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Infarction of Spinal Cord and Medulla Oblongata Caused by Fibrocartilaginous Emboli

Report of Case

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Summary. A fatal case of fibrocartilaginous embolization with massive infarction of the upper spinal cord and lower medulla oblongata is reported. Cartilage from intervertebral discs is believed to cause such emboli, probably first by intrusion into vertebral bodies (Schmorl's nodes) followed by retrograde venous transport from the bone marrow to the spinal veins. This route can be outlined by injecting India ink in the cancellous bone of vertebral bodies. Access of the emboli to arteries can be explained by postulating the existence of arteriovenous shunts in the normal spinal vasculature or by trauma-induced communications between the vascular beds. In our case, the 7th reported in the literature, the majority of occluding cartilaginous emboli were in small arteries and arterioles and the resulting infarcts were of the ischemic rather than the hemorrhagic type.

Introduction

Vascular accidents of the spinal cord are much less common than cerebral "strokes", but if they occur they may lead to paralysis and possibly death, particularly if they involve the upper cervical cord, causing quadriplegia and respiratory failure. Among the causes of such acute vascular accidents are thrombosis of spinal arteries and veins, a loss of collateral blood supply from the aorta (e.g. in dissecting aneurysm) or, less commlonly, hemorrhage into the spinal cord substance.

An unusual variant of spinal cord infarction, which has led to the death of the few patients in whom it has been reported, is caused by fibrocartilaginous emboli to the blood vessels of the cord (and sometimes lower medulla). The source of these emboli is believed to be the nucleus pulposus of the intervertebral discs. Only six such cases (plus one with asymptomatic embolization) have been reported so far, all of them either in neurological journals [1–3, 5] or in a general medical journal [4]. It was felt that a report of such a case would be of value to general pathologists who may perform autopsies on similar cases in the future.

Report of a Case

The patient was a 38 year old Negro woman who awoke the morning of October 27, 1971 with acute right posterior neck pain and inability to move her right arm. Minutes later she collapsed to the floor and within one hour after waking was taken to a local hospital emergency room complaining of difficulty in breathing. She then experienced a grand mal seizure which was followed by apnea. The patient required mechanical respiratory assistance and remained comatose for three days. Following this she regained consciousness with alertness.Physical examination revealed flaccid quadriplegia. Examination of spinal fluid upon admission

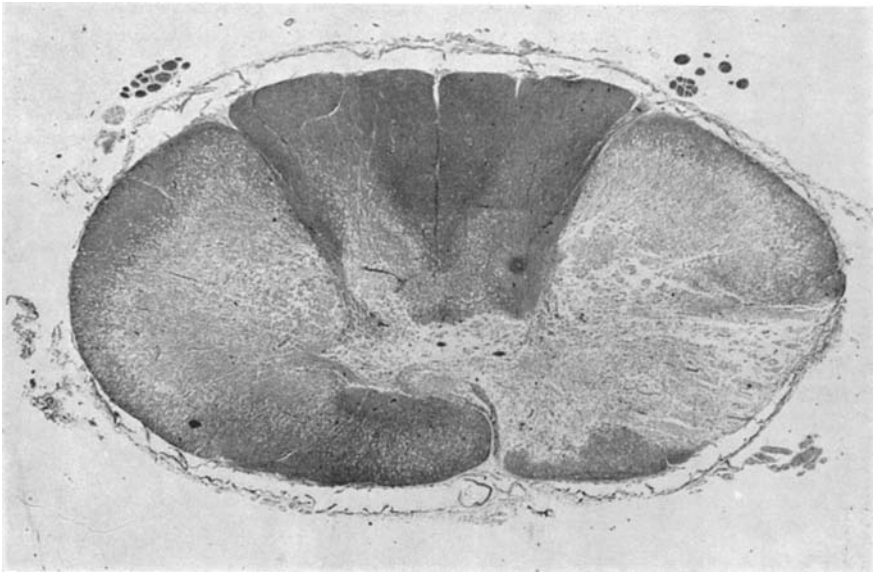


Fig. 1. Segment of spinal cord at C_2. Liquefaction necrosis involves most of the gray matter and the white matter of the lateral columns. (Weil-Weigert myelin stain, ×8)

showed 70 wbc's with 85% polys and 34 mg% protein. Ten days later a repeat examination of spinal fluid showed no cells and 64 mg% protein. X-ray examination of the cervical spine showed no fracture or dislocation of the vertebrae.

