Fibrocartilaginous embolism of the spinal cord: a clinical and pathogenetic reconsideration

Luigi Tosi, Gianfranco Rigoli, Alberto Beltramello

Abstract
A 16 year old girl did a handstand for fun, returned to her feet, experienced a sudden pain in her back, and became progressively paraplegic within 30 hours. MRI showed lumbar cord swelling, multiple Schmorl's nodes, a collapsed T11-T12 disc space, and intraspedous disc prolapse into the T12 vertebral body. These findings, related to the initial manœuvre, suggested that an acute vertical disc herniation could have occurred as the first step in a process leading to spinal cord infarction due to fibrocartilaginous emboli from the nucleus pulposus of the intervertebral disc. The medical literature so far reports 32 cases of fibrocartilaginous embolism (FCE) of the spinal cord, at all necropsy, with the exception of one histologically demonstrated in a living patient. A clinical diagnosis of FCE would be desirable for many important reasons, but was never made. This causes severe limitations in the knowledge of the disease and precludes any therapeutic possibility. On the basis of the clinical features and findings in the present case, compared with data from the reported cases, a first attempt is made to identify the clinical context within which new information obtainable through MRI examination can lead to a reliable clinical diagnosis of FCE. The vexed question of the pathogenesis has been reviewed. An increased intraosseous pressure within the vertebral body, due to acute vertical disc herniation, seems to offer a consistent pathogenetic explanation and some therapeutic prospects.

Keywords: fibrocartilaginous embolism; spinal cord infarction; intervertebral disc; magnetic resonance imaging

In 1961 Naiman et al. reported the case of a 15 year old boy who was thrust backward to the floor during a basketball game, rose and completed the game, then complained of a sudden epigastric pain spreading to his back, neck, and shoulders. He became progressively tetraplegic with breathing difficulties and died three hours later. At necropsy, the lethal lesion proved to be multiple fibrocartilaginous emboli from the nucleus pulposus of the intervertebral disc to the upper cervical cord and adjacent brainstem. Since then, 31 other cases of fibrocartilaginous embolism (FCE) of the spinal cord have been reported (table). All were fatal, with the exception of one patient with rapidly evolving paraplegia, in whom laminectomies were performed and fibrocartilaginous emboli found.

Summary of reported cases of fibrocartilaginous embolism of the spinal cord vessels

