From the Department of Orthopaedics, University of Göteborg, Sweden

STRUCTURAL CHANGES IN THE CERVICAL SPINE

A STUDY ON AUTOPSY SPECIMENS IN DIFFERENT AGE GROUPS

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To our wives

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Preface

The present study on structural changes in the cervical spine started in 1964 and was completed two years later. During 1967 the collection of information was brought together and the report to follow written. The authors want to thank particularly dr. Erland Lysell and dr. Yngve Olsson for most valuable assistance during different phases of this project, mrs. Inga-Lisa Elzer and miss Lena Johnsson for skilfull technical work and mrs. Birgitta Pande for secretarial help.

During 1965 and 1966 dr. Jorge Galante held a research scholarship from the International College of Surgeons permitting him to stay in Göteborg. Professor Fritz Schajowicz made several research visits to this institution to participate and activate the completion of this investigation. It received its final shape at a country place on the Swedish east coast during an unforgettable peaceful summer vacation made possible by affectionate understanding of our wives.

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Herräng, Sweden
July, 1967

Introduction

Disturbances in the cervical spine causing restriction of motion, neck stiffness and referred pain either through the upper extremities, the head, the face or through the chest are extremely common. According to Hult (1954) approximately 70% of the Swedish population suffer from this condition once or repeatedly.

The onset of the symptoms is mostly in middle age but it is not uncommon even in young adults. Although the prognosis is in general good for the majority of cases treated conservatively there has been a growing tendency during the last decades to attempt surgical procedures in the severely afflicted.

The symptoms have been related to different patho-anatomical lesions of various components of the cervical spine. Narrowing of the intervertebral foramen caused by osteo-arthritis of the apophysial joints, osteophyte formation of the unco-vertebral region, degenerative changes in the discs with or without posterior herniations and abnormal motion in vertebral segments have been the principal patho-anatomical lesions implicated.

These conditions have been thought responsible for the involvement of the neural and/or of the vascular elements in the foramen which are in close relationship to the posterior and lateral parts of the vertebral components.

Different diagnostic methods have been introduced to elucidate the type and site of the underlying mechanism. There is often a lack of correlation between the clinical and radiographic picture. Symptoms and signs of degenerative lesions of the cervical spine may be present in the absence of radiological findings on plain films, while gross radiological changes may be present in patients in the absence of symptoms. In view of this, other roentgenological methods such as laminography, cineradiography, discography, myelography, intraosseous vertebral venography and vertebral artery angiography have been employed in order to extend the visualization of the lesions. But in spite of these extensive diagnostic techniques the correlation between the clinical picture and the pathological lesion is still uncertain (Hirsch 1960, Hirsch, Wickbom, Lidström and Rosengren 1964).

Clinical radiographic procedures visualizing structural changes in the cervical spine (Hirsch, Wickbom et al., 1964).

A. Plain X-rays
B. Discography
C. Myelography
D. Venography

Fig. 1 A AP, lateral and oblique plain X-rays of a female patient of 52 illustrating a narrowed disc between C.VI and C.VII and osteophytes protruding into the corresponding intervertebral foramen.

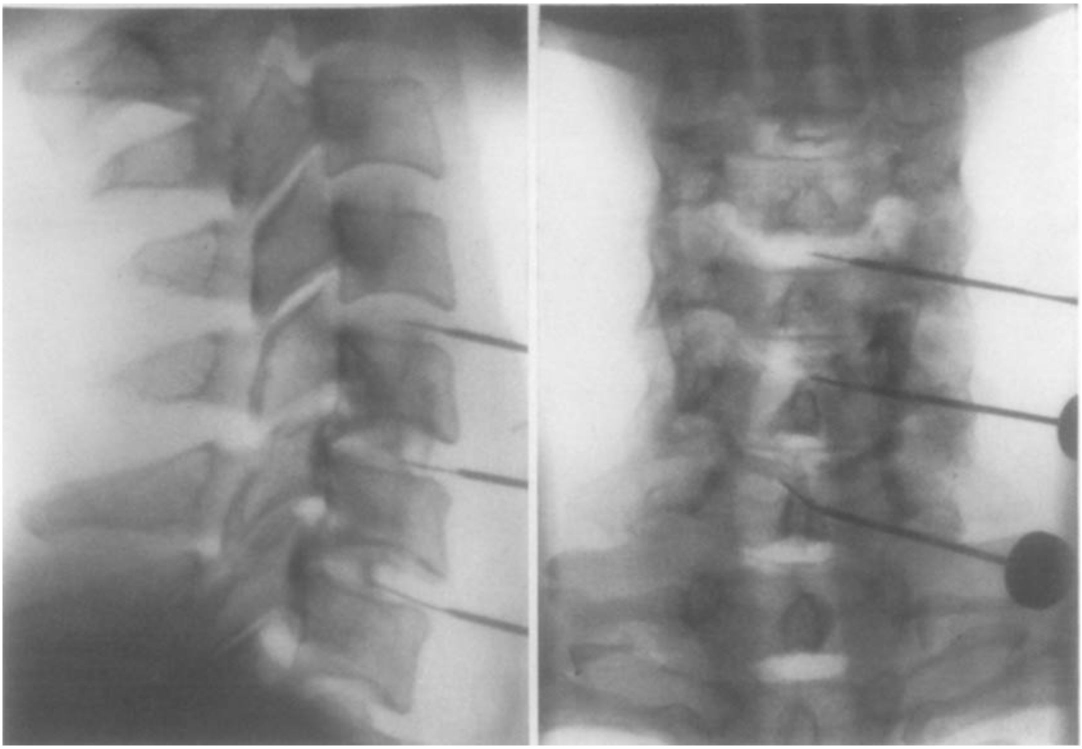


Fig. 1 B Female patient of 48. On plain films the C.V—C.VII levels look normal. Needles have been introduced under television X-ray control in order to perform discograms at C.V, C.VI and C.VII disc levels. Water soluble radiopaque contrast has been injected into C.VI and C.VII but not yet into C.V. The contrast has leaked mainly postero-laterally bulging into the spinal canal and the intervertebral foramen through the uncus region.

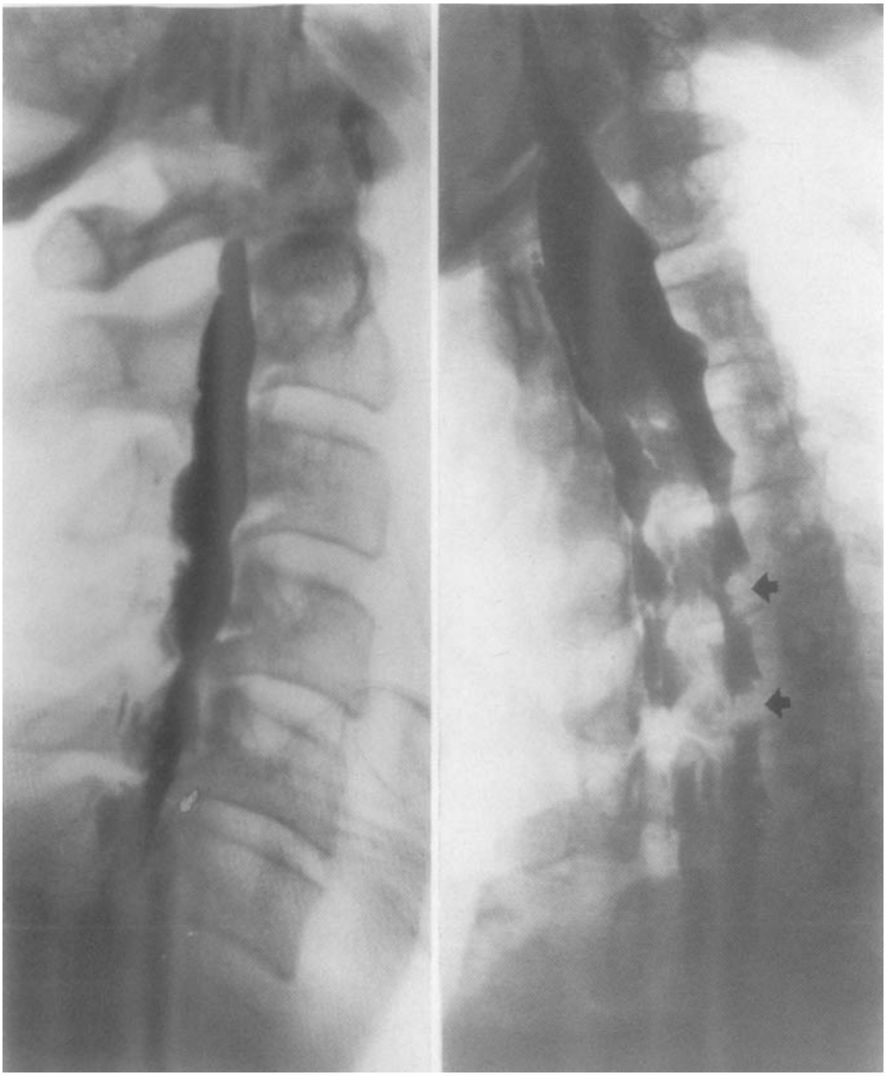


Fig. 1 C Male patient of 51. Pantopaque myelogram illustrating indentations at C.VI—C.VII and to a less degree at C.V—C.VI.

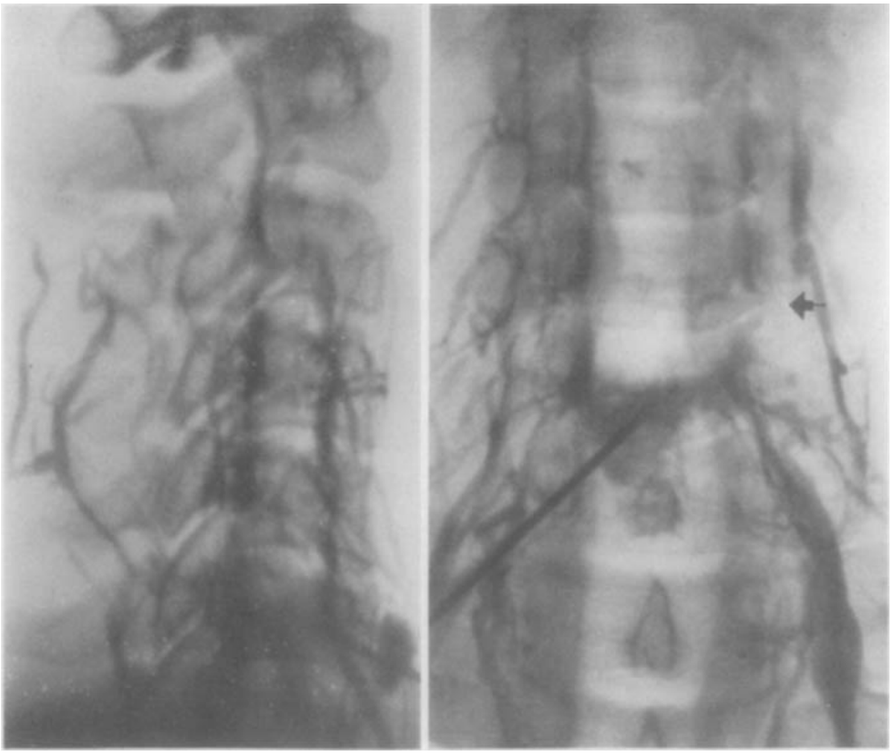


Fig. 1 D Venography after injection of contrast material in the C.VI vertebral body. On the left side the filling of the venous plexus is interrupted at the C.V —C.VI level (arrow) illustrating the fibrous tissue elements causing the indentations on the myelogram in Fig. C affecting both the root sleeves and the veins which are lying anatomically very close in the foramen.

As the main clinical complaint is pain sometimes accompanied by other neurological disturbances great attention has been given to methods indicating involvement of nerve elements mainly by electro-diagnostic means, especially electro-myography. Since symptoms can be relieved by local anaesthesia, para-vertebral ganglion blocks have been tried to determine the site of the lesion. All the above-mentioned methods have their obvious clinical limitations.

The lack of basic knowledge of cervical spine physiology, anatomy and pathology and a clear understanding of the etiology of the clinical symptoms has led to many different surgical procedures in order to decrease or eliminate the possible causal factors. In principle two lines have been adopted: 1. Decompression of nerve and vascular elements at the foramen by laminectomy, hemifacetectomy, resection of osteophytes and protruding disc material. 2. Fusion of vertebral bodies with or without removal of degenerated discs to eliminate motion and abnormal mechanical influences upon nerve structures. The result of these surgical procedures have not always been satisfactory. This has resulted in a great controversy with respect to the efficacy of the different procedures.

There is to-day a growing tendency to accumulate more information about the normal and morbid conditions of the cervical spine in order to be able to evaluate the significance of the different structural changes and their clinical importance. With this in mind it was felt that a comparative morphological study covering different age groups would help to clarify some features of possible clinical importance still under discussion.

Survey of Literature

During the last decades a growing number of papers and several monographs have been published regarding the cervical spine (Ecklin 1960, Jackson 1965, Hall 1965, Brain—Wilkinson 1967). Both the normal and morbid anatomy still seem to be subject for discussion.

According to Bowden (1966) the nucleus lies closer to the back than to the front of the disc. However, it is Jackson's (1965) opinion that the nucleus is placed slightly anterior to the centre of the disc and that the annulus is thicker posteriorly than ventrally.

Töndury (1959 and earlier) and Ecklin (1960) found degenerative changes in the disc starting in the unco-vertebral region at the age of 20 years. The changes are more conspicuous and the number of levels increases with age. The levels of C.V.—C.VI and C.VI—C.VII according to Payne and Spillane (1957) have the highest frequency of disc involvement.

Osteo-arthritis of the apophysial joints is more common in the mid-cervical and upper cervical regions (Holt and Yates 1966). According to Friedenberg et al. (1959) and Payne and Spillane (1957) there seems to be no correlation between the changes in the apophysial joints and the discs. These joints frequently escape involvement even when the disc shows marked degeneration, and severe degeneration of apophysial joints could occur in the presence of normal discs. Degenerative changes especially spur formation in discs and/or joints may make the vertebral foramen narrower and reduce its size to $^1/_4$ with flattening and destruction of the nerve (Hadley 1944).

Nerve root lesions are frequently associated with disc degeneration and apophysial joint arthritis. Holt and Yates (1966) found cysts in the posterior nerve roots where they join the dorsal root ganglion. The frequency varied from none in the second and third root to more than 10 % in the sixth. Frykholm (1951) found root sleeve fibrosis causing constriction and angulation of the nerve roots. The root sleeve fibrosis is usually secondary to chronic compression of the radicular nerve.

Roentgenographic studies by Hadley (1944) which included oblique views and tomograms with good demonstration of the intervertebral foramen and adjacent areas, indicated that degenerative changes in discs are not sufficiently demonstrated by this technique. Morton (1950) found that fissuring of the discs, posterior herniation and posterior protrusions of the annulus could not be identified roentgenologically. Lipping and eburnation of the vertebral bodies, thinning and ossification of the discs and osteo-arthritis were visible. The correlation between roentgenographic and anatomical findings regarding the disc degeneration was 67% but it was poor concerning changes in the apophysial joints (Friedenberg et al. 1959).

A great part of the literature on the normal and morbid anatomy of the cervical spine deals with the postero-lateral or unco-vertebral region of the disc and vertebra. The reason for this is obvious because of the close anatomical relationship between this area, the foramen containing the nerve root and the vertebral vessels.

Since Luschka (1858) described the region as a semi-joint (Halbgelenk) it is usually called the "Luschka-joint". There has been a continuous dispute whether it is a true joint or just a degenerative phenomenon. Trolard (1893) stated that the bony surfaces are covered by cartilage and Compère et al. (1959) demonstrated in adult specimens all of the elements of a true joint including a joint space, articular cartilage and synovial tissue.

Jackson claimed (1965) that the disc does not extend to the lateral and postero-lateral margin of the vertebral body and that there is articular cartilage and a well-defined capsular ligament but made no mention of a synovial membrane. Giraudi (1931) claimed in a purely roentgenological and clinical investigation to have demonstrated a joint. In opposition to "the true joint view" Rathke (1934) could not find the joint described by Luschka neither macroscopically nor microscopically. Frykholm (1951) thought that "unco-vertebral joints" genetically belong to the annulus because the apophysial ring completely covers the uncinate process, and all the structures enclosed between the apophysial ring must be equivalent to the annulus in other regions. Krogdahl and Torgersen (1940) doubted that it is adequate to use the word joint because the region lacks many of the criteria of a true joint but they chose the term because they thought it was the best way to describe the anatomical condition.

Many authors have in opposition to the joint hypothesis expressed their findings as fissures in the lateral part of the disc, (Rathke 1934, Krogdahl and Torgersen 1940, Töndury 1943, 1955, 1958, Frykholm 1951, Payne and Spillane 1957, Hadley 1957, Orofino et al. 1960, Ecklin 1960, Hall 1965, Silberstein 1965) and none of these authors has been able to demonstrate synovial lining in specimens from young individuals. The fissures are not found in specimens from foeti or new-born infants (Orofino et al. 1960, Hadley 1957). The postero-lateral space of this zone of the disc is filled with loose fibrous tissue (Rathke 1934), containing blood vessels (Töndury 1943, Hadley 1957, Ecklin 1960, Orofino et al. 1960, Hall 1965). At the age of 6—9 years the uncinate processes are beginning to grow and form and are fully developped at age 18 (Rathke 1934). During growth, fissures appear and are well established at age 14 (Töndury, Ecklin, Hall, Silberstein). Töndury (1958) stated that these fissures seem to be the start of centrally directed bigger fissures and Ecklin (1960) who summed up Töndury's earlier work, pointed out that the fissures start in normal disc tissue. They are the result of the function of the cervical spine. With increasing age degenerative changes occur. The surfaces of the fissures may undergo cartilaginous metaplasia forming a "neoarthrosis" where Silberstein (1965) in specimens from the 7th decade of life found tissue that appeared to have synovial characteristics.

Most authors agree that arthritic changes in this region are frequent and appear early in life. Spur formation directed backwards or laterally narrows the intervertebral foramen (Krogdahl and Torgersen 1940, Hadley 1957, Payne and Spillane 1957, Orofino et al. 1960) and may compress the vertebral artery (Krogdahl and Torgersen 1940). There is a high degree of correlation between arthritic changes here and disc narrowing at the same level. Many investigators find these changes to be only part of a general disc degeneration and not an isolated phenomenon (Giraudi 1931, Frykholm 1951, Payne and Spillane 1957, Friedenberg et al. 1959, Silberstein 1965).

The uncinate processes are considered to restrict sideward flexion (Frykholm 1951) or to help to prevent lateral or posterior subluxation and to serve as a barrier to postero-lateral extrusions of the disc (Compère et al. 1959). The processes may also serve as a guide-raise during translatory motion (Ecklin 1960).

Material and Methods

This study is based on fresh human autopsy material. A total number of 111 cervical spines were investigated.

Individuals from all age groups were sampled. Subjects known to have malignant disease with bone metastasis were excluded. The study group is described in Fig. 2 and Table 1.

All the spines studied were obtained within 48 hours following death.

All together close to 700 discs were investigated and more than 3000 microsections studied.