Past Medical History. The patient experienced the usual childhood illnesses without complications and had been in good health prior to her present illness. Three weeks prior to the onset of her symptoms the patient was an occupant in a car which struck a cement filled barrel. There was no apparent injury to herself and she was not seen by a physician. She had been taking Enovid 5 mg/day for birth control. There was no previous history of epilepsy or neurological deficit.

Hospital Course. The patient was hospitalized at a local hospital for about one month. During this time she received steroids and intermittent antibiotics. She remained alert with flaccid quadriplegia and apnea. After three weeks she became comatose again and was transferred to Kansas University Medical Center. Laboratory values here revealed a nonketotic hyperosmolar state with blood sugar values as high as 1650 mg%. Spinal fluid showed no cells and 50 mg% protein. EEG's showed gross abnomalities with generalized suppression of electrical activity. The patient remained in deep coma for the remainder of her hospital course which was complicated by renal failure, cardiac failure and pneumonitis. The patient died on 12-6-71.

The *general autopsy* showed acute tracheobronchitis with extensive bilateral bronchopneumonia, fatty metamorphosis of the liver and multiple gastric mucosal ulcers with 200 cc of recently clotted blood in the stomach. In view of the high blood sugar levels it was of interest that the pancreas appeared histologically normal with preservation of beta granules in the islets of Langerhans. It was thus surmised that the patient's hyperosmolar coma was probably of central origin.

Central Nervous System. The brain weighed 1110 g and showed some generalized swelling but the hemispheres, basal ganglia, cerebellum and upper brain stem appeared otherwise normal. The arteries of the circle of Willis and the leptomeninges were unremarkable. The medulla oblongata was quite edematous

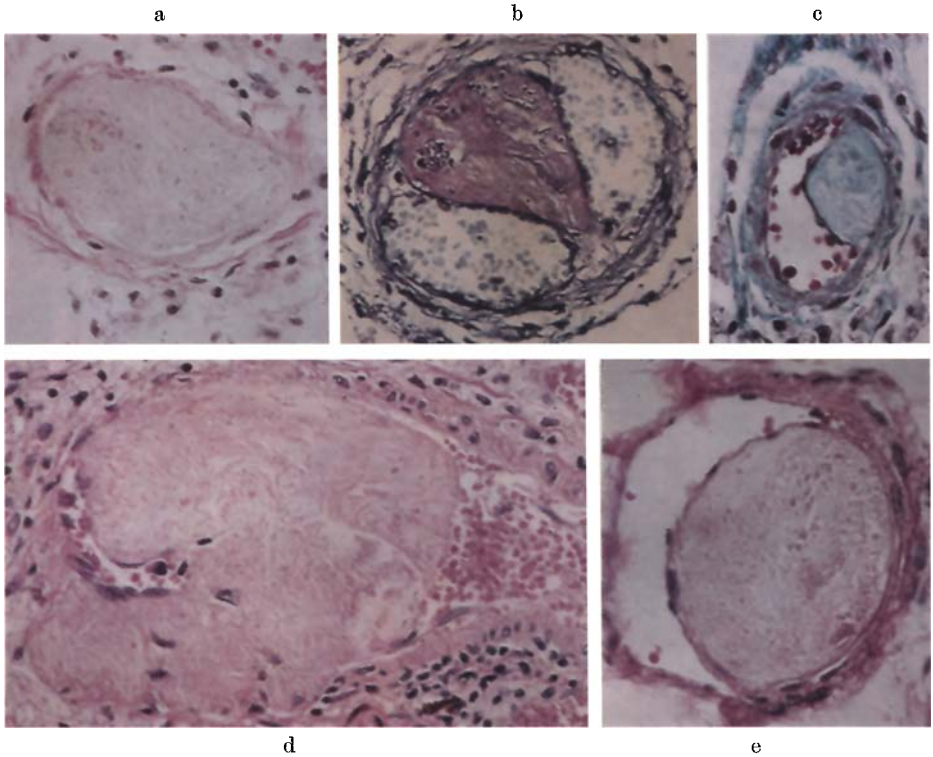


Fig. 2a—e. Partial to total occlusion of small vessels by fibrocartilaginous emboli. (Note endothelium covering the embolic fragments. ×160.) a) Hematoxylin-eosin, b) purple metachromasia with 1% Thionine, c) Gomori's trichrome stain, d) and e) PAS

with a soft consistency. The spinal canal was opened from behind and the vertebral arches and processes were found in their normal position with no signs of injury. The vertebral bodies were also properly aligned with no impingement on the spinal canal. The posterior longitudinal ligament was intact. At the level of the first and second cervical cord segment a small ($1.5 \times 0.4 \times 0.2$ cm) flat partly organized hematoma was found attached to the outer surface of the dura on the right side. There was no evidence of compression of the cord by this small hemorrhage. After opening the dura the cervical cord appeared somewhat thinner than usual. Its leptomeninges were normal and no grossly visible alterations were encountered in the spinal blood vessels.