<table>
<thead>
<tr>
<th>Case reference</th>
<th>Year</th>
<th>Age/sex</th>
<th>Progression</th>
<th>Death after</th>
<th>Site</th>
<th>Embolism AV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Naiman1</td>
<td>1961</td>
<td>16/M</td>
<td>1 hour</td>
<td>3 hours</td>
<td>MO-C2-T2</td>
<td>A (ASA)</td>
</tr>
<tr>
<td>2 Laterre2</td>
<td>1962</td>
<td>31/F</td>
<td>2 hours</td>
<td>3 months</td>
<td>C6-T1</td>
<td>A (ASA)</td>
</tr>
<tr>
<td>3 Feigen et al3</td>
<td>1965</td>
<td>49/F</td>
<td>Some hours</td>
<td>6 weeks</td>
<td>C6-T6</td>
<td>V (ASA)</td>
</tr>
<tr>
<td>4 Feigen et al3</td>
<td>1965</td>
<td>39/F</td>
<td>50 minutes</td>
<td>4 days</td>
<td>C4-T6</td>
<td>A-V (PSA)</td>
</tr>
<tr>
<td>5 Bodechtel4</td>
<td>1968</td>
<td>28/F</td>
<td>12 hours</td>
<td>6 days</td>
<td>MO-whole cord</td>
<td>V (ASA)</td>
</tr>
<tr>
<td>6 Bruno et al5</td>
<td>1969</td>
<td>47/F</td>
<td>40 hours</td>
<td>4-5 months</td>
<td>C1-C7</td>
<td>A-V (ASA)</td>
</tr>
<tr>
<td>7 Lvovsky6</td>
<td>1969</td>
<td>21/M</td>
<td>4 hours</td>
<td>5 days</td>
<td>C2-C7</td>
<td>A (ASA)</td>
</tr>
<tr>
<td>8 Jerkovic and Eiben7</td>
<td>1970</td>
<td>66/F</td>
<td>?</td>
<td>18 days</td>
<td>C7-T-L</td>
<td>V (ASA)</td>
</tr>
<tr>
<td>9 Kepes and Reynolds8</td>
<td>1973</td>
<td>38/F</td>
<td>1 hour</td>
<td>40 days</td>
<td>MO-C4</td>
<td>A-V (ASA)</td>
</tr>
<tr>
<td>10 Huber et al9</td>
<td>1974</td>
<td>63/F</td>
<td>?</td>
<td>Some hours</td>
<td>C3-C7</td>
<td>A-V (ASA)</td>
</tr>
<tr>
<td>11 Hubert et al10</td>
<td>1975</td>
<td>17/F</td>
<td>48 hours</td>
<td>11 days</td>
<td>C4-T6</td>
<td>A (ASA)</td>
</tr>
<tr>
<td>12 Rottensch et al11</td>
<td>1975</td>
<td>69/F</td>
<td>?</td>
<td>11 months</td>
<td>T12-L4</td>
<td>A-V (ASA)</td>
</tr>
<tr>
<td>13 Peiffer et al12</td>
<td>1976</td>
<td>36/M</td>
<td>48 hours</td>
<td>2 months</td>
<td>?</td>
<td>A-V = A*</td>
</tr>
<tr>
<td>14 Hanski et al13</td>
<td>1977</td>
<td>51/M</td>
<td>?</td>
<td>4 days</td>
<td>C5-T1</td>
<td>A (ASA)</td>
</tr>
<tr>
<td>15 Schaeter and Von Albert14</td>
<td>1977</td>
<td>19/F</td>
<td>3 hours</td>
<td>9 months</td>
<td>C5-T-L</td>
<td>A-V (PSA)</td>
</tr>
<tr>
<td>16 Budka et al15</td>
<td>1979</td>
<td>49/F</td>
<td>10 hours</td>
<td>14 weeks</td>
<td>T11-conus</td>
<td>A-V (PSA)</td>
</tr>
<tr>
<td>17 Ho et al15</td>
<td>1980</td>
<td>22/F</td>
<td>30 minutes</td>
<td>9 days</td>
<td>C3-T1</td>
<td>A (ASA)</td>
</tr>
<tr>
<td>18 Bots et al16</td>
<td>1981</td>
<td>29/F</td>
<td>2.5 hours</td>
<td>15 days</td>
<td>MO-C1-T4</td>
<td>A</td>
</tr>
<tr>
<td>19 Bots et al16</td>
<td>1981</td>
<td>32/F</td>
<td>3 hours</td>
<td>11 months</td>
<td>MO-C1-T5</td>
<td>A-V (ASA)</td>
</tr>
<tr>
<td>20 Bots et al16</td>
<td>1981</td>
<td>77/M</td>
<td>Some hours</td>
<td>22 hours</td>
<td>C1-C4</td>
<td>A</td>
</tr>
<tr>
<td>21 Bots et al16</td>
<td>1981</td>
<td>60/F</td>
<td>?</td>
<td>3 months</td>
<td>T10-T11</td>
<td>A</td>
</tr>
<tr>
<td>22 Stingley et al17</td>
<td>1981</td>
<td>45/M</td>
<td>17 hours</td>
<td>1 month</td>
<td>C3-C6</td>
<td>A (ASA)</td>
</tr>
<tr>
<td>23 Kase et al18</td>
<td>1983</td>
<td>23/F</td>
<td>Minutes</td>
<td>12 days</td>
<td>MO-C5</td>
<td>A</td>
</tr>
<tr>
<td>24 Barz and Majerowitsch19</td>
<td>1986</td>
<td>56/F</td>
<td>2 hours</td>
<td>13 days</td>
<td>T12-conus</td>
<td>A</td>
</tr>
<tr>
<td>25 Barz and Hachebel20</td>
<td>1989</td>
<td>77/F</td>
<td>4 hours</td>
<td>14 days</td>
<td>S-conus</td>
<td>A</td>
</tr>
<tr>
<td>26 Banerjee and Drobhat21</td>
<td>1989</td>
<td>21/M</td>
<td>2 hours</td>
<td>14 days</td>
<td>C2-T6</td>
<td>A</td>
</tr>
<tr>
<td>27 Kestle et al22</td>
<td>1989</td>
<td>43/M</td>
<td>48 hours</td>
<td>14 days</td>
<td>T2-conus</td>
<td>A</td>
</tr>
<tr>
<td>28 Bockenhoff et al23</td>
<td>1990</td>
<td>20/M</td>
<td>Some hours</td>
<td>6 years</td>
<td>C4-T4</td>
<td>? (ASA)</td>
</tr>
<tr>
<td>29 NEJM24</td>
<td>1991</td>
<td>13/M</td>
<td>6 hours</td>
<td>Hours</td>
<td>C2-C4</td>
<td>A</td>
</tr>
<tr>
<td>30 NEJM24</td>
<td>1991</td>
<td>64/F</td>
<td>Hours</td>
<td>Alive</td>
<td>T11-S1</td>
<td>A-V</td>
</tr>
<tr>
<td>31 Moorhouse et al25</td>
<td>1992</td>
<td>63/F</td>
<td>35 hours</td>
<td>2 days</td>
<td>T10-L1</td>
<td>A (ASA)</td>
</tr>
<tr>
<td>32 Toro et al26</td>
<td>1994</td>
<td>16/F</td>
<td>15 minutes</td>
<td>6 weeks</td>
<td>L-S</td>
<td>A-V</td>
</tr>
</tbody>
</table>