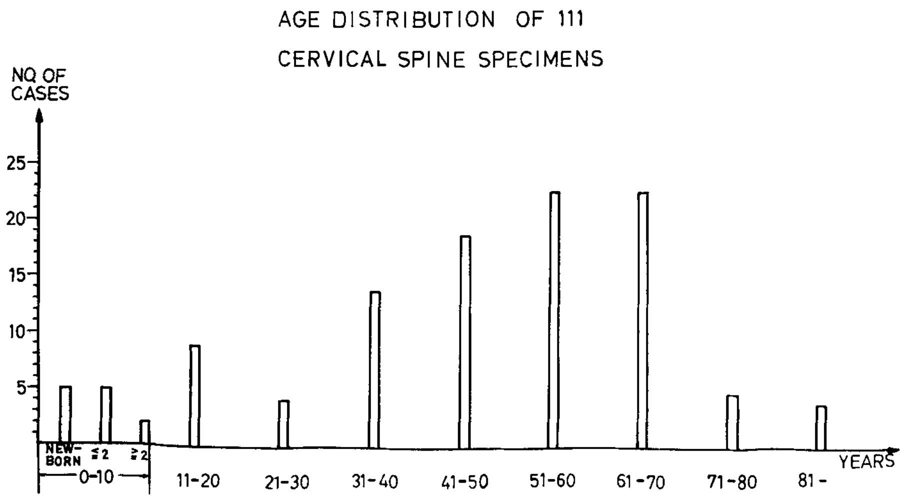


Fig. 2

TABLE 1

Age group	Case number	Age	Sex	X-ray	Cause of death
0—10	1	1 day	M	x	Aspiration. Pleurisy. Atelectasis.
	2	1 ,,	M	x	Aspiration. Pleurisy. Atelectasis.
	3	1 ,,	M		Foetus maceratus.
	4	2 days	M	x	Pneumothorax. Mediastinal emphysema. Atelectasis.
	5	4 ,,	M	x	Congenital heart failure.
	6	7 months	M	x	Bilateral encephalopathy. Broncho-pneumonia.
	7	7 ,,	F		Congestion of lung and circulatory failure.
	8	14 ,,	F	x	Increase of intracranial pressure.
	9	2 years	F		Subtentorial tumour of the brain.
	10	2 ,,	F		Meningococcal meningitis.
	11	7 ,,	F	x	Encephalopathy. Broncho-pneumonia.
	12	10 ,,	F		Circulatory failure.
11—20	13	11 ,,	F	x	Brain tumour.
	14	11 ,,	M	x	Extradural haematoma.
	15	14 ,,	F	x	Oliguria and uremia.
	16	15 ,,	F	x	Aneurysm of carotid artery.
	17	15 ,,	F	x	Oesophageal varices with haemorrhage.
	18	16 ,,	M	x	Acute leukaemia. Broncho-pneumonia.
	19	18 ,,	M	x	Cancer of the nasal cavum.
	20	19 ,,	M	x	Fat-embolism in lung and brain.
	21	20 ,,	M	x	Cerebral haemorrhage.
21—30	22	22 ,,	M		Information missing.
	23	24 ,,	M	x	Rupture of the aorta.
	24	25 ,,	F	x	Information missing.
	25	28 ,,	F	x	Cerebral tumour.
31—40	26	32 ,,	F	x	Venefitium.
	27	32 ,,	F	x	Information missing.
	28	33 ,,	M	x	Glioma of the cerebellum.

Age group	Case number	Age	Sex	X-ray	Cause of death
	29	34 years	M	x	Aspiration pneumonia.
	30	34 ,,	F	x	Circulatory failure.
	31	34 ,,	M	x	Cholangitis with jaundice. Partial hepatectomy.
	32	35 ,,	F	x	Sequelae of right-sided nephrectomy. Pyonephrosis and broncho-pneumonia.
	33	36 ,,	F	x	Gastric cancer.
	34	36 ,,	M	x	Rupture of the aorta.
	35	37 ,,	M	x	Broncho-pneumonia. Pulmonary embolism.
	36	37 ,,	F	x	Malignant tumour of gallbladder.
	37	38 ,,	F	x	Mammary cancer with metastases in lymph glands. Circulatory failure.
	38	40 ,,	F	x	Gangraenous granuloma.
	39	40 ,,	M	x	Malignant abdominal tumour.
41—50	40	41 ,,	F	x	Uremia.
	41	43 ,,	F	x	Intracranial arterial aneurysm with haemorrhage.
	42	43 ,,	M	x	Pulmonary embolism.
	43	44 ,,	F	x	Bronchial cancer.
	44	44 ,,	M	x	Myocardial infarction and cardiac failure.
	45	47 ,,	F	x	Circulatory failure.
	46	47 ,,	F	x	Ovarian cancer.
	47	47 ,,	M	x	Reticular sarcoma of the nasal pharynx.
	48	47 ,,	F	x	Uremia and pulmonary congestion.
	49	48 ,,	F	x	Cancer of the colon.
	50	48 ,,	F	x	Chronic pyelonephritis.
	51	49 ,,	M	x	Pneumonia.
	52	49 ,,	M	x	Intestinal fistulas with intraabdominal abscesses.
	53	49 ,,	F	x	Ovarian cancer with liver metastases.
	54	49 ,,	F	x	Tuberculosis of the lungs and respiratory and circulatory failure.
	55	50 ,,	F	x	Cancer of the choledochus, cholangitis.

	56	50 years	M	x	Uremia. Chronic pyelonephritis.
	57	50 „	M	x	Chronic glomerulonephritis with uremia.
	58	50 „	F	x	Cancer of the choledochus with cholangitis.
51—60	59	52 „	F		Cerebral haemorrhage.
	60	52 „	M	x	Cancer of the lungs and broncho-pneumonia.
	61	52 „	M	x	Pulmonary embolism.
	62	52 „	M	x	Prostate cancer.
	63	53 „	F	x	Malignant renal tumour and broncho-pneumonia.
	64	53 „	M		Cerebral contusion.
	65	53 „	M	x	Broncho-pneumonia.
	66	53 „	F		Cancer of the rectum and metastases of the lungs.
	67	53 „	F		Encephalomalacia and broncho-pneumonia.
	68	54 „	M	x	Cerebral tumour.
	69	54 „	F	x	Chronic pyelonephritis and uremia.
	70	55 „	F	x	Pleuropneumonia.
	71	55 „	M	x	Broncho-pneumonia.
	72	55 „	F	x	Tuberculosis of the lungs and cachexia.
	73	56 „	F	x	Cancer of the right breast.
	74	56 „	M	x	Uremia.
	75	56 „	F	x	Subarachnoid haemorrhage.
	76	57 „	M	x	Myocardial infarction.
	77	57 „	F	x	Gastric cancer.
	78	57 „	F	x	Cerebral tumour and pyelonephritis.
	79	57 „	F	x	Cerebral tumour.
	80	58 „	F	x	Cancer of the lungs.
	81	60 „	F	x	Cardiac failure. Thrombosis in superior mesentary artery with infarction of intestine.
61—70	82	61 „	M	x	Acute leukaemia.
	83	61 „	F	x	Uremia.
	84	62 „	F	x	Pancreatic cancer. Hepatic cirrhosis.
	85	62 „	M	x	Pulmonary cancer. Congestion of the lungs.
	86	63 „	M	x	Operated cancer of stomach.

Age group	Case number	Age	Sex	X-ray	Cause of death
	87	63 years	F	x	Operated cancer of the breast. Abscess of the lungs and broncho-pneumonia.
	88	63 ,,	M	x	Embolism of the pulmonary artery.
	89	63 ,,	M	x	Cardiac failure.
	90	64 ,,	M	x	Respiratory failure with cardiac failure.
	91	64 ,,	F	x	Aneurysm of the right medial cerebral artery.
	92	64 ,,	M	x	Pancreatic cancer.
	93	64 ,,	F	x	Malacia of cerebrum.
	94	65 ,,	M	x	Myocardial infarction.
	95	65 ,,	M	x	Information missing.
	96	66 ,,	F	x	Periarteriitis nodosa and subacute nephritis. Pancreatitis. Broncho-pneumonia.
	97	66 ,,	F	x	Cardiac failure.
	98	66 ,,	M	x	Cirrhosis of the liver with oesophageal varices and gastro-intestinal haemorrhage.
	99	67 ,,	F	x	Cancer of the breast. Embolus of the pulmonary artery.
	100	67 ,,	F	x	Myocardial infarction.
	101	68 ,,	F	x	Myocardial infarction.
	102	68 ,,	M		Cerebral haemorrhage and broncho-pneumonia.
	103	68 ,,	M	x	Arthritis urica with nephropathia.
	104	70 ,,	F	x	Cancer of the pancreatic head.
71—80	105	71 ,,	F	x	Uremia.
	106	72 ,,	M	x	Pulmonary embolism.
	107	76 ,,	F	x	Myocardial infarction.
	108	76 ,,	F	x	Circulatory failure.
	109	77 ,,	M		Cancer of the prostate and liver with jaundice.
81—	110	84 ,,	F	x	Cardioarteriosclerosis and cystopyelonephritis.
	111	96 ,,	F	x	Cardiac rupture.

Anatomico-radiological studies

At post-mortem examination cervical spines were removed from the first cervical to the first thoracic vertebra. The specimens were then X-rayed in the A.P., lateral and oblique projections.

With a band-saw a thin sagittal slab, approximately 4 mm. thick, was cut from the midline of the specimens (Fig. 3:1). This section was planned to allow study of the subchondral bone, the cartilage end-plates, the anterior and posterior annulus fibrosus and longitudinal ligaments and the nucleus pulposus at each disc level.

From one of the remaining lateral segments a new 4 mm. thick slab was sawed off along a plane perpendicular to the neural foramina, including these foramina and the intervertebral joints in the slab (Fig. 3:2). The apophysial joints, the neural foramina and nerve roots, the unco-vertebral processes and postero-lateral aspect of the intervertebral discs and vertebrae were then available for study on one same section.

The remaining lateral segment was sectioned horizontally at the level of each intervertebral disc and slabs 4 mm. thick were removed (Fig. 3:3). These blocks presented the nerve roots and ganglia, the apophysial joints, the unco-vertebral processes, the lateral aspect of the intervertebral disc and the vertebral arteries. In a small number of specimens a slab cut along the frontal plane was obtained (Fig. 3:4).

Contact X-rays on Kodak type R industrial film and colour and black and white photographs were made of each one of the sections described.

The specimens were then divided in small blocks including each an intervertebral disc and neighbouring structures and fixed in 10% formaldehyde and decalcified in Parenghi's solution or 10 % nitric acid.

Following decalcification the blocks were embedded in paraffin and sectioned for histological study. Hematoxilyn-Eosin and PAS stains were used on the histological sections.

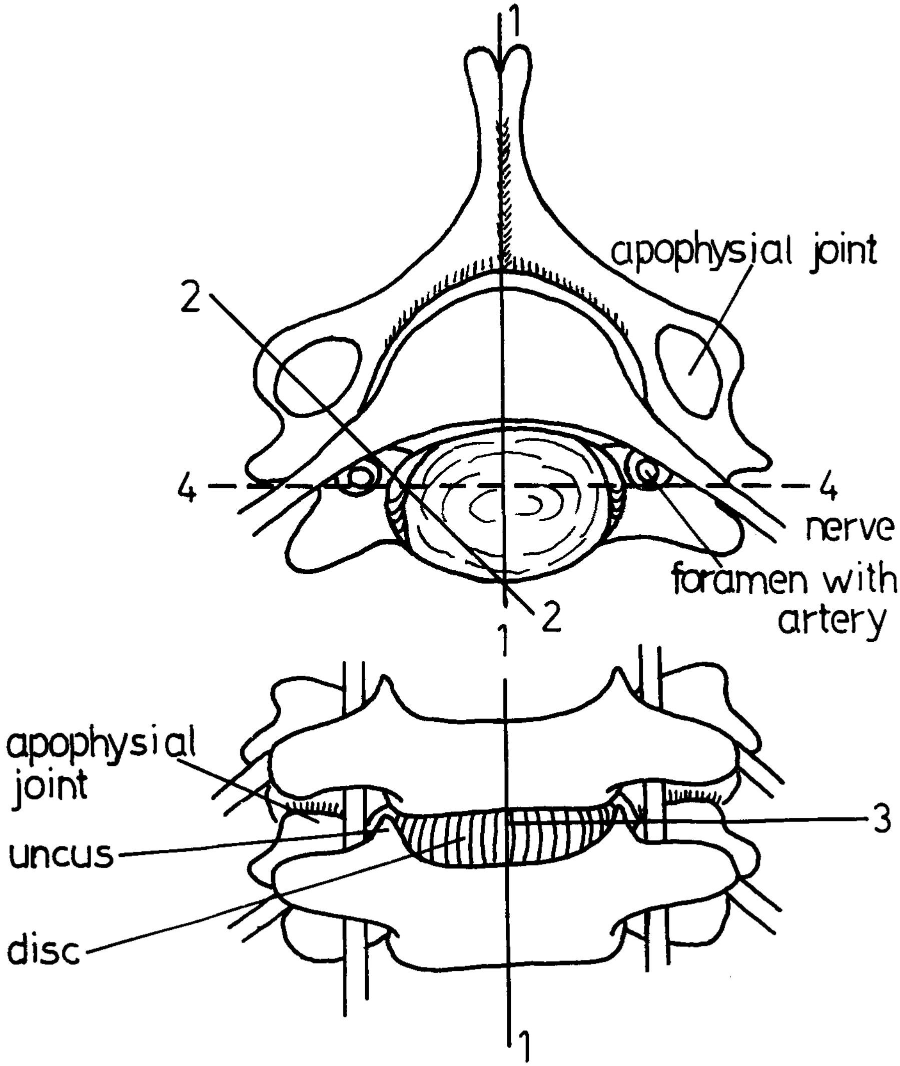


Fig. 3 Drawing illustrating how the specimens were cut.

Discograms

Following removal from the body, in 10 spines, discograms were performed. Each intervertebral disc was punctured anterolaterally with a fine needle (same caliber as the one used in clinical discography) and 0.2 cc. of contrast U (perabrodil) injected slowly into the disc space. X-rays were then taken in the A.P., lateral and oblique projections. The specimens were then processed in the manner previously described.

Vascular perfusion studies

In 10 spines perfusion studies of the arterial systems were made. Following the post-mortem examination both vertebral arteries were catheterized in the neck and ligated at the base of the skull.

Perfusion through one of the catheterized arteries was performed with either one of two solutions: a 30% suspension of Micropaque (finely divided barium sulphate) with 4% Berlin Blue, or a solution of 5% Berlin Blue. Some specimens could not be perfused in situ and the same procedure was performed on the isolated cervical spine with its surrounding soft tissues immediately after removal. No measurements of injection pressures were made.

The spines were then X-rayed, fixed in 10% formaldehyde and decalcified in 10% nitric acid.

Following decalcification the specimens were sectioned in slabs along the lines previously described. Colour and black and white photographs of each slab were made and contact roentgenograms taken of the specimens injected with the barium suspension.

The slabs were then cut in blocks including each a disc and related structures. Each block was divided in two halves. One half was processed for histological study, was embedded in paraffin, sectioned and stained with Hematoxylin-Eosin and PAS. The other half was sectioned in a freezing microtome. The sections were then processed according to the method of Spalteholz to clear the tissues and observe the vascular tree.

The Formation of Discs and Vertebral Bodies

At the time of birth the ossified central part of the vertebral body has an ovoid shape and its height is less than the cartilage part of the body including the disc. The cartilage end-plate is distinguishable and the nucleus pulposus and annulus fibrosus can be differentiated as separate structures (Fig. 4). It is possible to see that the nucleus pulposus is slightly displaced posteriorly. This is clearly seen in one of the specimens of 14 months (Fig. 5) where an evident difference between the ventral and dorsal part of the annulus fibrosus exists. The annulus is thicker and more compact anteriorly similar to the conditions of the lumbar disc. Even the laminar structure of the cervical annulus fibrosus has the same pattern as in the lumbar spine described previously by Hirsch and Schajowicz (1952). The vascularization of the ossified vertebrae is very abundant but there are no vessels penetrating into the annulus fibrosus and nucleus pulposus as the histologic and angiographic studies demonstrate (Fig. 6). Vessels penetrate into the cartilage part of the body before a clear differentiation from the cartilage end-plate has taken place. Once it has been formed no vessels penetrate into it until the moment when the calcification of the lateral epiphysial nuclei starts. This was observed in the 14- and 15-year-old specimens (Fig. 7). There is a typical growing zone between cartilage end-plate and subchondral bone with only low columns of hypertrophic and proliferating cartilage cells.

The first ossification holes (Schmorl's "Ossifikation-Lücken") appeared in a 7 year-old specimen increasing their number in the 14 and 15 year-old cases (Fig. 8). At this stage the calcified nuclei of the anterior and posterior marginal crest were already

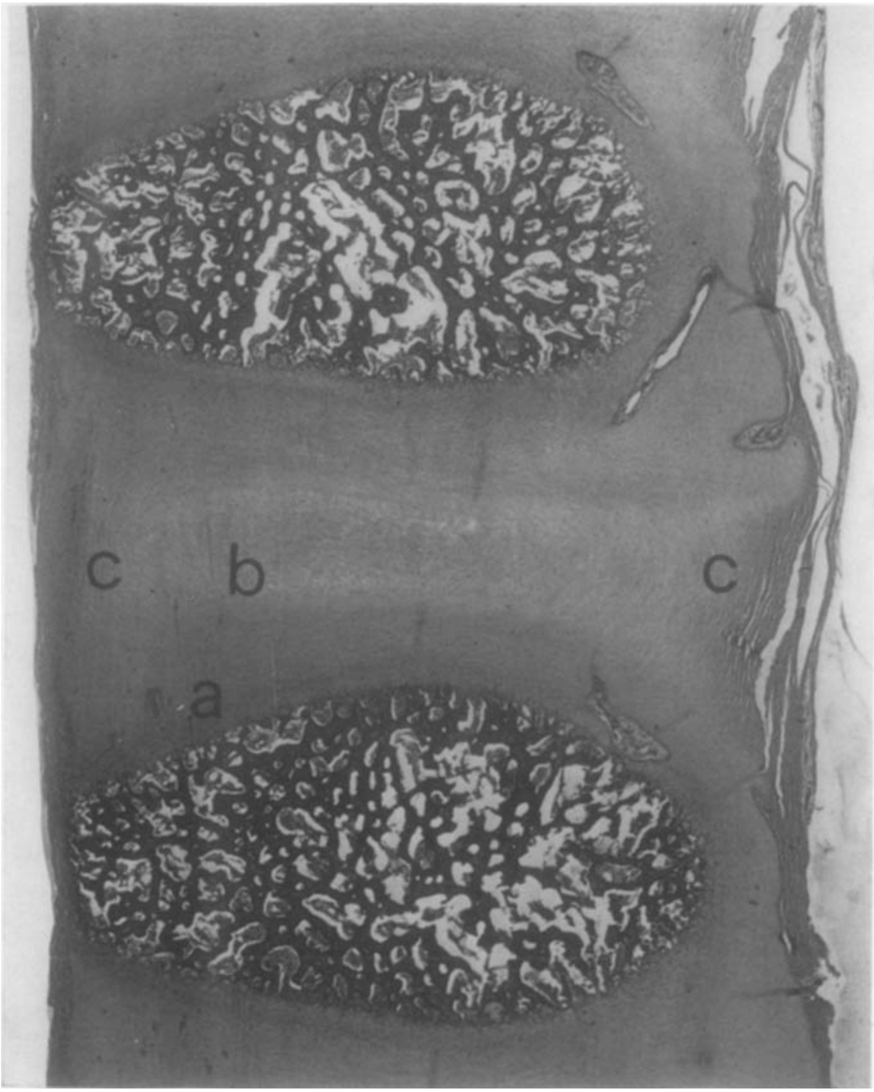


Fig. 4 Case number 5 Four days old infant
Topographic microphotograph of sagittal section of the 4th disc and adjacent bodies.
The different components of the disc can already be identified, a the cartilage end-plate is high, b the nucleus pulposus is located slightly posteriorly and the annulus fibrosus c is thicker anteriorly similar to conditions in the lumbar region (x 7).

Note
In all the pictures to follow the anterior part of the cervical spine or part of it is always to the right.