Sectioning of the lower medulla and spinal cord showed an area of softening involving the anterior portions of the first four segments of the spinal cord and of the lower one-third of the medulla oblongata. The involved area was light yellow-brown but not hemorrhagic and slightly depressed on cut surface consistent with an infarct of some weeks' duration. Segments of the cord below C_4 appeared normal.

Microscopic examination confirmed the gross impression of extensive infarction of the anterior half of the upper cervical cord segments (Fig. 1) and showed

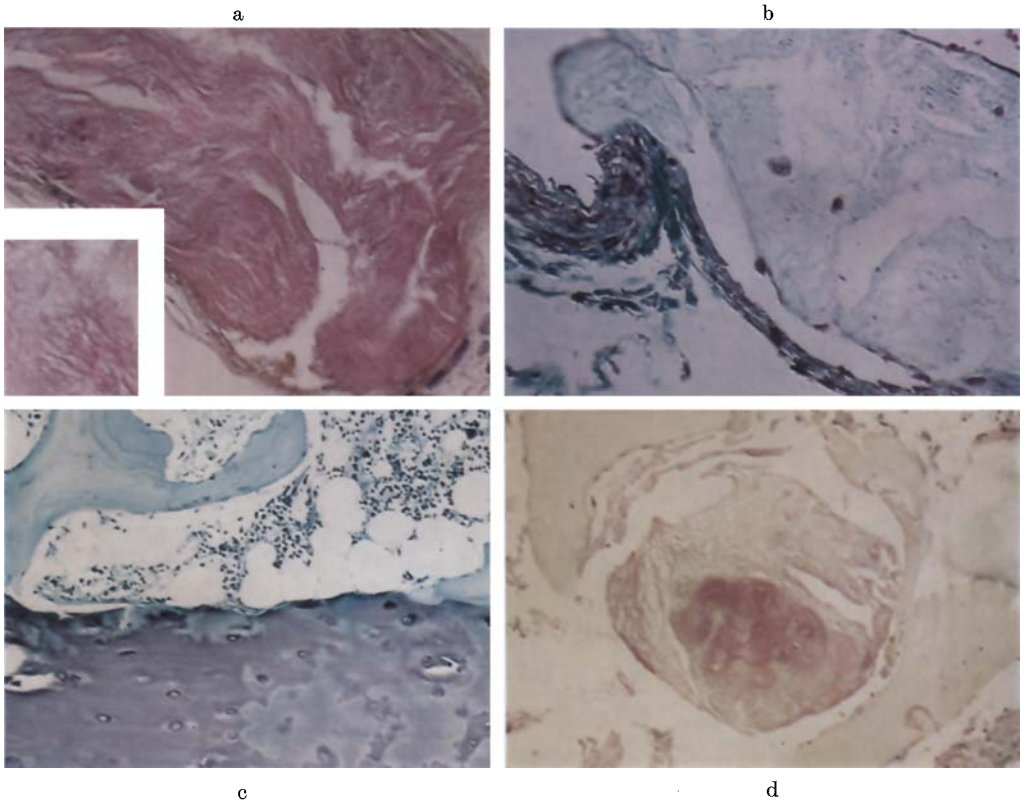


Fig. 3. a) Mucicarmine stain of embolus. Insert: same stain on fragment of surgically removed herniated nucleus pulposus from another patient (×200). b) Gomori's trichrome stain with chondrocytes in embolus (×160). c) 5th cervical vertebra and adjacent disc. Note absence of compact bony plate separating cartilage from marrow cavities. (1% Thionine, ×60.) d) 6th cervical vertebra. Fragments of fibrocartilage present in the midst of bony spicules. (Mucicarmine, ×200)

a large wedge-shaped infarct of the medulla, with its base towards the ventral surface. The infarcted areas showed marked accumulation of gitter-cells (fatty macrophages) and some proliferation of astrocytes with focal deposits of glial fibers. In the affected areas, both gray and white matter were involved.