Progression = time from sudden pain at onset to maximum neurological deficit; Embolism AV = emboli in arteries, veins, or both; discriminates between A and V; A = arteries; V = veins; MO = medulla oblongata; C = cervical; T = thoracic; L = lumbar; S = sacral; Conus = conus medullaris; ASA = territory of the anterior spinal artery; PSA = territory of the posterior spinal arteries; ? = not given; *exclusively arterial on re-examination by Schaeter and Von Albert.27

Ospedale "Sacro Cuore", Negar, Verona, Italy
L Tosi
G Rigoli

Istituto di Radiologia, Universita di Verona, Italy
A Beltramello

Correspondence to:
Dr Luigi Tosi, Servizio di Neurologia, Ospedale "Sacro Cuore", 37024 Negar, Verona, Italy.

Received 20 March 1995
and in revised form 22 August 1995
Accepted 6 September 1995
laginous emboli were histologically demonstrated in the vessels of the spinal cord. Only one fatal case of systemic FCE with cerebral and myocardial infarction has been reported. So far the diagnosis of FCE has only been from histology. There are, however, important reasons for aiming at a clinical diagnosis. The disease is probably not as rare in humans as it seems. In animals, and especially in dogs, it is frequent enough to appear in a veterinary review under the heading "common neurologic problems." Many patients probably survive with no definite diagnosis or are classed as something else—for example, as acute transverse myelitis, acute ischaemic or necrotising myelopathy, anterior spinal artery syndrome, Guillain-Barré syndrome, or spinal cord injury without radiographic abnormalities. The relative frequency of the involved spinal cord level is surely distorted. Cervical localisation is apparently more frequent because fatal cases mainly result from the involvement of the cervical cord and adjacent medulla oblongata, whereas lumbar localisation, leading to death only after complications, should be more frequent, as in any other diseases of the intervertebral discs. The number of pathological diagnoses is certainly reduced in the absence of clinical suggestion. The histological diagnosis of FCE requires multiple specific stains of many sections and careful identification of the emboli in the regional vasculature, a non-routine examination that would be carried out appropriately only on clinical indication. All this is attested by the experience of Bots et al.: in their second and third cases, the diagnosis was suspected before death on the basis of previous experience, and a fourth case resulted through re-examination of a specimen used in a teaching programme under the diagnosis "acute transverse myelopathy." A better understanding of this peculiar type of embolism "must await a firm clinical diagnosis in a living patient." In fact, the study of the pathogenesis is impoverished without ante-mortem suggestion. When the histological diagnosis on fixed specimens arrives, after some weeks, the time for a profitable investigation of the vertebral column is over. Moreover, the clinical presentation of FCE is that of a sudden pain in the back or the neck, followed by a progression of signs and symptoms indicating a spinal stroke in evolution. A therapeutic intervention could be possible, provided that a clinical diagnosis is made. On the basis of the clinical features and findings of the reported case compared with data from the histologically demonstrated cases, a first attempt is made here to identify the clinical setting within which new information obtainable through MRI examination can lead to a reliable clinical diagnosis of FCE of the spinal cord.