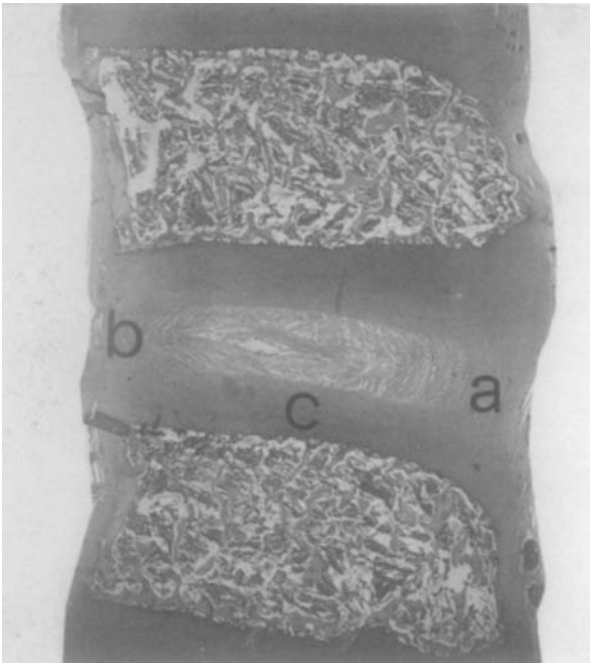
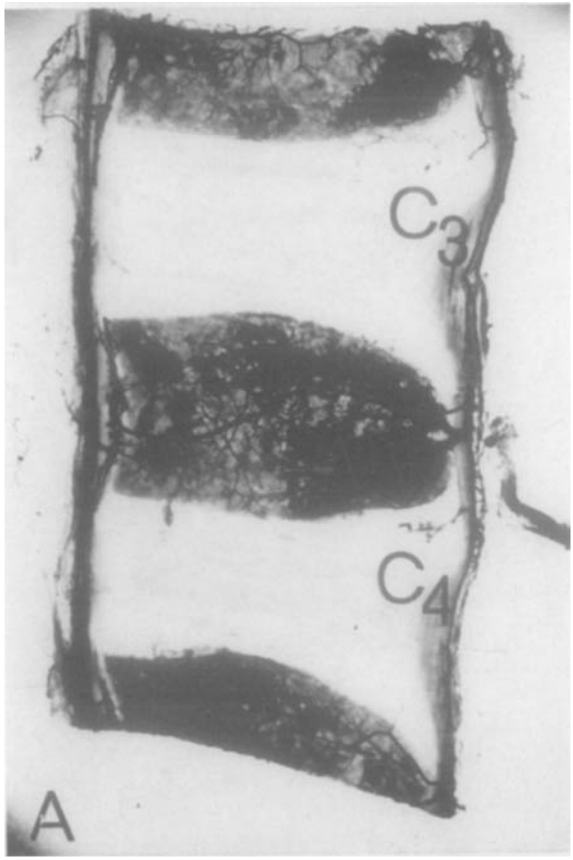
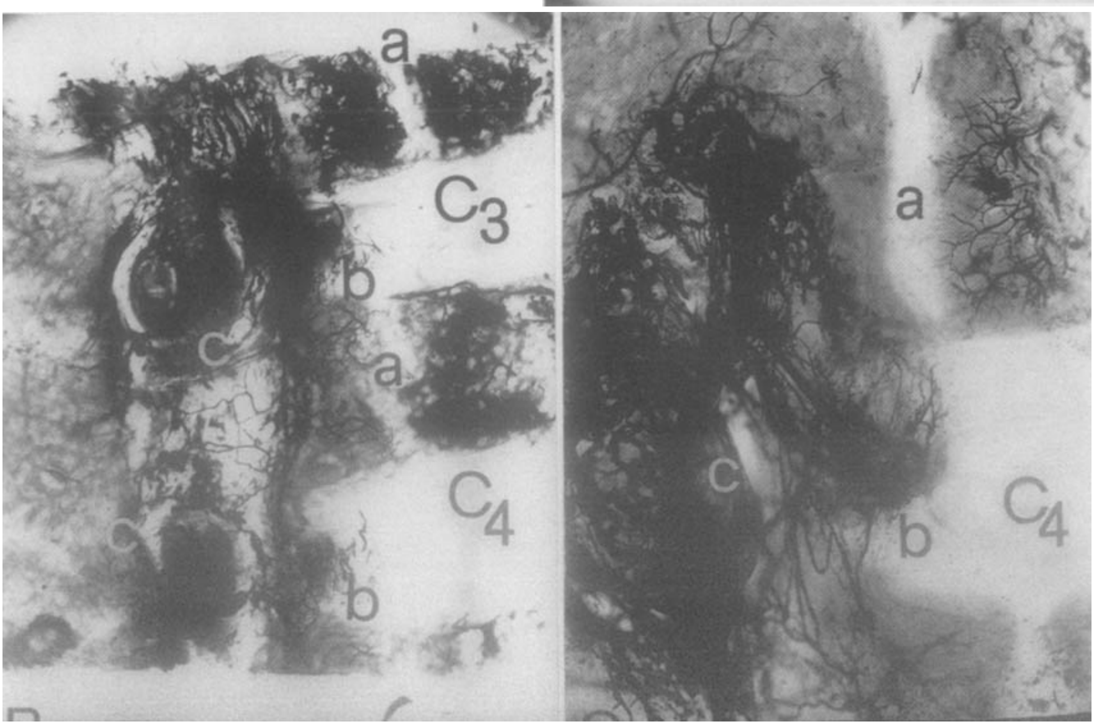


Fig. 5 Case number 8 Fourteen month-old child
Microphotograph of the 6th cervical discs and adjacent vertebrae.
Sagittal section showing clearly the different components of the disc and the greater thickness of the anterior a than the posterior part b of the annulus fibrosus. The cartilage end-plates c are distinguishable from the nucleus pulposus.

formed in several discs. Sometimes the calcification extends irregularly in form of a discontinuous plate anterior and posterior over and in close contact with the ossification holes as has been described in the dorsal and lumbar spine by Schajowicz (1938). This phenomenon is not a sign of degeneration as Ecklin states but a normal condition during growth and calcification of the end-plates. Once the calcified nucleus of the cartilage end-plates starts its ossification at its antero-lateral and posterior borders the marginal crest is formed and the calcified area in the central part of the disc disappears.

Fig. 6 Case number 10 Two-year-old child
Microangiograms of C.III and C.IV and adjacent vertebral bodies (Berlin Blue and Spalteholz method).
A Sagittal section. The vascularization of the osseous vertebrae is visible as well as small vessels penetrating into the cartilaginous portions of the bodies. The nucleus pulposus and annulus fibrosus do not show any vascular connections.
B Oblique section of the postero-lateral portions of C.III and C.IV.
a Intermedial growth cartilage between anterior and posterior parts of the osseous vertebral bodies are lacking vessels as well as the discs except the posterior indentations where numerous vessels b are approaching the disc from the foramen c.
C Another section from C.IV-level at higher magnification.





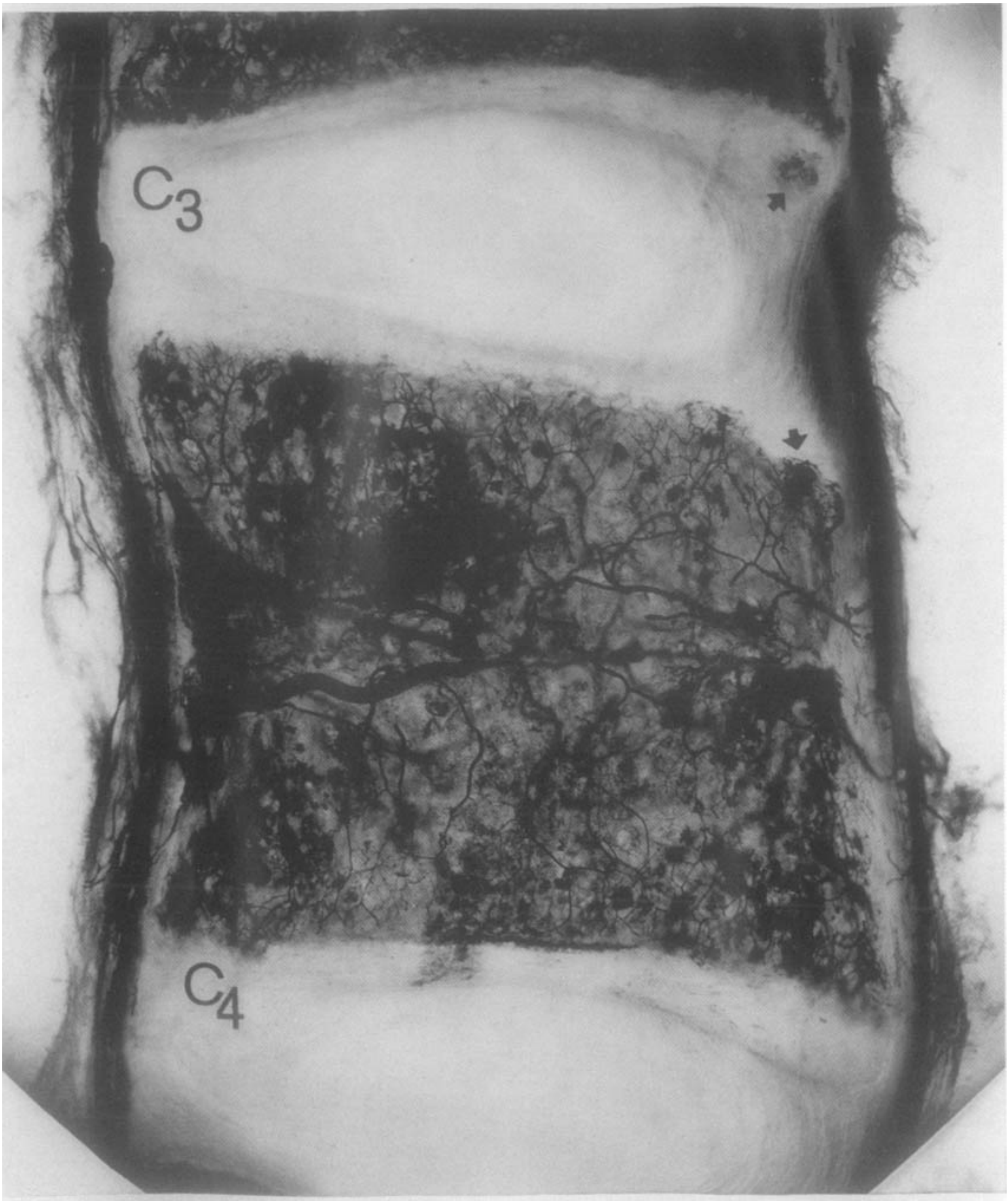


Fig. 7 Case number 17 Age 14
Microangiogram of a sagittal section of C.III and C.IV (Berlin Blue and Spalteholz method).
The vascular pattern of the vertebral body is shown. The cartilaginous end-plates, the nucleus and the annulus are lacking vessels with exception of the anterior edges of the end-plates where the osseous marginal epiphyses are being formed (arrow).

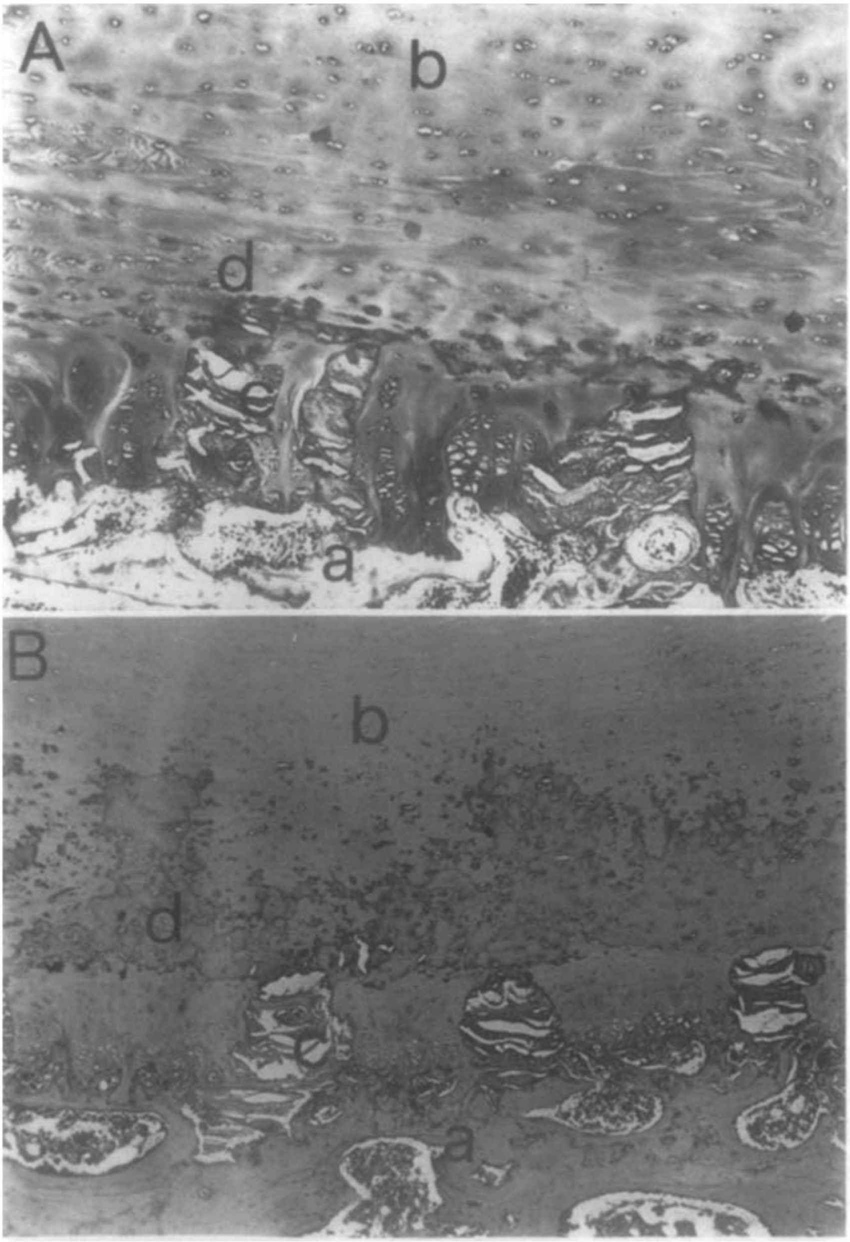


Fig. 8 Case number 16 Age 15
Microphotograph of A: C.VI and B: C.VII illustrating the growth zone between vertebrae a and cartilage end-plate b. The classical "ossification holes" (Schmorl) c are interrupting the growth cartilage. Irregular calcification areas d of different sizes, partly discontinuous, cover the region. This is not a degenerative phenomenon but a normal finding in enchondral ossification in discs.

The Unco-Vertebral Region

At the time of birth a wide zone of growing cartilage is present between the anterior and posterior parts of the ossified vertebral body where the future uncus will be formed which we prefer to call uncus-anlage. Töndury and Ecklin named this area "vertebral arch epiphysial growth cartilage" and Jackson "intermedial growth cartilage". The cartilage end-plate of the vertebral body covers this intermedial growth cartilage and extends up to the inner border of the uncus-anlage. However, the outer line of the annulus does not reach so far and thus at this area a triangular shaped loose vascular connective tissue is formed proceeding from the foramen. It occupies the space left between the cartilage end-plates (Fig. 9 and 10).

At 14 months (Fig. 11) the intermedial growth cartilage has clearly decreased in size and the cartilage end-plates extend up to the posterolateral border of the uncus-anlage while the annulus ends at some distance more ventrally. The same loose vascular connective tissue containing some thicker vertical collagen bundles, fills the space between the thinned postero-lateral portions of the cartilage end-plates reaching the uncus border. The angiograms of the 2 year-old specimen (Fig. 6) illustrate the great number of vessels at this zone between the disc and the paravertebral tissues from the foramen. In this age group no fissure of joint-like space formation was found.

At age seven (Fig. 12) the intermedial growth cartilage has disappeared and both portions of the vertebral body are fused. The uncus which is already formed and slightly elevated is covered up to its postero-lateral border by the cartilage end-plate like the lower surface of the above vertebra ("Gegenpol" of

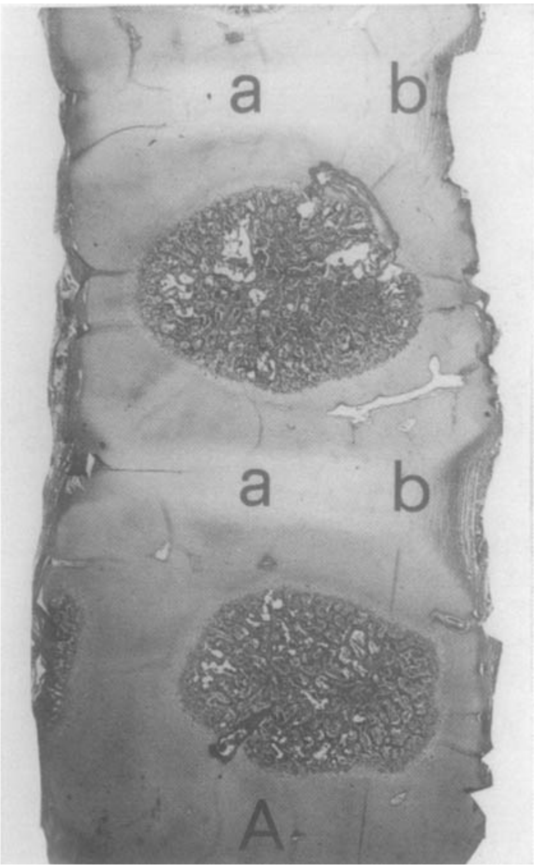


Fig. 9

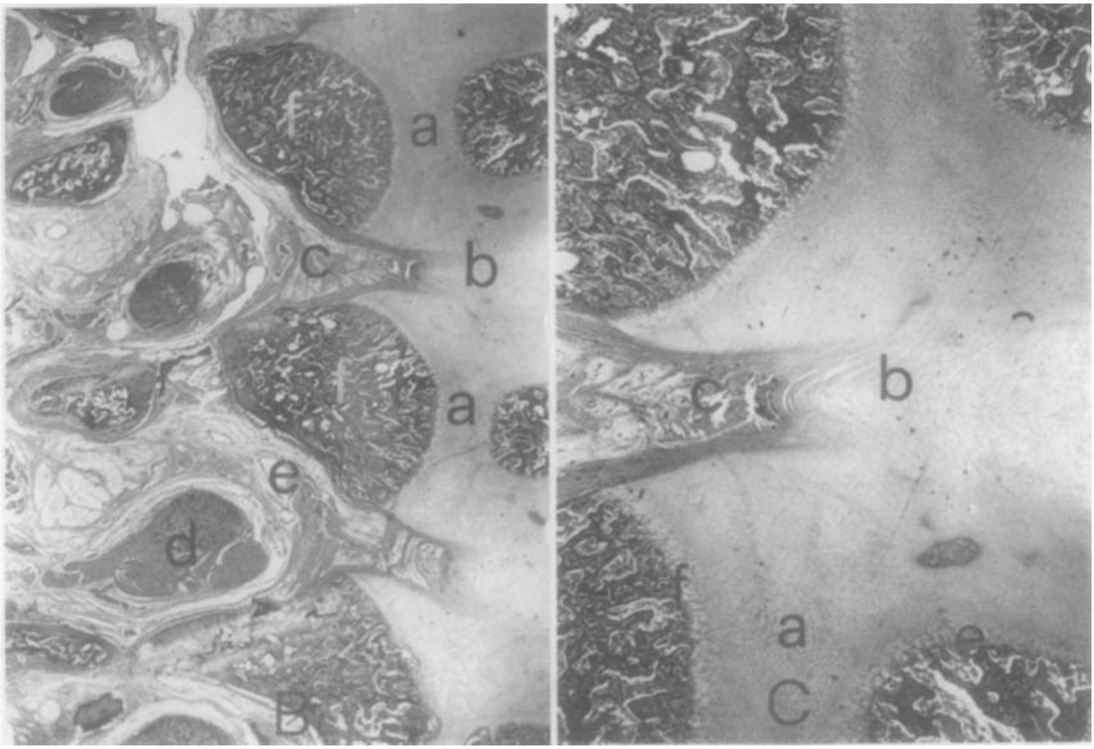


Fig. 9

Fig. 9 Case number 1 One day old baby
A and B Topographic microphotographs.
A Sagittal section of the 5th and 6th cervical discs and adjacent vertebral bodies. In the disc area different structures can be observed corresponding to the nucleus a and annulus b. A great part of the vertebra is cartilaginous. The vessels penetrate ventrally and dorsally only through the cartilaginous vertebral bodies into the ossified centres but not into the nucleus and annulus. (x 8)
B Oblique section of the 5th and 6th discs and adjacent bodies in the postero-lateral region. a represents the growth cartilage area between the anterior and posterior portion of the uncus-anlage f of the vertebral body. This is called Wirbelbogenepiphyse by Töndury and intermedial cartilage by Jackson.
At this stage the disc b does not reach the posterior area of the vertebral body. The uncus-anlage f is in contact with loose vascular connective tissue c penetrating from the vertebral foramen where nerve d and vascular elements e can be seen. (x 8)
C Area of the 5th disc b at higher magnification illustrating the relationship between intermedial growth cartilage a and the loose connective tissue c from the intervertebral foramen. e and f are the anterior and posterior portions of the osseous vertebral body. (x 22,5)

