considerable stress may occur between the annulus and the ligaments.

This mechanical explanation makes it possible to understand why severely degenerated discs do not cause any pain. If the disc has lost its function, its elastic structure being largely replaced by the ingrowth of connective tissues, the interspace is stable and no such stress actions can occur between the long ligament or any surrounding sensitive tissues and the remnants of the disc.

In 40 per cent of those with acute low back pain it was stated that the onset of the attack started while the patient was under mechanical stress. Our mechanical experiments offer an explanation for this. If a disc is under compression part of its shock-absorbing capacity is used up because the collagenous structure is stretched. There is thus less available when some extra stress suddenly strikes the spine. The tensile strength is exceeded and the breaking point is reached. It was recently shown by Perey (1957) that in young people two things might happen: if the disc is normal the vertebra breaks; if the disc is degenerated the fibres of the annulus rupture.

**CONCLUSIONS**

Disc degeneration starts as an avascular necrosis. In the lower lumbar area the discs deteriorate early because of mechanical stresses. During certain early periods of degenerative changes a mechanical disorder between the annulus and the posterior longitudinal ligament may cause tiredness and pain. When the disc is completely degenerated and has lost its physical properties backache disappears.

**SUGGESTION**

Because of the biological appearance of ageing processes in lumbar intervertebral discs, theoretically there might be two ways of eliminating backache. Either we will have to find methods by which discs can recover biologically and we will have to improve the nutritional mechanism, which does not seem to lie within our reach; or we will have to find methods by which the deterioration can rapidly pass the stage at which a mechanical disorder causes pain. Sooner or later a substance may be found by which a degenerated disc could be transformed to dense connective tissue. It might be possible to create a chondrolytic enzyme
that, injected into a disc, would cause a connective tissue reaction. We already know several bacteria in which such enzymes are present. It might be possible in one way or another to make them available.

REFERENCES