Case report
A 16 year old girl was in good health on the afternoon of 7 May 1994, when she cycled to her grandmother’s house to play with her cousins. She was active and sport loving, her only complaint being some back pain after exertion. She did a handstand for fun, to show off. When she got up, she “felt something snap” and experienced a sudden pain in her back. She cycled home and rested for half an hour but the back pain persisted, radiating down to her upper thighs. Walking became more and more difficult; pain radiated first to the left and then to the right leg, while her left foot weakened. At 1100 pm she was admitted to a neurological department. Flexion and extension of the foot were abolished on the left and weak on the right, whereas the strength in the proximal segments was preserved. Knee jerks were normal, ankle jerks were absent, and the plantar responses were unobtainable. Touch, pain, and temperature appreciation were reduced on the left leg below the knee, but proprioception was preserved. During the night the back pain persisted and micturition became difficult. Next morning she could stand only with support. Knee jerks were also abolished and touch, pain, and temperature sensation were reduced bilaterally below the knee. In the afternoon the weakness progressed to paralysis and there was urinary

Figure 1 Day 3 MRI of the lumbar region. The T1 weighted sequence (left) shows enlargement of the distal cord and conus, without evidence of enhancement. The T2 weighted sequence (right) shows increased signal within the cord from T11 to L1 vertebral level. (By kind permission of the Service of Neuroradiology, City Hospital, Verona.)

Figure 2 Day 10 MRI of the thoracic (left) and lumbar region (right). The T2 sequences show extension of signal hyperintensity within the cord to the mid-dorsal region. Conus enlargement is more evident. (By kind permission of the Service of Neuroradiology, City Hospital, Verona.)
Fibrocartilaginous embolism of the spinal cord: a clinical and pathogenetic reconsideration

Figure 3 Follow up MRI study five months later. In the T1 weighted image (left) pronounced atrophy of the epiconus is evident maximally at the T11-T12 vertebral level, and the T2 image (right) shows signal hyperintensity within the atrophic cord. In all the MRI studies, the T11-T12 intervertebral disc space appeared very narrow with a vanishing nucleus pulposus signal and very large Schmorl’s nodes at the opposite end plates.

retention with complete sensory loss below T12. Plain spinal radiographs showed Schmorl’s nodes in the thoracolumbar region but no evidence of fracture. Her CSF was normal. She was transferred to a neurosurgical department. Neurological examination confirmed full paraplegia with flaccid areflexic lower extremities and absent pinprick sensation below T12; proprioception was also abolished. An MRI study 48 hours after onset showed enlargement of the distal cord and conus medullaris, with a non-enhancing area of increased signal intensity on the T2 weighted sequences (fig 1). Conventional and computed myelography were non-contributory. Selective spinal angiography showed a patent great radicular artery arising at the T8 vertebral level on the left but no evidence of dissecting aneurysm or vascular malforma-

Figure 4 (A) Day 10 MRI. Cross section of the T12 vertebral body shows prolapse of disc material into the vertebral body. (B) Schematic drawing inspired by Netter.44 Nucleus pulposus material prolapsed under pressure into the cancellous bone of the vertebral body causing retrograde arterial embolisation to several segments of the spinal cord, mainly in the territory of the anterior spinal artery.
tions. Brain and cervical region MRI was normal. Sensory conduction velocity was normal whereas motor conduction velocity was unobtainable and EMG showed complete denervation in the lower limbs. No abnormalities were found in the upper limbs. At a control MRI on day 10 (fig 2), the area of increased signal intensity on T2 in the enlarged segments had extended and other poorly defined areas of increased signal intensity appeared in the mid-dorsal region. Examination of CSF showed an increase of protein content to 1.43 g/l. An extensive investigation of blood and CSF for metabolic, infectious, and immunological changes was negative. Paraplegia remained complete. A follow up MRI study five months later (fig 3) showed pronounced atrophy of the lower spinal cord. As in the first MRI study, the T11-T12 intervertebral disc space seemed very narrow, and cross sections showed intraspinosus disc material in the T12 vertebral body (fig 4A). Five very large Schmorl's nodes were present in the thoracolumbar region.