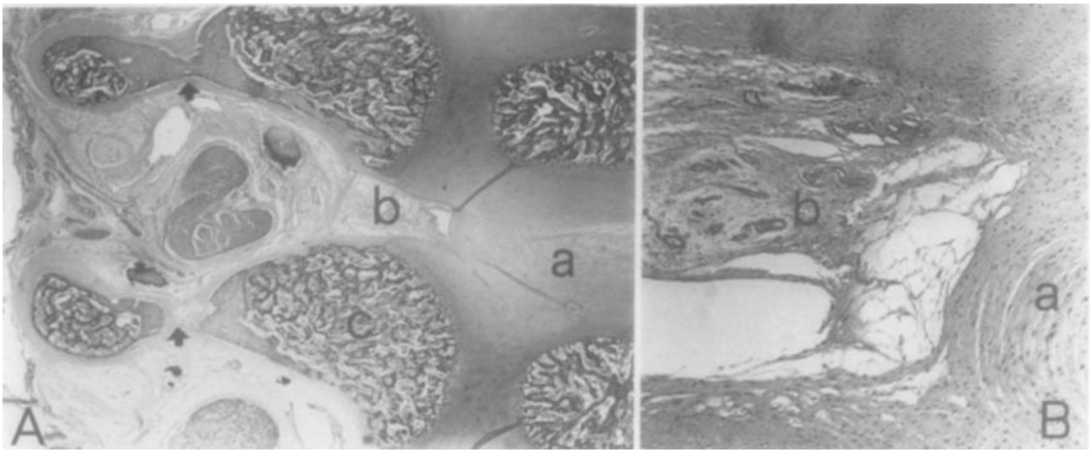


Fig. 10 Case number 5 Four-days-old infant
A and B Microphotographs of oblique sections of the 4th disc. The relationship of the various components of the foramen and the vertebral body are illustrated. The arrow points at the vertebral arch. The border zone of the disc a and the loose vascular connective tissue b proceeding from the foramen is shown at lower (x 9) and higher (x 90) magnification. c uncus-anlage.

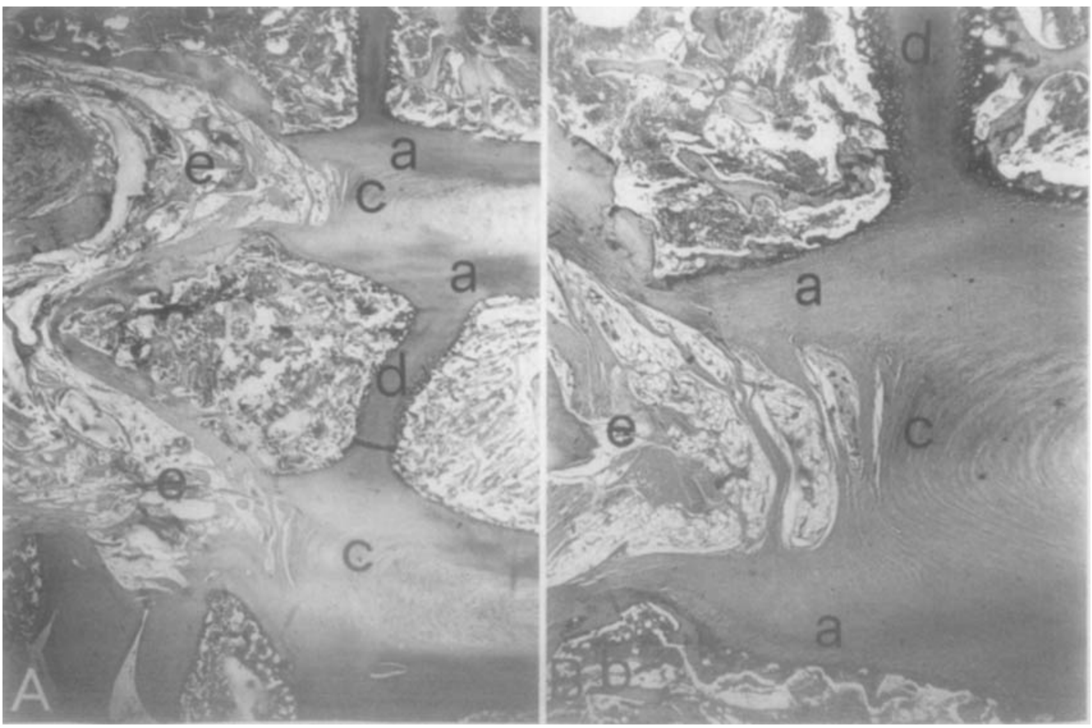


Fig. 11 Case number 8 Fourteen month-old child
A and B Oblique sections of the postero-lateral part of the discs. The cartilaginous end-plates a extend over the uncus-anlage b while the annulus fibrosus c ends a short distance before. d intermedial growth cartilage which has decreased in size. The connective tissue e reaching the annulus c is located between

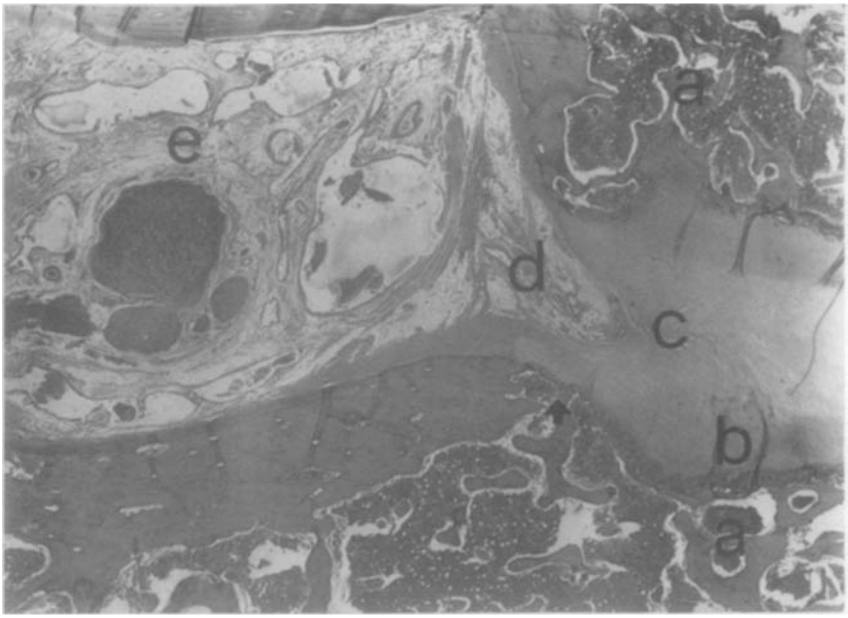


Fig 12 Case number 11 7-year-old child
Microphotograph of the postero-lateral area of the 3rd disc. The bony parts of the vertebra are fused a. The uncus (arrow) is formed and has a ridge which is covered by the cartilage end-plate b. The same is seen at the vertebra above. These borders are not reached by the annulus c, because of an indentation containing the same vascular connective tissue d as described in the younger age groups. e intervertebral foramen with ganglion, nerve roots, numerous veins and small arteries. Where the annulus is in contact with the connective vascular tissue small fissures are seen in the annulus (x 9,5).

Töndury, "Echancrure" of French authors). These borders are not reached by the annulus because the triangular indentation still persists containing the same loose vascular connective tissue as described in younger age groups. Where this area is in contact with the annulus, fibrillation and small fissures have been observed in the annulus extending slightly centrally. Already at age seven a slight to moderate increase of basophilia could be noticed at the borders of some fissures but no evident alterations or proliferation of the surrounding cells could be demonstrated.

In the 14, 15 and 18 year-old cases the fissures and cracks became more frequent, increased in size and width extending towards the nucleus. These fissures were seen not only in the upper but also in several lower discs (Fig. 13 and 14). At this stage the cartilage end-plates as well as the annulus reach the border of the uncus and its opposite pole. However, the vascular connective tissue penetrating from the foramen into the disc is no longer quite of normal histological nature. The annulus surrounding the fissures and clefts which are occasionally wide, forms a real cavity simulating a joint. The annulus shows evident degenerative alterations with increase of basophilia of the fibers and metaplasia. The cells become rounded, increase in size, being more recognizable as chondrocytes as they often have capsules or are multiplied forming clones. In this manner a true joint space may be simulated but the alterations described are evidently secondary to the fissures. A real synovial membrane has not been observed.

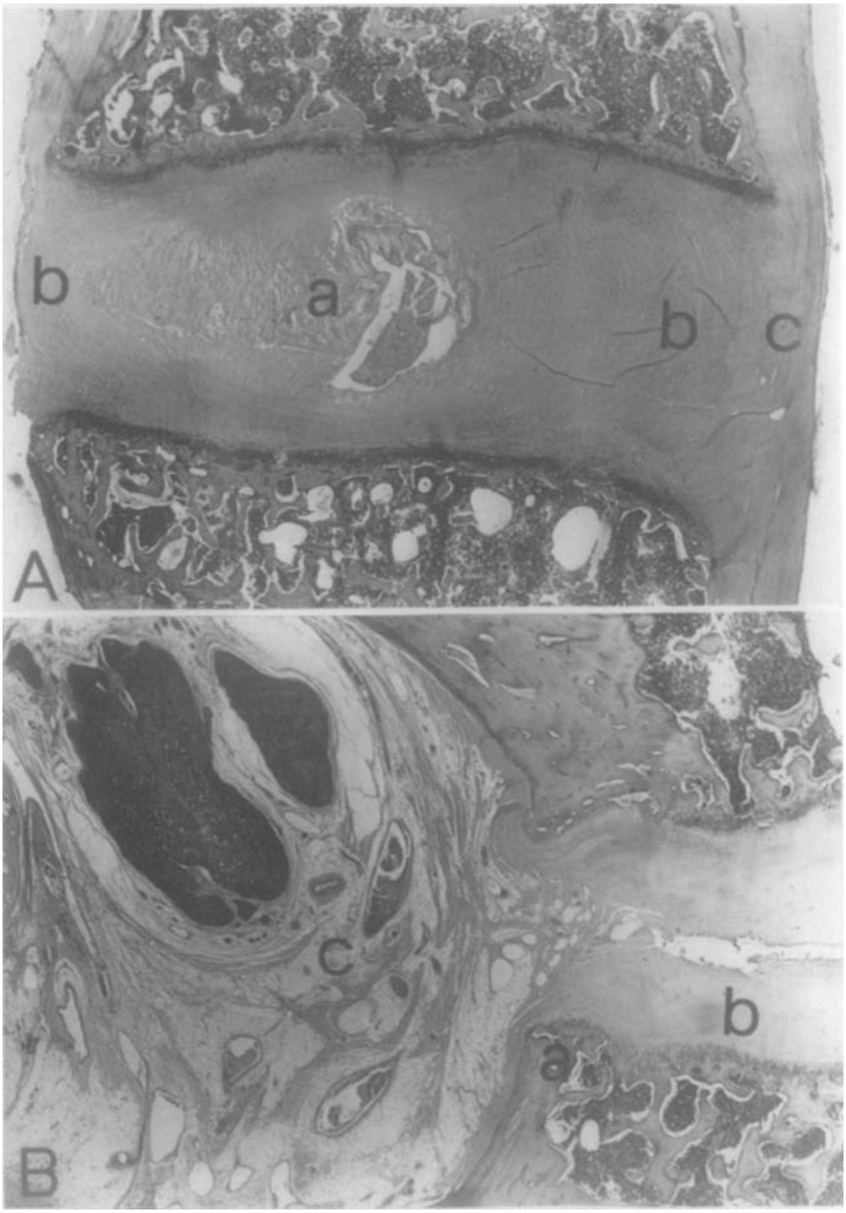
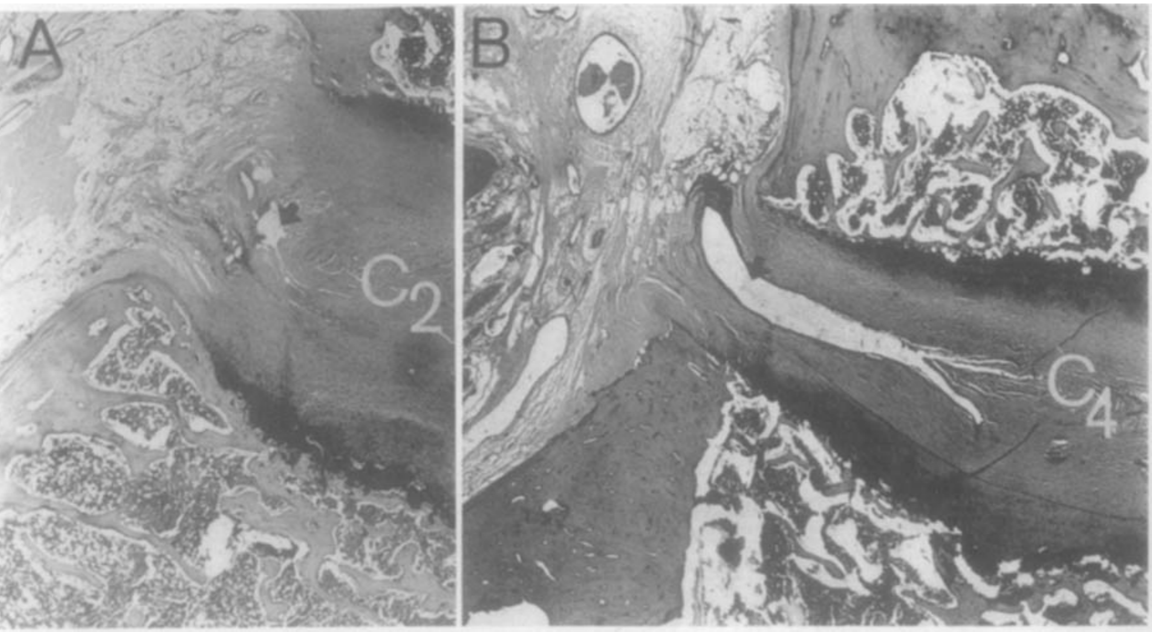


Fig. 13 Case number 15 Age 14
A Microphotographs of sagittal section of C.VI. The nucleus pulposus a is lying more dorsally. The annulus fibrosus b is much thicker and denser ventrally. The anterior longitudinal ligament c is firmly attached to the annulus.
B Oblique section of C.III. a uncus, b disc, c foramen. A large horizontal fissure is reaching the posterior border of the disc and is in contact with the foramen.



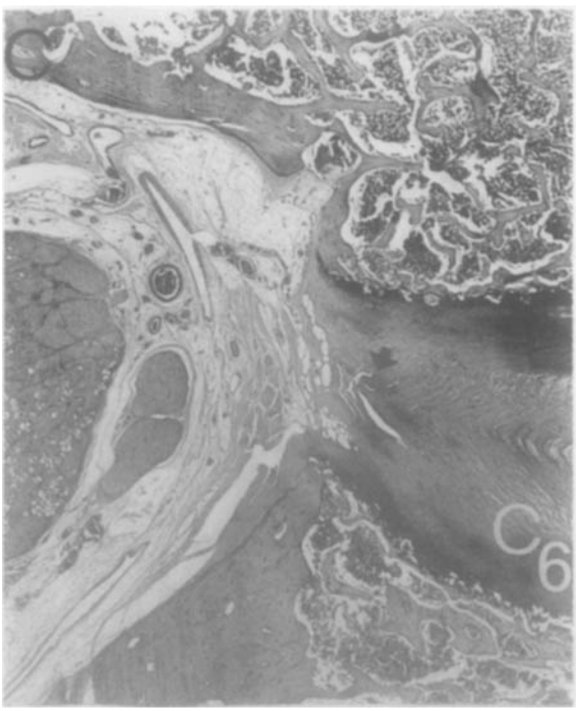


Fig. 14 Case number 16 Age 15
Microphotographs of oblique sections of the unco-vertebral region of A:C.II, B:C.IV and C:C.VI illustrating transverse fissures in the postero-lateral part of the annulus of different size and shape, in B simulating a joint space ("Luschka joint") — see area marked by arrows.

In the younger age groups no evidence of hypervascularization or vascular connective tissue reaction was found. This reaction appeared first at age 24 and became more evident later in life. In one case, age 35, many blood vessels, mainly dilatated and hyperaemic capillaries, located in a more or less loose connective tissue could be seen, advancing from the foraminal tissue towards the fissured degenerated disc. Similar reactions are common when radial posterior fissures and clefts appear extending as they quite often do from the nucleus pulposus to the posterior ligament (Fig. 15, 16 and 17). This hypervascularized connective tissue in the posterior ligament reaching the radial fissures, is more frequently found after age 40 but was only present in about 20% of this material (Fig. 18, 19 and 20). The same vascular reaction was found in the lumbar discs and described by Hirsch and Schajowicz (1952). However, in the early forties and not infrequently even earlier, advanced degenerative changes may appear, mainly mucoid degeneration, necrobiosis or necrosis, slight calcification accompanied by proliferative processes, such as hypertrophy and proliferation of cartilage cells especially around clefts and cracks of the nucleus.

In the older age groups these clefts advance often ventrally and are commonly located near the lower marginal crest towards the anterior longitudinal ligament (Fig. 21). However, most frequently the extension of the fissures is found dorsally communicating with large fissures dorso-laterally in the uncovertebral region (Fig. 22 and 23).

After the fourth decade the cartilage end-plates frequently show degenerative changes of predominantly mucoid degenera-

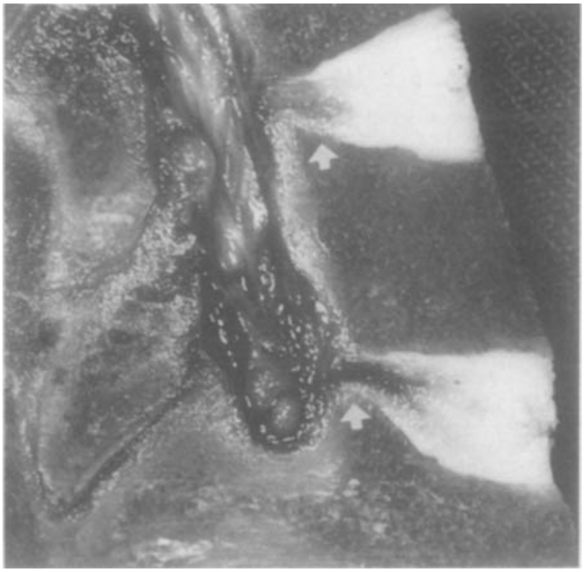


Fig. 15 Case number 23 Age 24
Photograph of oblique section from C.IV and C.V discs showing fissures in the posterior parts in the uncus area (arrow) penetrating into the central part of the disc.

tion, circumscribed areas of increased basophilia, small horizontal or oblique clefts and cartilage cell hypertrophy and proliferation. Although these degenerative changes are present in all discs, it is evident that the severe changes occur most frequently at C.IV to C.VI levels (Fig. 24 and 25).