As the cause of the infarction we found no atheromatosis, thrombosis or thromboemboli in the blood vessels of the cord, but in several areas small vessels, predominantly arterioles but also some very thin-walled vessels consistent with venules of the pia and cord were partially or totally occluded by a partly fibrillary, partly amorphous substance, which stained light gray-blue on H&E. First, we thought the substance represented thrombotic material but fibrin stains with phosphotungstic acid-hematoxylin were consistently negative. The possibility of the material being cartilaginous ground substance was then considered and indeed it had all the staining characteristics of loose fibrocartilage: it stained metachromatically purple red with 1% buffered Thionine, green with Gomori's tri-

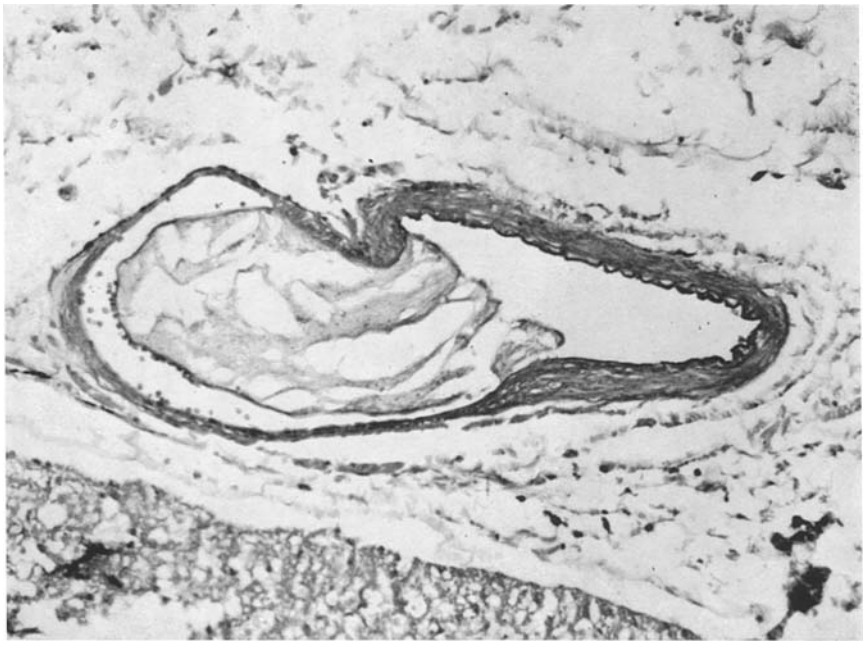
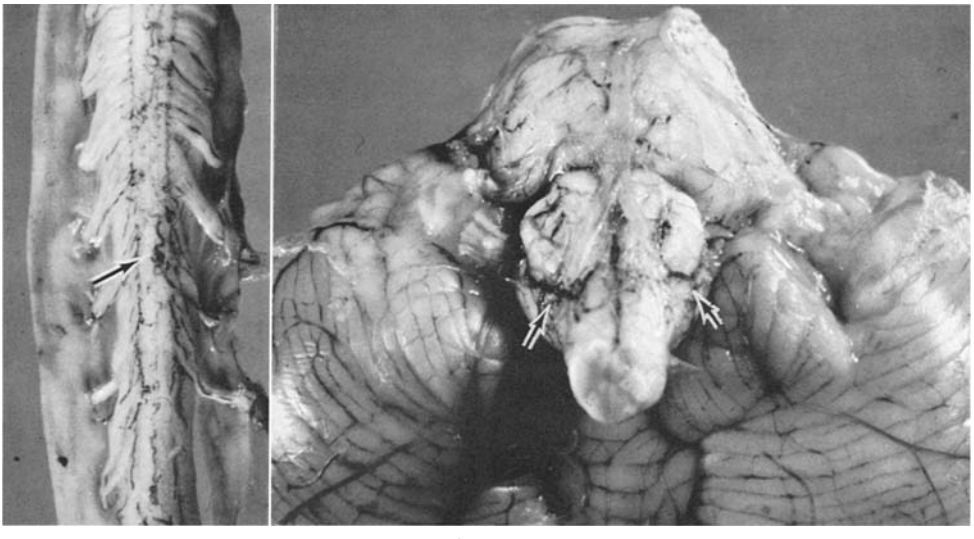