Fig. 16 Case number 29 Age 35
A and B radiographs in AP and lateral sections of the specimen.

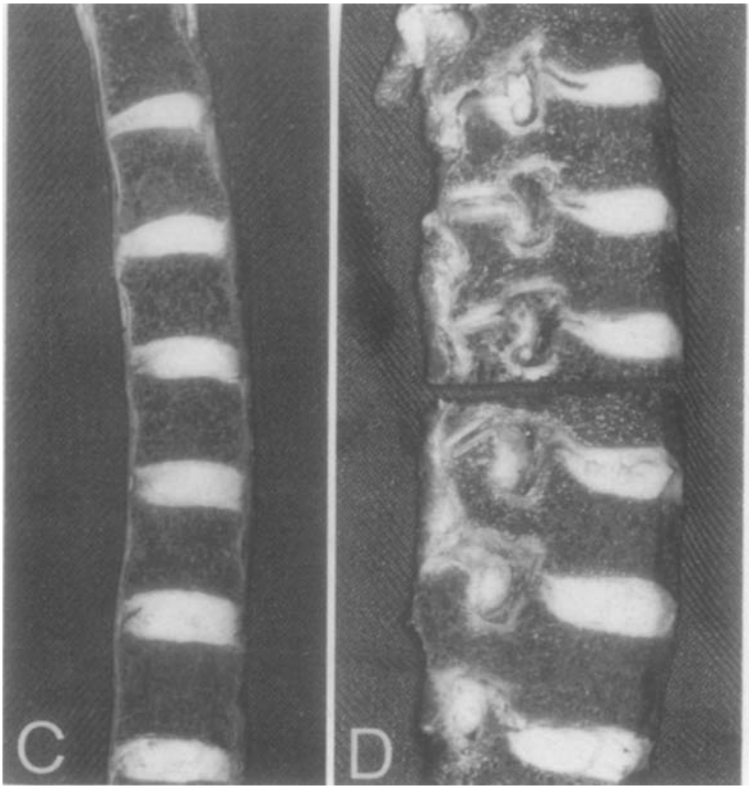


Fig. 16
C and D are photographs of sagittal and oblique sections of the specimen. In D deep fissures of different magnitude are seen in the unco-vertebral region of the upper four discs.

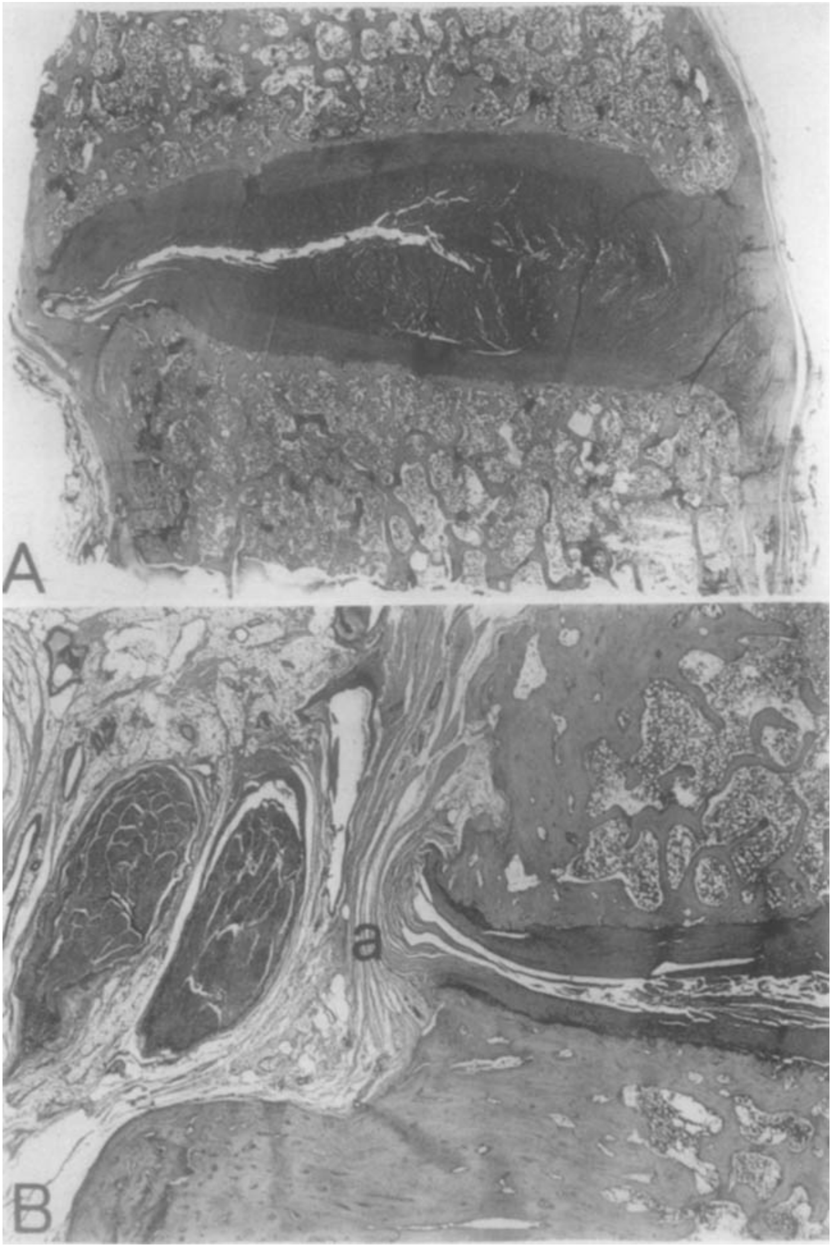
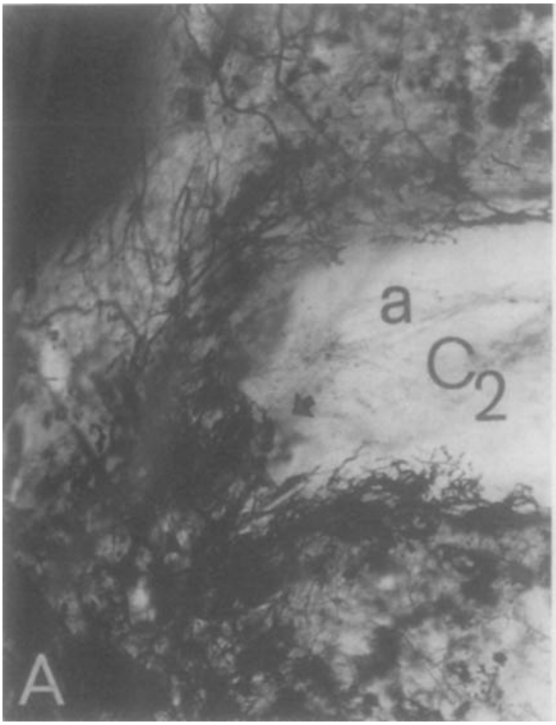
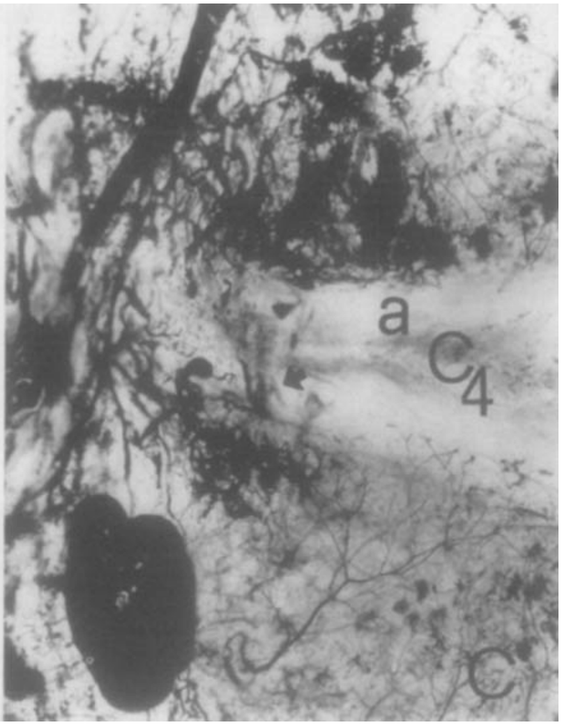


Fig. 17 Case number 33 Age 36
A Microphotograph of a sagittal section of C.IV showing a large horizontal fissure extending from the nucleus posteriorly reaching the posterior longitudinal ligament.
B Oblique section of the disc showing the fissure in the unco-vertebral area. The fissure enters into the foraminal space and is surrounded by a dense fibrous tissue simulating an articular capsule, a (x 9,5).





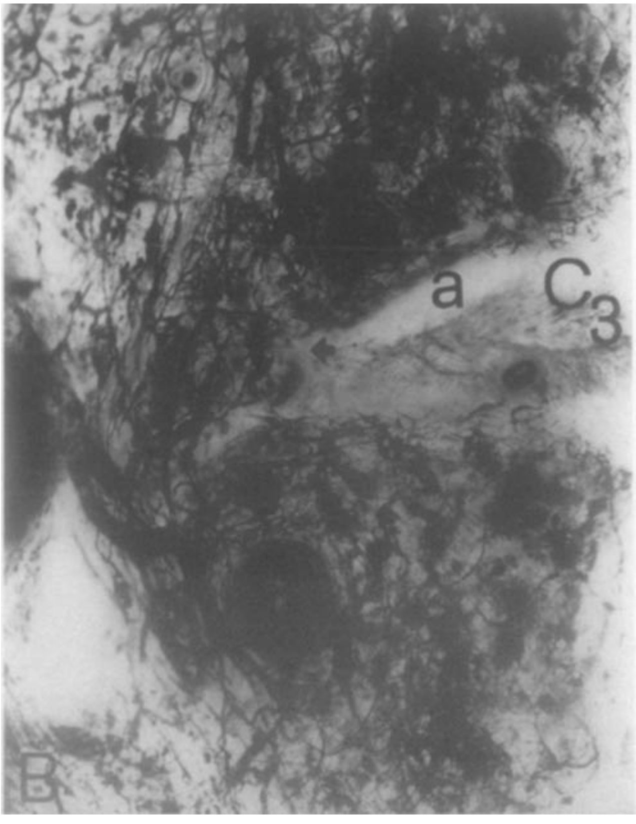


Fig. 18 Case number 44 Age 44
Microangiograms of A:C.II, B:C.III and C:C.IV (Berlin Blue and Spalteholz method). Oblique sections showing the uncus area and degenerated discs a. Numerous vessels from the foramen are advancing towards the discs (arrow).

Fig. 19

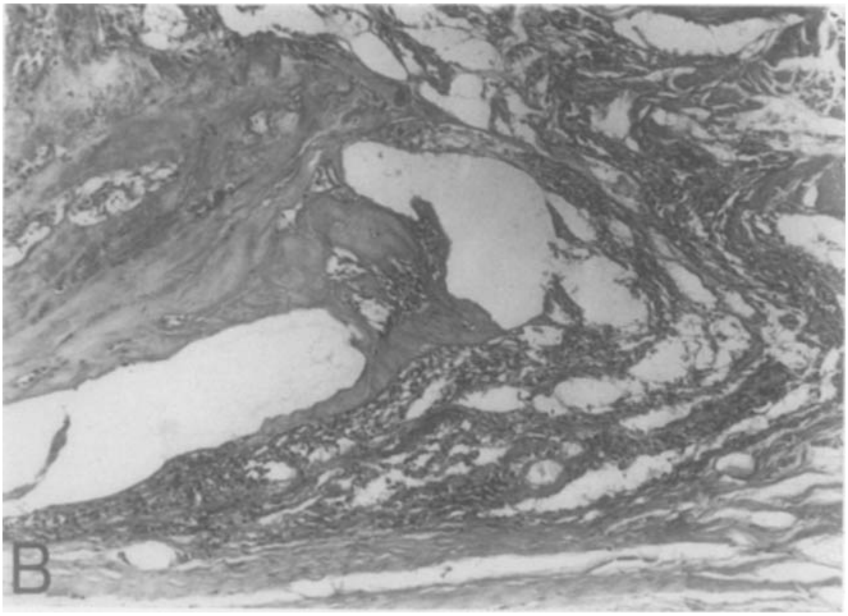


Fig. 19 Case number 45 Age 47
Microphotographs at lower A (x 9,5) and higher B (x 115) magnification of C.III illustrating changes accompanying extensive fissures and cavities in the postero-lateral portion of the disc. a beginning osteophyte formation. b and c vascular connective tissue coming from the intervertebral foramen d approaching the disc fissures.
B Zone c from Fig. A at higher magnification showing the pronounced vascularization and hyperaemia.

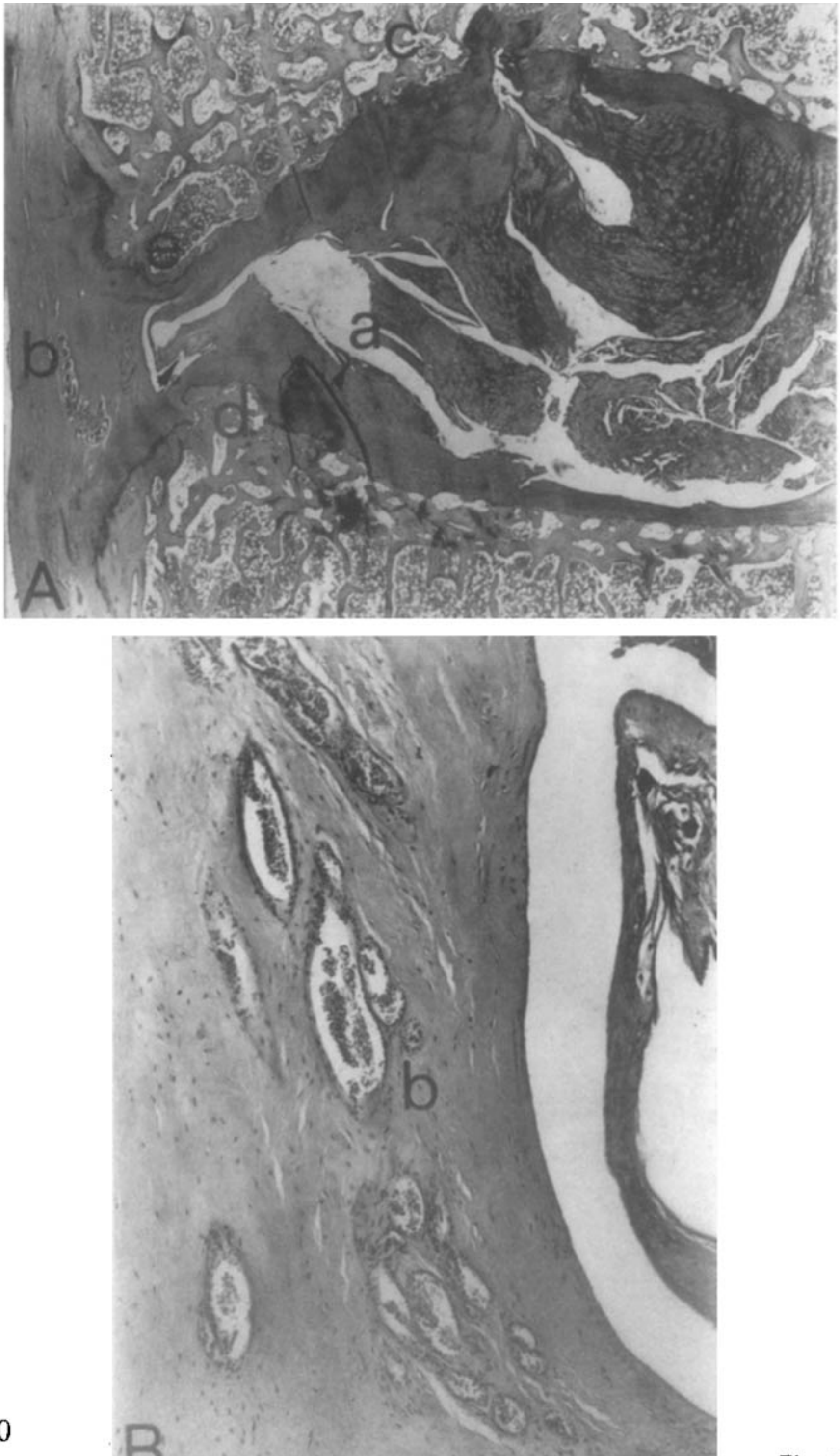


Fig. 20.

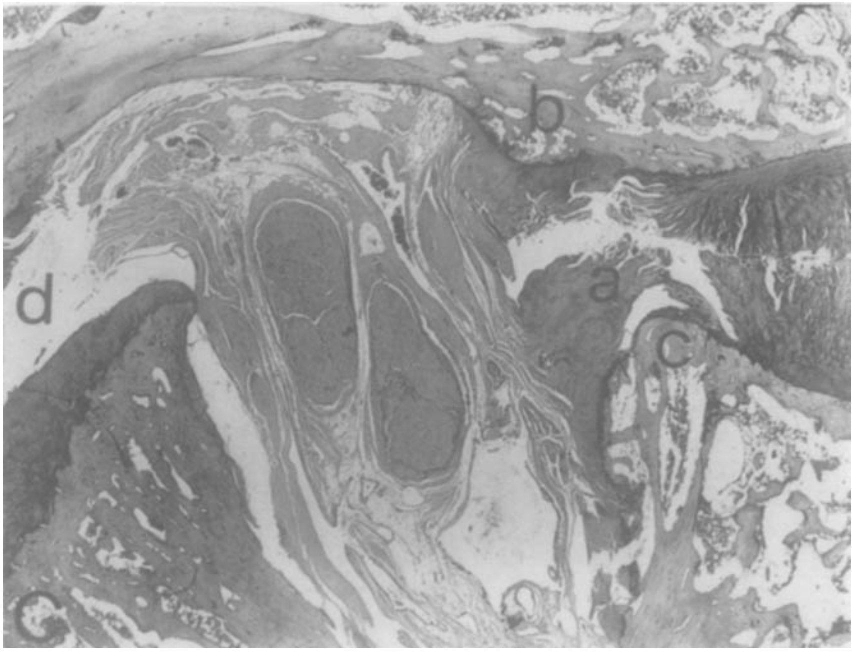


Fig. 20 Case number 56 Age 50
Microphotograph of sagittal section of C.V at lower A (x 9,5) and higher B (x 120) magnification. The pictures illustrate the posterior parts of the disc. The disc is extensively degenerated. a numerous fissures reaching the posterior longitudinal ligament b. Newly formed capillary vessels are penetrating towards the degenerated disc. The border between the disc and subchondral bone is completely irregular and the end-plate is interrupted at c. d and e osteophyte formation at the posterior ridges of the vertebrae.
B Higher magnification of area b. Capillary vessels approaching the degenerated disc.
C Oblique section showing identical severe degenerative lesions of the disc a and the secondary alteration of the subchondral bone and osteophyte b and c. The apophyseal joint d shows only moderate arthritic changes.

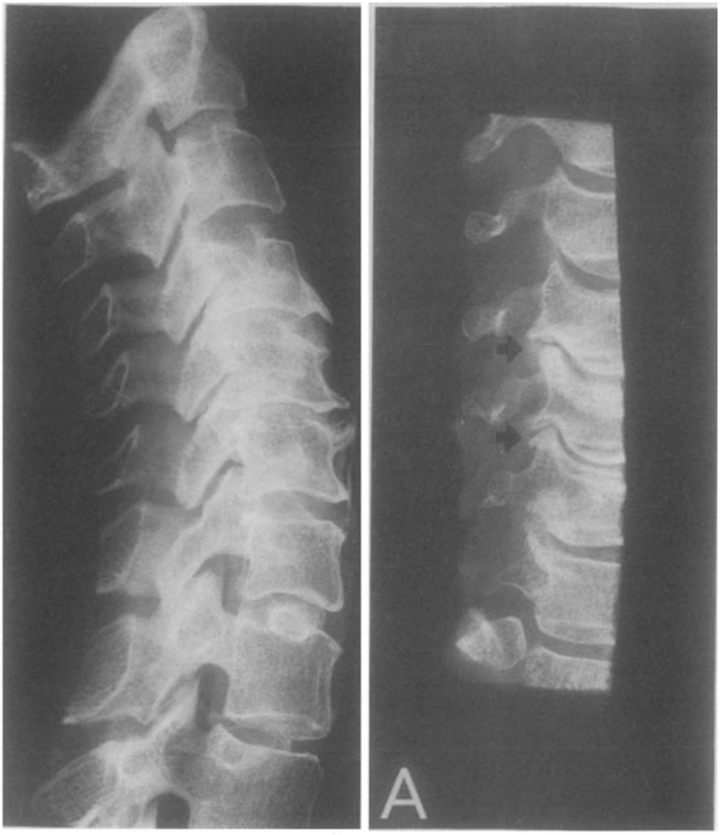
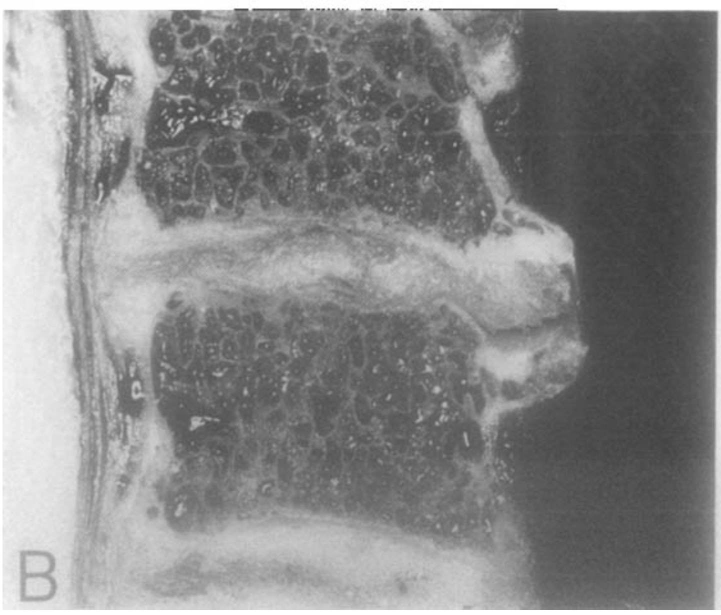


Fig. 21



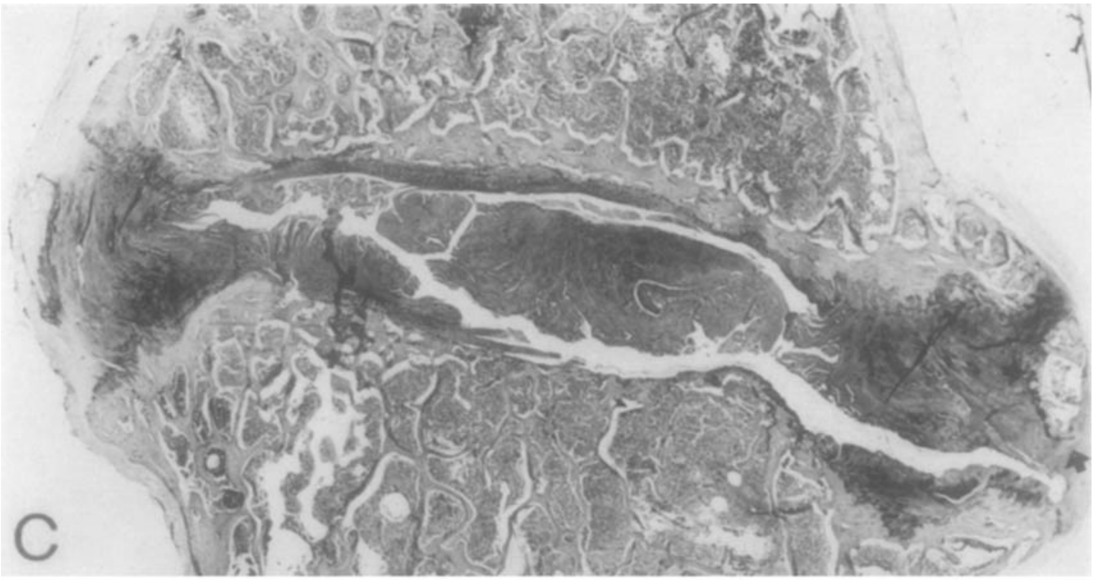


Fig. 21 Case number 63 Age 53

A Lateral and oblique radiographs. The C.IV and C.V discs are degenerated with pronounced osteophytic reactions anterior and postero-lateral in the unco-vertebral areas (arrow).

B Photograph of sagittal section of the C.V disc showing the advanced degenerative changes in the disc and the big osteophytes ventrally.

C Microphotograph illustrating the destructive changes of the disc, the irregularity of the osteocartilage border, the massive formation of osteophytes, specially ventrally where intraligamentous ossifications are present (arrow).

D Microphotographs of the oblique section of the same disc. a degenerated and narrowed disc surrounded by heavy bony sclerosis b. c osteophyte posteriorly narrowing the space of the intervertebral foramen d. In spite of the advanced disc changes the apophyseal joint shows only moderate arthritic lesions e.

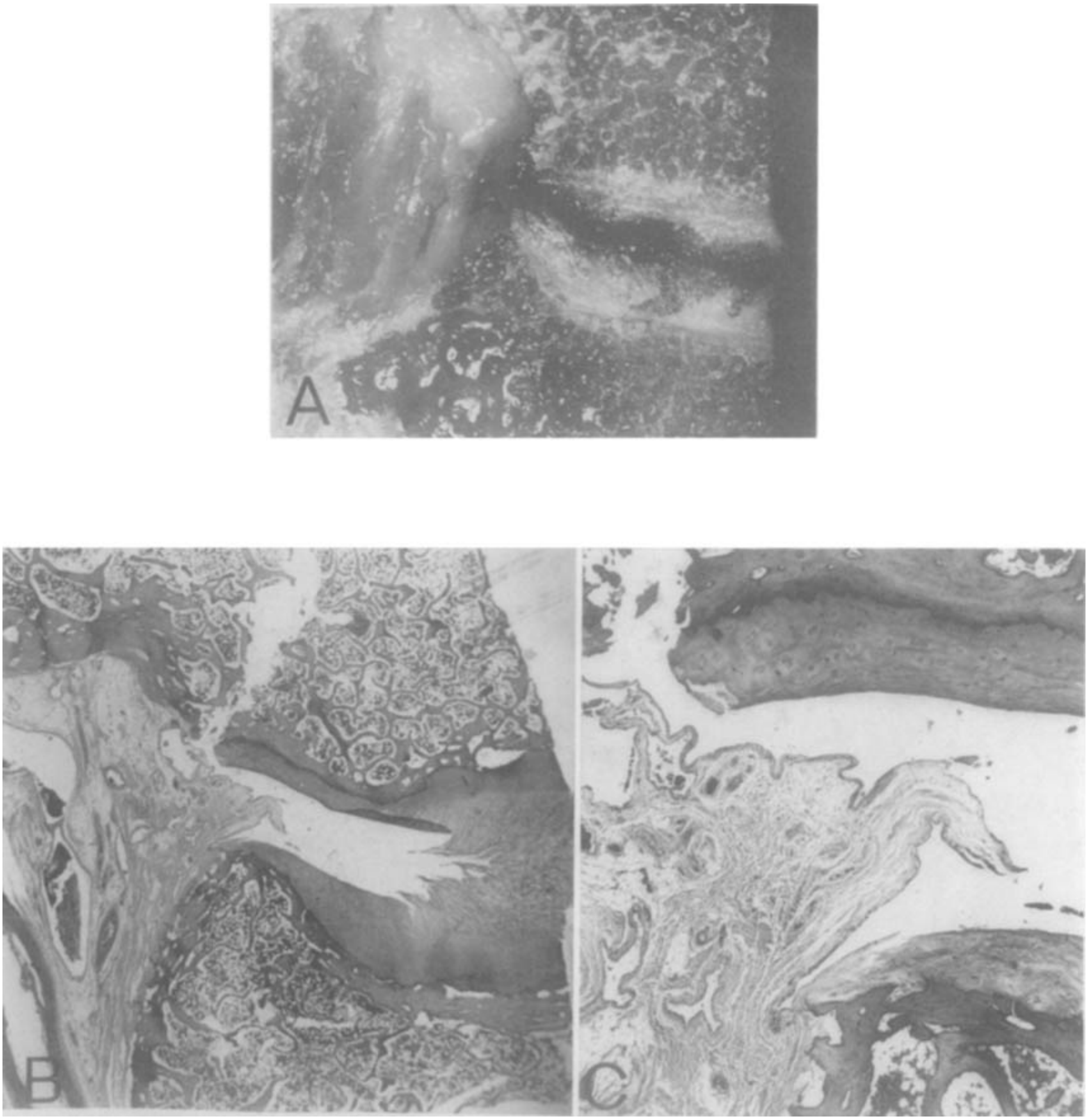


Fig. 22 Case number 65 Age 53
A Photograph of oblique section of the postero-lateral region through the uncus area of C.III. The disc is degenerated with a large fissure from the nucleus to the foramen.
B and C Microphotographs at lower B and higher C magnification.
C (x 23,5) showing a cavity in the disc at the uncus zone. From the foramen vascular connective tissue is entering into the cavity simulating a synovial villus. The cartilaginous end-plates have remained but show degenerative changes. This condition can be mistaken for a true joint with arthritic lesions.

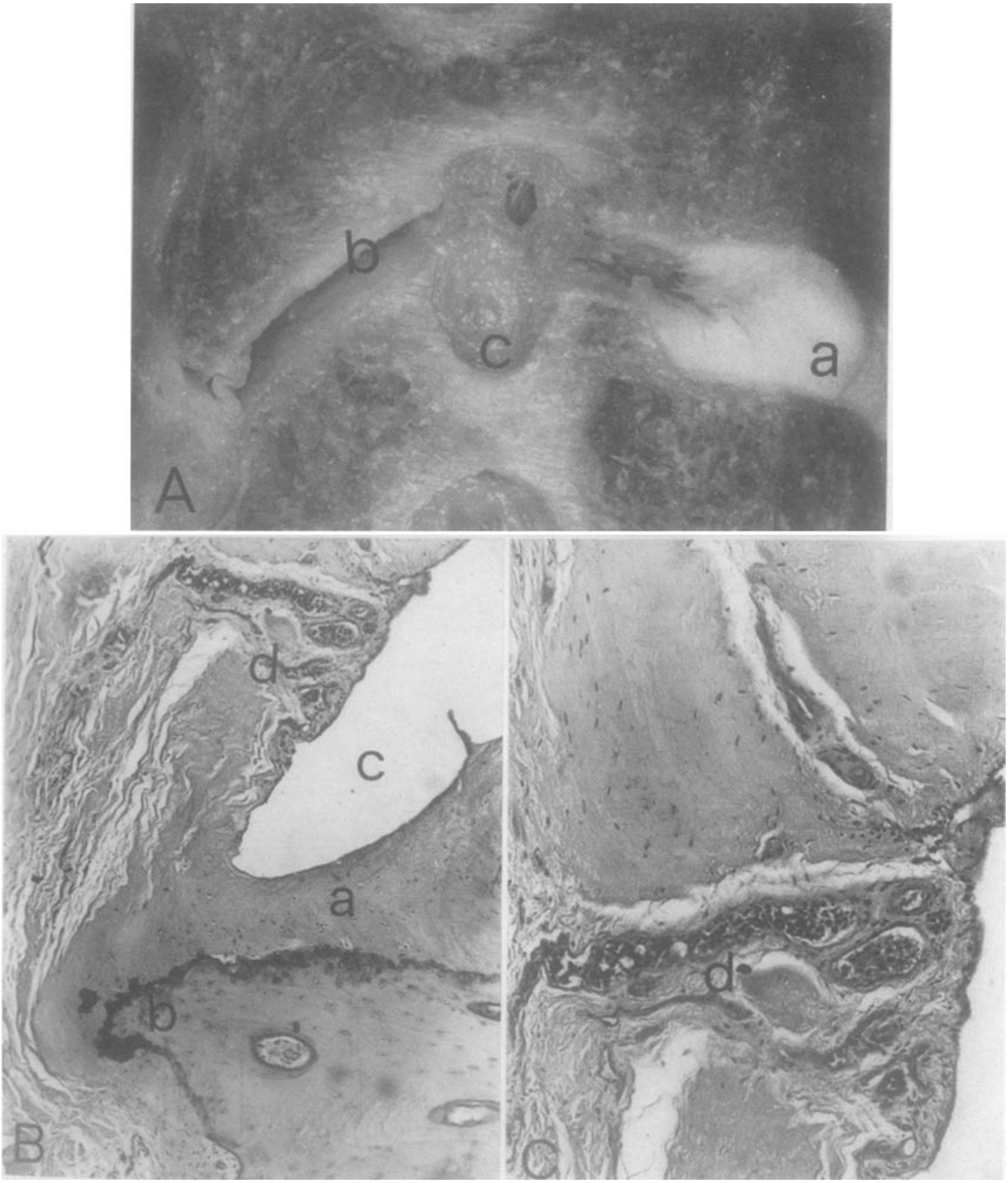


Fig. 23 Case number 77 Age 57
A Photograph of oblique section of C.III showing the postero-lateral part of the disc. a fissures and defects in the disc. b apophyseal joint with normal appearance. c foramen.
B and C Microphotographs of the uncus region of the above disc. a rest of the cartilage end-plate with degenerative alterations covering an osteophyte b at the uncus. c an irregular cavity in the disc approached by congestive newly formed vessels d coming from the foramen.

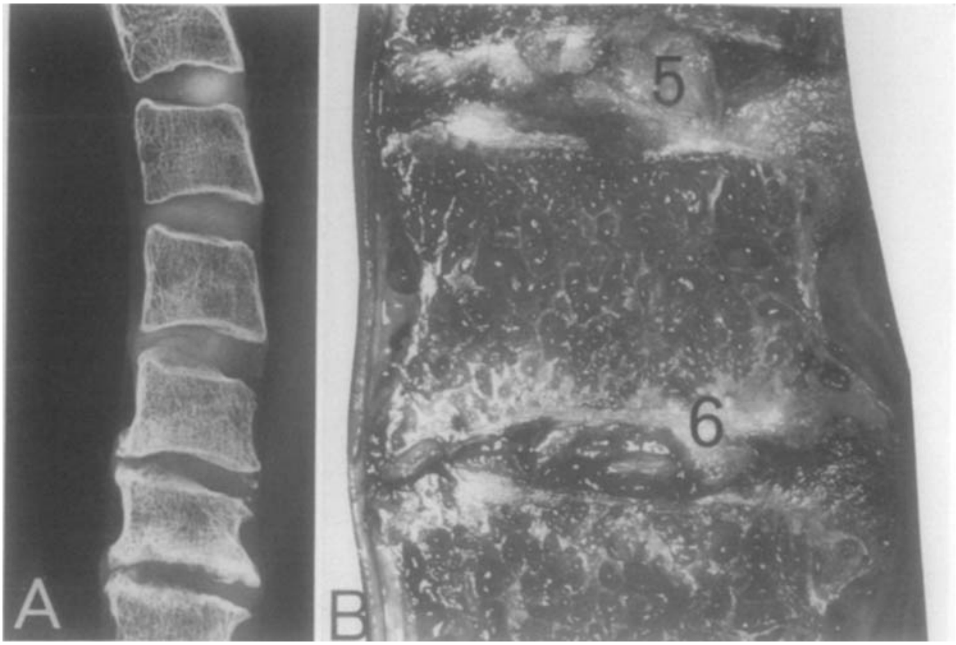


Fig. 24 Case number 100 Age 67
A Radiograph of a 4 mm sagittal section. The degenerative changes are most pronounced at C.V and C.VI levels.
B Photograph of sagittal section showing the discs at C.V and C.VI.
C Topographic microphotograph of C.VI showing very advanced degenerative and proliferative alterations of the disc and adjacent vertebral bodies. The disc is centrally replaced by dense fibrous tissue containing numerous newly formed vessels a coming from both vertebral bodies.
D Higher magnification of the above area.
E Posterior portion of C.VI. a showing besides the heavily degenerative and proliferative changes, bone sclerosis b, osteophyte c, and a cavity d, like a joint space similar to those observed commonly in the uncus area.