Fig. 4. Fibrocartilage embolus wedged in small artery. Thin walled portion may represent stretched vessel wall or perhaps anastomosing vein. (Verhoeff-Van Gieson stain, ×120)

chrome stain and was positive and diastase resistant on periodic acid Schiff stain (Fig. 2). No organization in the usual sense was observed but many of the occluding fragments became covered by endothelium and thereby sequestered from the residual lumen of the vessel. At the level of the second cervical segment we found one major branch of the anterior spinal artery occluded by material which appeared even more fibrillary. Mucicarmine stain of this material was strongly postive, a staining reaction identical with that seen in surgically removed fragments of herniated nucleus pulposus from other patients. While most of the involved vessels contained acellular material, in some areas a few chondrocytes could be detected within the fibrillary matrix (Fig. 3). In a few areas part of the vessels wall surrounding the fibrocartilage showed transition from typical small artery with well defined internal elastic membrane to a much thinner structure containing no elastic tissue. We considered the possibility that such areas may mark an anastomosis between an artery and a vein (see later in discussion) or that it may be perhaps the result of stretching of the arterial wall by the embolus (Fig. 4). Since at the time of autopsy no gross abnormalities were noted about the first four cervical vertebrae, no sections were taken from them, but we saved as routine portions of cervical vertebrae 4 to 6. We were impressed by the fact that the borderline between intervertebral discs and vertebral bodies was not always marked by a plate of compact bone and in several areas the annulus fibrosus was directly adjacent to marrow spaces of the cancellous bone (Fig. 3c). In addition we found scattered islands of fibrocartilage within the marrow spaces as far as



a b

Fig. 5. a) Injection of India ink into body of the 4th cervical vertebra in 8 week old infant's cadaver resulted in extensive filling of radicular and pial veins of spinal cord. b) Filling of pial veins of medulla (same injection as in Fig. 5a)

the center of the vertebral body (Fig. 3d). Extensive search of lung sections (60 H.E., Mucicarmine and PAS stained sections from different areas) failed to reveal any cartilaginous emboli in branches of the pulmonary artery.

Discussion

Occlusion of spinal cord vasculature by fibrocartilaginous emboli was first described by *Naiman* and co-workers in 1961 [1]. Their patient, a 15 year old boy, while engaged in basketball practice, fell and landed on his buttocks and right shoulder. He was able to get up but 20 min later developed severe pain in the epigastrium, back, neck and shoulders, followed by flaccid quadriplegia with respiratory paralysis. He died within three hours after the onset of symptoms. Autopsy revealed small hemorrhages in the spinal cord at all levels, predominantly in the gray matter and with greatest concentration in the midcervical region. Fibrocartilaginous emboli were present in the lumina of arterioles of the lower medulla and in 10 sections of the spinal cord from C_2 to T_7. Naiman and his co-workers felt that rupture of the annulus fibrosus and simultaneous tearing of an adjacent radicular artery led to the extrusion of nucleus pulposus fragments into the artery.

Laterre [2] in 1962 reported the case of a 31 year old woman, who, without antecedent history developed sudden interscapular pain followed shortly by weakness of the extremities progressing to total quadriparesis and anesthesia below the level of T_2. The patient was hospitalized for three months with no change in her neurological status, and finally died of renal failure secondary

to pyelonephritis. Autopsy showed flattening and central necrosis of the spinal cord from C_6 to T_1 and fibrocartilaginous emboli in the arteries of the ventral portions of the cord at the same level.

Feigin et al. [3], in 1965 reported three additional cases of fibrocartilaginous emboli which involved the venous system of the spinal cord. Two of these patients died as a result of this embolization while the third patient whose single embolus was located in a vein next to a dorsal root ganglion had no symptoms related to this finding. In their second case they felt that one of the occluded vessels was possibly a small artery and postulated that perhaps arteriovenous anastomoses of the cord permitted the entry of a cartilage embolus into the artery. The authors were able to demonstrate in the two symptomatic cases the presence of Schmorl's nodules, i.e. islands of fibrocartilage within the cancellous portions of vertebral bodies, in addition to degenerative changes in intervertebral discs.

Bodechtel [4] in 1968 reported a fatal case of fibrocartilaginous embolization in veins of the medulla and all levels of the spinal cord in a 28 year old woman during the seventh month of her pregnancy, without a precipitating event.

The most recent report of fibrocartilaginous embolization of the spinal cord was by *Jurkovic* and *Eiben* in 1970 [5]. This patient was a 66 year old woman who after having carried a heavy load during a shopping trip developed acute lumbo-sacral pain the following day. This was followed by paraplegia and death from sepsis and pulmonary thrombo-emboli on the 18th hospital day. Autopsy showed fibrocartilaginous emboli in the veins of the spinal cord at various levels with associated central necrosis of the involved segments. Schmorl's nodes were found in four lumbar vertebrae.

All the authors of the previously reported cases agreed on the source of the fibrocartilaginous emboli being the nucleus pulposus of one or perhaps more intervertebral discs. Trauma may possibly play a role in the embolization of nucleus pulposus material. Naiman *et al.*'s patient developed his symptoms very shortly after injury in the course of basketball practice. The fact that this boy's accident consisted of falling and landing on his buttocks would be consistent with sudden increased pressure on one or more intervertebral discs and extrusion of disc material. Jurkovic and Eiben's patient carried a heavy load on the day prior to the onset of lumbo-sacral pain and paraplegia. Our patient was allegedly involved in a car accident 3 weeks before the onset of the quadriplegia, but the exact nature of patient's injuries was not known. The organizing small epidural hematoma in the upper cervical area was certainly consistent with traumatic origin. There was no history of trauma in Laterre's, Bodechtel's and Feigin *et al.*'s patients.

One may speculate on the possible role of sex hormones in the loosening of the annulus fibrosus which would facilitate rupture or extrusion of nucleus pulposus. Five of the six reported symptomatic cases were women, as was our patient too. Bodechtel's patient was in the 7th month of her pregnancy and our patient was regularly taking Enovid tablets.

As to the mode of access of this material to spinal cord blood vessels Naiman *et al.* considered in addition to rupture of the annulus fibrosus and direct penetration of cartilaginous material into a simultaneously torn radicular artery, the possibility of increased pressure within a disc with intact annulus fibrosus and

embolization through persistent vessels of the nucleus pulposus which are sometimes seen in children up to adolescence. A third possibility mentioned by them was anomalous vasculature outside but close to the intervertebral disc. Laterre considered the possibility of the emboli representing organized thromboemboli with a cartilaginous metaplasia but he rather favored the mechanisms postulated by Naiman *et al.* Feigin *et al.* felt that the first step in the process is extrusion of disc material into the cancellous portion of the vertebral body (Schmorl's nodes, found in about 38% of adult population). Fragments of such material may gain access to sinusoids and veins of the marrow and if this process is coupled with increased intrathoracic pressure (e.g. coughing) retrograde transport to spinal cord veins may follow (in analogy with suggested retrograde venous spread through spinal venous plexuses in prostatic carcinoma and other disease processes (*Batson* [6]).

We would tend to agree with Feigin *et al.* as to the pathomechanism of this embolization at least in those cases where the cartilage emboli are located primarily in veins. It is known from the anatomical studies of *Suh* and *Alexander* [7] that there are direct communications between the veins of the spinal cord and the radicular veins. These authors injected a mixture of India ink and formaldehyde into the anterior spinal vein to study the extent of possible retrograde flow. They found that no valves existed to stem retrograde flow in these veins at least not until the transition between veins of the 4th and 3rd order. There they observed rudder-like intimal cushions that prevented retrograde filling of small venules and capillaries.

In order to visualize retrograde venous flow from vertebral body to spinal cord we have injected 5 cc of 50% India ink/formaldehyde into the body of the 4th cervical vertebra in an 8 week old infant who died of unrelated causes. Using slight manual pressure and a 20 cc syringe with a 16 gauge needle, we were able to fill with India ink most of the spinal epidural venous plexus as well as the superficial veins of the spinal cord. The filling of radicular veins was quite conspicous (Fig. 5a) and India ink was observed in pial veins as high as the pontomedullary junction (Fig. 5b). Microscopic sections of this cord showed India ink particles within pial and intramedullary veins and venules but nowhere was any arterial filling observed. The relatively easy access of intra-osseously injected India ink to the spinal cord and medulla makes it likely that fibrocartilage emboli could follow the same route, particularly if, because of degeneration, the cartilage undergoes partial liquefaction.

Feigin *et al.* have postulated that the occasional presence of embolic material in *arterioles* may be explained by small arteriovenous shunts in the spinal vasculature. When the *majority* of cartilagnous emboli are found to obstruct arteries and arterioles as in Naiman's, Laterre's and our own case then the possibility of direct access, perhaps through traumatic communications between arteries and veins should also be considered. In Naiman's case at least, this trauma was well documented and in our case the organizing cervical epidural hematoma attests to the likely seriousness of the car accident in the patient's history. In the cases of predominantly arterial occulusion there is a better correlation between the type of vascular occlusion and the resulting infarcts since the latter have been described in all the reported cases as being of the ischemic type and lacking the marked

hemorrhagic component one usually associates with infarcts caused by venous occlusion. This was also true for the spinal cord and medullary infarcts seen in our case.

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