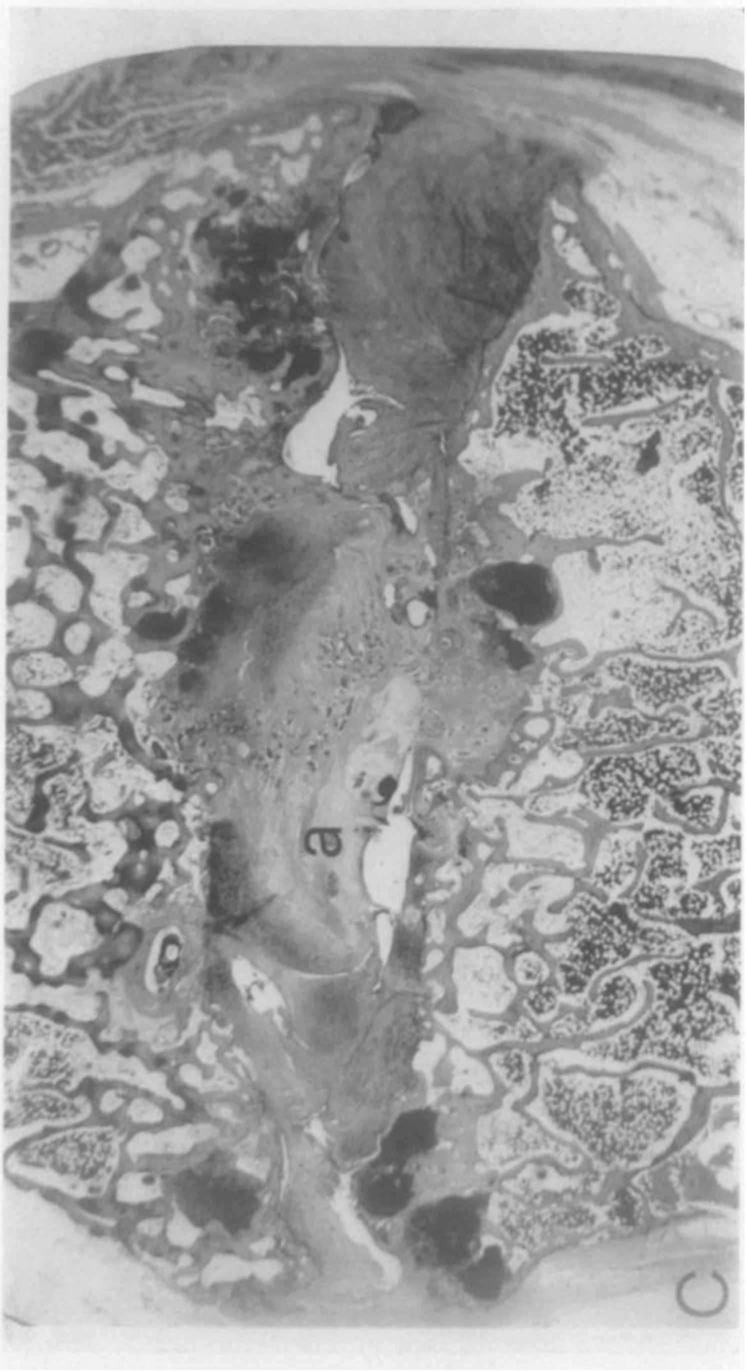


Fig. 24

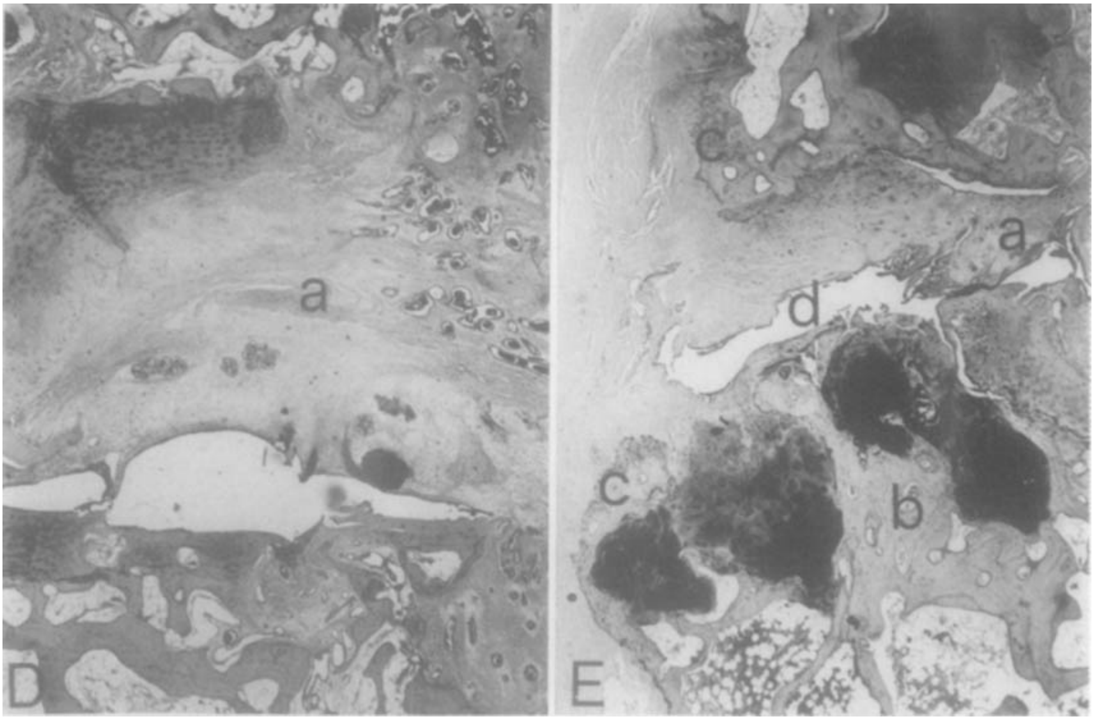


Fig. 24

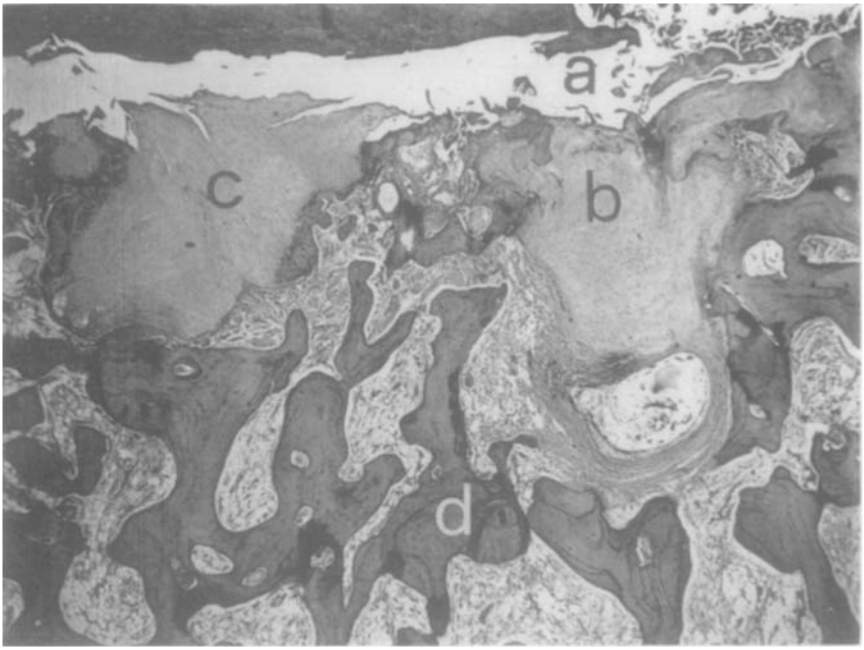


Fig. 25 Case number 106 Age 72
Microphotograph of a heavily degenerated C.V disc. a subchondral fibrocystic alterations, b and c bone marrow surrounded by sclerotic bone trabeculae d. These structural changes are identical to those found in osteoarthritis in real joints.

Reactive Changes Following Disc Degeneration

The deterioration of the disc causes different secondary phenomena in the vertebral bodies. A degenerative disc induces a circulatory response characterized by increased vascularization and hyperaemia of the marginal zones of the vertebral bodies visible on angiograms (Fig. 18 and 26). Vessels penetrating towards the discs and ligaments are followed by new production of bone in terms of osteophyte formation and sclerosis of the subchondral bone trabeculae. It is found not only on the ventral parts of the vertebra but also in early stages and very frequently in the postero-lateral uncus area. This, together with the cartilage metaplasia and the degenerative and proliferative alterations of the disc tissue surrounding the fissures and clefts, has in principle the same appearance as those in arthritic joints constituting as Rathke stated general signs of "spondylosis deformans" (Fig. 27).

Frequently the postero-lateral osteophytes extend towards the foramen and may narrow the foraminal lumen. However, in spite of this, little evidence of mechanical deformation of ganglion and nerve roots or the vertebral artery has been seen. On the other hand distinct grades of perineural fibrosus were often noticed especially in the older age groups.

In some subjects at age 50 or later numerous rounded lamellated and calcified bodies with a hyalin central part were present in the sheaths covering the spinal roots and the peripheral nerves. These bodies were most frequently observed in the epineural and the perineural connective tissue and less often in endoneural connective tissue septa. Around some of the bodies a few lymphocytes and plasma cells were noted (Fig. 28).

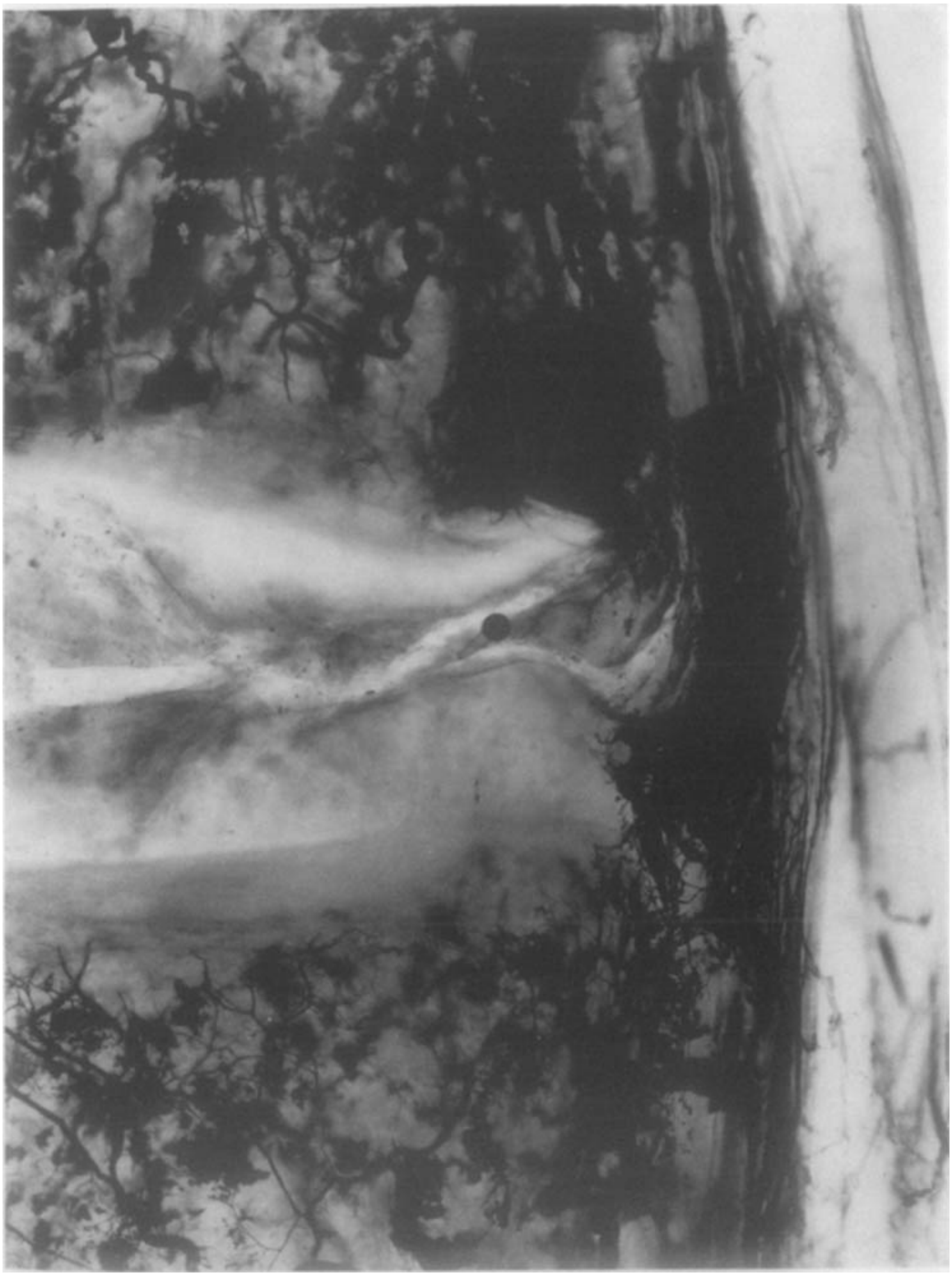


Fig. 26 Case number 97 Age 66
Microangiogram (Berlin Blue and Spalteholz method). C.IV level. Disc degeneration and ventral osteophytes. There is evidently hypervascularization of this area.

Fig. 27 Case number 111 Age 96
Advanced disc degeneration of C.V with formation of anterior osteophytes and irregular subchondral borders. The hypervascularization of the bone marrow is intense with the exception of an area in the lower vertebral body which is either an ischaemic zone or may be an injection failure.

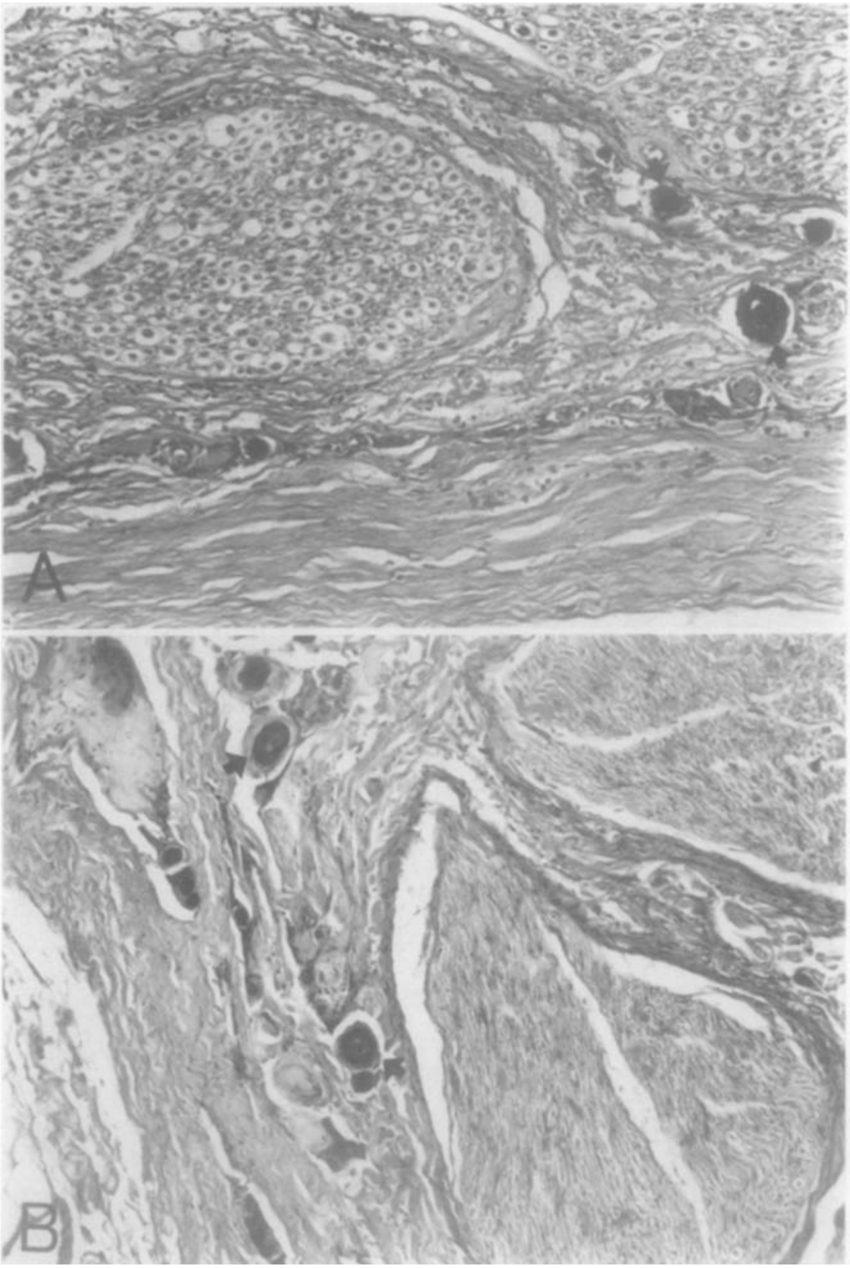


Fig. 28
A Case number 56 Age 50
Microphotograph of calcified bodies of C. V level in foraminal perineural and epineural connective tissue (x 180).
B Case number 63 Age 53
Microphotograph of calcified formations at C.VII level similar to the case above (x 140).

The morphological appearance of the lamellated formations corresponds to that of Renaut's bodies previously described in peripheral nerves by Krücke (1955) and by Lang (1964). Recently Hassler (1967) in a study with microradiographic technique observed similar formations in the spinal arachnoid. According to Krücke (1955) these formations might represent a tissue response to pressure. Though Lang (1964) was of the opinion that these bodies are altered and degenerated blood vessels their origin must still be regarded as quite obscure.

Cystic formations of arachnoidal origin described recently by Holt and Yates (1966) have not been verified in the present material.

In the anterior region the vascular penetration is visible at the borders between the anterior longitudinal ligament and the vertebral body coming from the marginal bone crest penetrating into the ligament and annulus with consecutive osteophyte formation. On some occasions separate bone nodules containing bone marrow may be formed in the anterior longitudinal ligament (Fig. 21).

In severe disc degeneration, generally accompanied by narrowed discs mostly at C.IV—C.VI levels, reactive changes appear in the cartilage end-plates and the subchondral bone in *central* parts of the vertebral bodies (Fig. 24 and 25). The de-

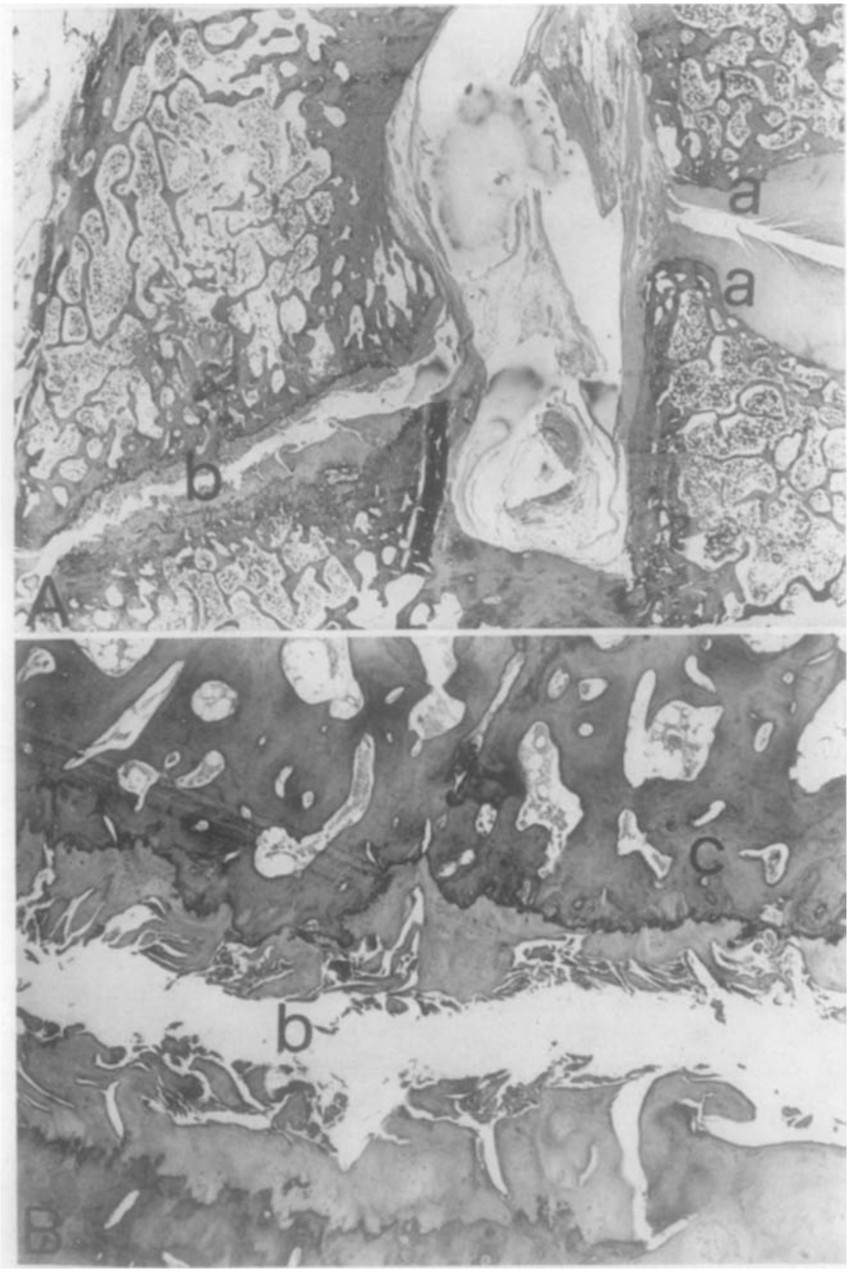


Fig. 29 Case number 45 Age 47
Microphotographs at lower A (x 6) and higher B (x 35) magnification of an oblique section of the posterior part of C.II including the apophyseal joint. a osteophyte formation at the uncus region with the fissured disc inbetween. b very pronounced arthritic lesions of the apophyseal joint.
B Higher magnification of the apophyseal joint showing the extensive degenerative and proliferative alterations of the articular cartilage b and the sclerosis of the subchondral bone c.

generated cartilage end-plate shows an irregular increase in thickness of its calcified zone and ingrowth of blood vessels into the uncalcified areas of the cartilage end-plate and the disc itself. Histological and angiographic pictures demonstrated an increase in number of mainly capillary dilated and hyperaemic blood vessels. This is very similar to observations made by Harrison, Schajowicz and Trueta in arthritic hip joints. However, the presence of a certain degree of passive hyperaemia, as Rutishauser claimed in arthritic hips, cannot be denied in the cervical spine as an additional fact.

The vessels are often accompanied by a loose connective tissue gradually replacing the disc. It may be followed by reactive new bone formation generally reaching only the cartilage end-plates. In this way "central osteophytes" are formed. The borderline between the disc and the subchondral bone becomes very irregular (Fig. 24). Disc material may be displaced into the subchondral bone marrow which then shows fibrosis and cysts surrounded by sclerotic bone trabeculae (Fig. 25). Subchondral bone sclerosis may however, sometimes be observed without disc protrusion or "cyst" formation.

As mentioned earlier a similar histological pattern can be observed in unco-vertebral areas. Only rarely do the penetrating vessels and the accompanying connective tissue of neighbouring vertebral bodies replace completely heavily degenerated disc tissue causing a fibrous union between the vertebrae. A complete osseous fusion observed by other authors in very advanced disc degeneration has not been found.

The apophysial joints were frequently less affected by arthritic lesions. Different degrees and stages of the classical pattern of osteo-arthritis have been observed (Fig. 29). There was no evident relationship between the degree of disc degeneration and osteophyte formation of the vertebral bodies and alterations in the apophysial joints.

Discussion and Conclusions

Most of the patho-morphological, radiographic and clinical attention has been centered around the postero-lateral part of the cervical spine, the so-called unco-vertebral region due to its close relationship to the vertebral foramen with its nerve and vascular elements. This area has been named by Luschka (1858) as "hemiarthrosis intervertebralis lateralis" and since then often called the Luschka-joint. Many others like Trolard (1893) who introduced the name unco-vertebral joint and recently Jackson (1965) who adopted the term lateral intervertebral joint or lateral interbody joint to distinguish it from the posterior apophysial joint, accepted the anatomical fact of a true synovial joint. But the great majority of investigators have joined Rathke's first classical presentation of 1934 stating that in the unco-vertebral region a real joint does not exist. Most of the anatomical controversy is in fact due to the way in which this area has been examined. Studies only in horizontal, sagittal or transverse sections do not give a clear view of the topographic morphology. Our investigation adopting a combination of sagittal, horizontal and especially oblique sections which were examined radiologically, angiographically, macroscopically and histologically, proved that the unco-vertebral area is not a joint but has certain morphological characteristics simulating, during certain periods of life, a space covered by altered disc components and surrounded postero-laterally by fibrous tissue similar to a joint capsule but never covered by a synovial membrane.

Early in life at 4 years of age (Hall 1965) or between 9 and 10 years of age (Töndury 1943, 1952 and 1955, Ecklin 1960) fibrillation and fissures in the annulus fibrosus of the uncus region were seen which increased in size and extent with age and reached the nucleus pulposus. According to Töndury this was more frequent in the upper cervical levels. Since he considered these fissures to develop in normal and not degenerated disc material he felt that they constituted a biomechanical adaptation in order to increase the mobility of the upper cervical region.

In our material we can confirm the early beginning of fissuration seen at age 7. From the age of 14 and on, they were constantly found varying in size and not only present in the upper disc levels but also frequently at the lower discs. Although it is true that in the 4-year-old case of Hall's and in our 7-year-old child the degenerative changes in the annulus only constitued an irregular increase of basophilia in the neighbourhood of the fissures, the signs of degenerative changes in the annulus fibrosus were obvious after age 14. The fact that fissures constantly are present early in life, connecting inner parts of the discs with postero-lateral regions, allowing leakage of contrast media into foraminal and posterior areas at many disc levels in the same subject eliminates the clinical value of discography as a mean of identifying significant disc pathology. This is in complete agreement with and confirms the findings by Holt (1964) in clinical material and normal controls.

Since the annulus fibrosus and the nucleus pulposus of the cervical discs according to our findings are from the time of birth avascular tissues, degenerative alterations may occur early similar to those described by Hirsch and Schajowicz (1952) in the lumbar spine. If and to what extent mechanical factors contribute to the development of these changes has as yet not been explained.

Attention has been paid by several authors to the relationship of the annulus fibrosus and the nucleus pulposus at different ages. This investigation showed that already in the newborn these components can be distinguished and that the time when a child starts to sit is not determinative for the differentiation as stated by Übermuth (1929). At 14 months of age the annulus is evidently thicker and more compact ventrally than it is posteriorly and the nucleus is located posteriorly in relation to the middle of the disc. This finding is contrary to Jackson's but in agreement with other investigators and similar to the conditions in the lumbar discs.

The fissures and cracks so commonly seen in the young age groups extend and increase mainly posteriorly and postero-laterally towards the unco-vertebral area. Often they cause secondary reactions in neighbouring paravertebral foraminal tissue and the vertebral borders.

The first type of reaction to disc degeneration is the production of highly vascularized connective tissue surrounding and penetrating towards the degenerated fissured areas of the discs. This phenomenon, however, is not constant and varies in extent and location and did occur in approximately 20% of this material.

The osteophyte formation of the vertebral borders is the second important consequence of the disc alterations. They were found not only ventrally but even more frequently in the postero-lateral area. The osteophytes together with the histological, degenerative and proliferative alterations of the disc tissue surrounding the spaces and fissures give to this area the typical appearance of an arthritic joint.

Quite often these postero-lateral osteophytes narrow the foraminal space. In our material, however, we have not found evidence of mechanical deformation of the ganglion and nerve roots nor of the vertebral artery. On the other hand perineural fibrosis was quite common sometimes especially in the elderly age groups accompanied by rounded deposits of calcium. In no case did we observe cystic formations of arachnoidal origin described by Holt and Yates (1966).

In advanced disc degeneration generally accompanied by narrowing of the disc, subchondral bone and cartilage end-plate reactions appear with the ingrowth of blood vessels into the disc passing through the often irregular enlarged calcified zones of the end-plate. The vessels are accompanied by connective tissue replacing the disc and sometimes causing a fibrous union between the vertebrae. The borderline between disc and subchondral bone becomes very irregular. Disc material may be displaced into the subchondral bone marrow where fibrosis and cyst formation surrounded by sclerotic bone trabeculae are often seen. This picture was also found in our material in the uncovertebral area and is very similar to the histo-pathology of osteoarthritis.

Apophysial joints were strikingly less frequently affected by osteoarthritis and there was no relation between the amount of disc lesion, osteophyte formation and alterations in the apophysial joints.

Structural changes in the cervical discs which take the form of progressive degenerative changes are usual phenomena which begin during adolescence and continue throughout life and are most probably related to the fact that the disc lacks a direct vascular supply. The earliest changes consist of postero-lateral and posterior fissures in the disc tissue. When the disc degeneration has reached a certain degree, the surrounding tissue reacts. Highly vascularized connective tissue of the type of granulation tissue is formed. This approaches the disc, then first beginning in the posterior and postero-lateral regions, penetrates and infiltrates the disc tissue. The vertebral bodies also exhibit structural alterations. Initially, in areas adjacent to the disc, an increase in the number of vessels is observed. Subsequently osteophyte formation, central and marginal, and subchondral bony alterations, sclerosis, occur. These changes are similar to the pathomorphological alterations of osteoarthritis in true joints.

The formation of vascular connective tissue, of the type of *granulation tissue could explain pain experienced by the patient as this tissue is supposed to contain nerve elements.*

Radiating pain may be due to the influence of this "granulation tissue" on neural elements in the intervertebral foramen.

As granulation tissue matures, it becomes less vascular and cicatrization occurs. This could explain the recovery from pain which occurs spontaneously in a certain number of patients or which follows conservative treatment or surgical interventions.

The pathomorphological changes and the clinical behaviour of both the cervical and lumbar spine have many obvious similarities, and generally speaking in both the pattern of pathomorphological changes is, in its advanced stages, that of osteoarthritis.

Die strukturellen Veränderungen der Halswirbelbandscheiben in der Art von progressiven degenerativen Veränderungen sind habituelle Prozesse die im Jugendalter beginnen und während des ganzen Lebens fortschreiten; Sie sind höchstwahrscheinlich durch die fehlende Gefässversorgung der Bandscheiben verursacht. Die frühesten Veränderungen bestehen in postero-lateralen und hinteren Spaltenbildungen des Bandscheibengewebes. Wenn die Bandscheibendegeneration einen gewissen Grad erreicht hat, reagiert das Nachbargewebe und ein gefässreiches Bindegewebe vom Typ des Granulationsgewebes wird gebildet. Dieses wuchert gegen die Bandscheibe und dringt in dasselbe verschieden tief ein, was zuerst hinten und hintenseitwärts beginnt.

Auch die Wirbelkörper zeigen strukturelle Veränderungen, die mit einer Zunahme der Gefässe in der subchondralen Zone beginnen. Anschliessend erscheinen Veränderungen (Sklerose) *der Spongiosa und Osteophytenbildung. Diese Veränderungen sind vergleichbar mit der Artrosis deformans in wahren Gelenken.*

Die Bildung des reaktionellen gefässreichen Bindegewebes, nach Art eines Granulationsgewebes, könnte den Schmerz der Patienten erklären, da anzunehmen ist, dass dieses Gewebe Nerven enthält.

Ausstrahlende Schmerzen könnten auch durch den Einfluss dieses "Granulations-Gewebes" auf die neuralen Element des intervertebralen Foramen verursacht werden.

Wenn ein Granulationsgewebe reift wird es gefässärmer und es vernarbt. Auf diese Weise könnte das spontane Verschwinden der Schmerzen oder nach konservativer oder chirurgischer Behandlung, erklärt werden.

Das patologisch-anatomische und das klinische Bild der Lenden- und Halswirbelsäulenveränderungen zeigen deutliche Ähnlichkeiten und entsprechen in seinen fortgeschrittenen Stadien der Artrosis deformans der wahren Gelenke.

Alteraciones estructurales de los discos cervicales en forma de lesiones degenerativas progresivas, constituyen un fenómeno habitual que comienza en la adolescencia y continúa en forma progresiva durante toda la vida; se deben con mayor probabilidad al hecho que el disco intervertebral no posee una vascularización propia.

Las primeras alteraciones consisten en fisuras postero-laterales y posteriores del tejido discal. Cuando el proceso de degeneración discal adquiere cierta intensidad, los tejidos vecinos reaccionan y se produce un tejido conectivo ricamente vascularizado, del tipo del tejido de granulación. Este avanza hacia el *disco y comienza a penetrar dentro del mismo; primeramente en la región posterior y postero-lateral.*

Los cuerpos vertebrales muestran también alteraciones de su estructura. Al comienzo se observa un aumento del número de vasos sanguineos en las areas adyacentes al disco, seguido por alteraciones del tejido óseo esponjoso subcondral y formación de osteofitos centrales y marginales. Estas lesiones son muy semejantes a las alteraciones morfológicas que se observan en las osteoartritis (artrosis deformante) de las verdaderas articulaciones.

La formación de un tejido vasculo-conectivo, del tipo del tejido de granulación, podria explicar el dolor que experimenta el paciente ya que puede suponerse que el mismo contenga elementos nerviosos.

El dolor irradiado podria deberse a la influencia de este "tejido de granulación" sobre los elementos nerviosos del foramen intervertebral.

Cuando un tejido de granulación madura desaparecen paulatinamente los vasos sanguíneos y se produce su cicatrización. Esto podría explicar la desaparición del dolor, lo que puede ocurrir espontáneamente o después de un tratamiento conservador o quirúrgico.

Las alteraciones anatomo-patológicas y el comportamiento clínico de la columna lumbar y cervical presentan muchas y evidentes semejanzas y en líneas generales el tipo de las lesiones corresponde en sus etapas avanzadas a la de una artrosis deformante.

Des changements structuraux des disques cervicaux en forme de lésions dégeneratives progressives constituent un phénomène ordinaire qui apparaît dès l'adolescence et continue progressive-

ment pendant toute la vie; avec la plus grande probabilité ces changements sont dus au fait que le disque intervertébral manque d'une vascularisation propre.

Les premiers changements sont des fissures postéro-latérales et postérieures du tissu discal. Quand le procès de dégénération discale atteint une certaine intensité les tissus voisins réagissent et il se produit un tissu conjonctif richement vascularisé, qui a le caractère du tissu de granulation. Celui-ci s'avance vers le disque et commence à y pénétrer, d'abord dans la région postérieure et postéro-latérale.

Aussi les corps vertébraux montrent des changements de leur structure. On voit d'abord une augmentation du nombre des vaisseaux sanguins dans les parties adjacentes au disque, et plus tard des changements du tissu osseux spongieux subcondral et une formation d'ostéophytes centraux et marginaux. Ces lésions sont très semblables aux changements morphologiques, qu'on voit dans les arthroses déformantes des articulations véritables.

La formation d'un tissu vasculo-conjonctif, du caractère du tissu de granulation, pourrait expliquer la douleur qu'éprouve le malade, parce qu'on peut supposer que ce tissu contienne des éléments nerveux.

La douleur irradiée pourrait être due à l'influence exercée par ce "tissu de granulation" sur les éléments nerveux du trou intervertébral.

Quand un tissu de granulation mûrit, les vaisseaux sanguins désapparaissent graduellement et une cicatrisation se produit. Cela pourrait expliquer la cessation de la douleur, ce qui peut arriver spontanément, ou après un traitement conservatoire ou chirurgical.

Les changements anatomo-pathologiques et le comportement clinique de la colonne cervicale ressemblent beaucoup à ceux de la colonne lombaire et, en principe, le caractère des lésions correspond, dans ses étapes avancées, à celui d'une arthrose déformante.

References

BOWDEN, R. E. M.: The Applied Anatomy of the Cervical Spine and Brachial Plexus. Proc. Royal Soc. Med. 59: 1141—1146, 1966.

BRAIN, LORD and WILKINSON, MARCIA: Cervical Spondylosis and Other Disorders of the Cervical Spine. Whitefriars Press Ltd, London, 1967.

COMPERE, E. L., TACHDJIAN, M. O. and KERNAHAN, W. T.: The Luschka Joints. Their Anatomy, Physiology and Pathology. Orthopaedics 1: 159—168, 1959.

ECKLIN, U.: Die Altersveränderungen der Halswirbelsäule. Berlin-Göttingen-Heidelberg. Springer Verlag, 1960.

FRIEDENBERG, Z. B., EDEIKEN, J., SPENCER, N. and TOLENTINO, S. C.: Degenerative Changes in the Cervical Spine. J. Bone Joint Surg. 41-A: 61—70, 1959.

FRYKHOLM, R.: Lower Cervical Vertebrae and Intervertebral Discs. Surgical Anatomy and Pathology. Acta Chir. Scand. 101: 345—359, 1951.

GIRAUDI, G.: L'artrosi deformante unco-vertebrale. La Radiol. Med. 28:1457—1475, 1931.

HADLEY, L. A.: Roentgenographic Studies of the Cervical Spine. Am. J. of Roentgenol. 52:173—195, 1944.

HADLEY, L. A.: The Covertebral Articulations and Cervical Foramen Encroachment. J. Bone Joint Surg. 39-A: 910—920, 1957.

HALL, M. C.: Luschka's Joint. Thomas, Springfield, 1965.

HARRISON, M. H. M., SCHAJOWICZ, F. and TRUETA, J.: Osteoarthritis of the Hip. A Study of the Nature and Evolution of the Disease. J. Bone Joint Surg. 35-B:4, 1953.

HASSLER, O.: Calcifications in the Spinal Arachnoid in Man. Acta Neuropath. 8: 163—170, 1967.

HIRSCH, C. and SCHAJOWICZ, F.: Studies on Structural Changes in the Lumbar Annulus Fibrosus. Acta. Orthop. Scand. XXII: 3, 1952.

HIRSCH, C.: Cervical Disc Rupture. Diagnosis and Therapy. Acta. Orthop. Scand. XXX: 3, 1960.

HIRSCH, C., WICKBOM, L., LIDSTRÖM, A. and ROSENGREN, K.: Cervical-Disc Resection. J. Bone Joint Surg. 46-A: 1811—1821, 1964.

HOLT, E. P.: Fallacy of Cervical Discography. J. of Am. Med. Association, 188: 799—801, 1964.

HOLT, S. and YATES, P. O.: Cervical Spondylosis and Nerve Root Lesions. Incidence at Routine Necropsy. J. Bone Joint Surg. 48-B: 407—423, 1966a.

HOLT, S. and YATES, P. O.: Cervical Spondylosis and Cysts of Dorsal Root Ganglia. Proc. Royal Med. 59: 1146—1148, 1966b.

HULT, L.: The Munkfors Investigation. A Study of the Frequency and Causes of the Stiff Neck-Brachialgia and Lumbago-Sciatica Syndromes. Acta Orthop. Scand. Suppl. XVI, 1954.

HULT, L.: Cervical, Dorsal and Lumbar Spinal Syndromes. Acta Orthop. Scand. Suppl. XVII, 1954.

JACKSON, R.: The Cervical Syndrome. Thomas, Springfield, 1965.

KROGDAHL, T. and TORGERSEN, O.: Die "Unco-vertebralgelenke" und die "Arthrosis deformans unco-vertebralis". Acta Radiol. 21: 231—262, 1940.

KRÜCKE, W.: Erkrankungen des peripheren Nervensystems. In Handbuch der speziellen pathologischen Anatomie und Histologie. Eds. O. Lubarsch, F. Henke und R. Rössle. Vol. XIII/5: 1—339, Springer Verlag Berlin.

LANG, J.: Über die Gefäße, die Faszikel und das Bindegewebe der Nerven während des Wachstums. Z. Zellforsch 63: 226—246, 1964.

LUSCHKA, H.: Die Halbgelenke des menschlichen Körpers. Reimer, Berlin, 1858.

MORTON, D. E.: A Comparative Anatomico-roentgenological Study of the Cervical Spine of Twenty Cadavers. Am. J. Roentgenol. 63: 523—529, 1950.

OROFINO, C., SHERMAN, M. S. and SCHECHT, D.: Luschka's Joint. — A Degenerative Phenomenon. J. Bone Joint. Surg. 42-A: 853—858, 1960.

PAYNE, E. E. and SPILLANE, J. D.: The Cervical Spine. An Anatomical Study of 70 Specimens with Particular Reference to the Problem of Cervical Spondylosis Brain 80: 571—593, 1957.

RATHKE, L.: Zur normalen und pathologischen Anatomie der Halswirbelsäule. Deutsch. Z. Chir. 242: 122—137, 1934.

SCHAJOWICZ, F.: Contributo alla struttura microscopica e alla patologia dei dischi intervertebrali nei giovani. Chir. Org. Movim. XXIV, 5—58, 1938.

SILBERSTEIN, Ch. E.: The Evolution of Degenerative Changes in the Cervical Spine and an Investigation into the "Joints of Luschka". Clin. Orthop. 40: 184—204, 1965.

SPALTEHOLZ, W.: Über das Durchsichtigmachen von menschlichen und tierischen Präparaten und seine theoretischen Bedingungen. 2, Aufl. Leipzig, 1914, S. Hirzel.

TROLARD, A.: Quelques articulations de la colonne vertebrale. Int. Monatsschr. f. Anat. u. Physiol. 10: 1—11, 1893.

TRUETA, J. and HARRISON, M. H. M.: The Normal Vascular Anatomy of the Femoral Head in Adult Man. J. Bone Joint Surg. 35-B, 1953.

TRUETA, J.: Studies on the Etiopathology of Osteoarthritis of the Hip. Clin. Orthop. 31: 7—19, 1963.

TÖNDURY, G.: Zur Anatomie der Halswirbelsäule. Gibt es Unco-vertebral-Gelenke? Z. Anat. Entwickl.-Gesch. 112: 448—459, 1943.

Töndury, G.: Zur Anatomie und Entwicklungsgeschichte der Wirbelsäule mit besonderer Berücksichtigung der Altersveränderungen der Bandscheiben. Schweiz. med. Wschr. 85, 35, 825 ff. 1955.

Töndury, G.: Entwicklungsgeschichte und Fehlbildungen der Wirbelsäule. Stuttgart: Hippokrates Verlag, 1958.

Töndury, G.: La colonne cervicale, son développement et ses modifications durant la vie. Acta Orthop. Belg. 25: 602—626, 1959.

Übermuth, H.: Bedeutung der Altersveränderung der menschlichen Bandscheiben für die Pathologie der Wirbelsäule. Langenbecks Arch. klin. Chir. 156: 567—578, 1929.