Discussion
The serial MRI studies showed that this patient had an infarction of the lower spinal cord and conus. Cord swelling and increased T2 signal in the acute phase, atrophy, and dyshomogeneous signal intensity in the chronic phase are typical findings of infarction, in the absence of cord compression and of any other known neurological disease. In our other patient the MRI study also showed multiple Schmorl's nodes, a collapsed T11-T12 intervertebral disc, and intraspinosus disc prolapse into the T12 vertebral body, suggesting that an acute vertical disc herniation could have occurred. In the pathologically established cases of FCE, radiological assessment with plain spine radiographs, myelography, and CT has been unrevealing. Two studies used MRI. Kestle et al reported that MRI showed multiple Schmorl's nodes but no abnormalities of the spinal cord, and was considered of no diagnostic value. Serial MRI examination in the only living patient showed an evolution of spinal cord infarction similar to ours, with the difference of an initial slight haemorrhagic component. A later high T2 signal intensity within the T11 vertebral body was considered to be "a focal pathologic process within the bony marrow cavity." Buckled end plates and disc space reduction appear in the images but were not discussed.

In our opinion an MRI finding of cord swelling associated with a collapsed disc space at the appropriate level, in a corresponding clinical setting, should strongly suggest, if not prove, that a vertical disc herniation into a vertebral body had occurred as the first step of a process leading to FCE. The same criteria are considered to be valid for clinical diagnosis of FCE in veterinary medicine. For the assessment of the appropriate clinical setting the main features of the 32 so far histologically demonstrated cases have been examined and summarised in the table.

The patients range in age from 13 to 77 (mean 39) years, with a bimodal distribution: the first peak occurs in adolescence through young adulthood (mean 22 years), and the second in late middle age (mean 60 years). There is a net predominance of women, 22 of 32 cases.

Precipitating factors
A close temporal relation with a significant minor trauma comparable with our case occurred in six cases: falls, a jump with a drop of 80 cm, a forced head movement during a brawl, and somersaults. In five patients symptoms appeared on awakening, in others after physical effort or Valsalva-like manoeuvres. Low back pain was present in the history of several patients; vehicle accident, vertebral body fracture, lumbar disc surgery, pregnancy, oral contraceptive, or corticosteroid treatment occurred in the history of one patient each. No relevant precipitating factor was reported in most cases. The hypothesis of a vertical disc herniation makes the discussion about precipitating factors very similar to that regarding posterior disc herniation, where only in a minority of cases can a clear time relation be established between minor trauma or physical effort and onset of symptoms.

Clinical features
In the clinical course of the histologically established cases of FCE, three main characteristics distinguishing it from thrombotic or embolic spinal cord infarction could be identified. The first was the sudden severe pain at onset, localised in the neck and the interscapular region in cases with cervical cord involvement, and in the back in cases with lumbar cord involvement. Extension of the pain to the chest or abdomen occurred in some cases, with the character of a somatic referred pain. In thrombotic or embolic infarction, a sudden pain can be absent and is hardly the leading symptom. If present, it has a radicular or girdle distribution. As a second characteristic, the neurological signs and symptoms in FCE had a free interval and a progression in time indicating a "spinal stroke in evolution." The interval from onset of pain to maximum neurological deficit ranged when definable from 15 minutes to 48 hours (table). In thrombotic or embolic infarction numbness and weakness of the limbs appear at onset, in most cases abruptly and at the same time as pain, if present. As a third characteristic, no case of FCE showed a significant improvement of the neurological deficit, whereas most patients with thrombotic or embolic infarction show substantial recovery, so that the favourable course contributes to the final diagnosis. A further difference is the higher prevalence of young women with FCE and of late middle aged or older men with thrombotic or embolic infarction.

Neuropathological lesions (table)
In 22 (69%) of the 32 reported cases, embolisation occurred in the cervical cord, extending in some patients to the lower medulla oblon-
Fibrocartilaginous embolism of the spinal cord: a clinical and pathogenetic reconsideration

Fibrocartilage within the marrow spaces was documented in other cases, and in the study of Srigley et al. the C2-C3 vertebral bodies were directly apposed, whereas disc tissue was displaced into the C3 vertebral body through microfractures in the endplate and fragments were found as emboli in the sinusoids of the bony marrow. Barz found in both reported cases fresh intrusion of fibrocartilage, surrounded by granulation tissue, in the marrow of one vertebral body. Emboli were found in sinusoids and veins and also in arteries, and these were considered to be the site of entry of disc material into the vascular system. From there emboli could be forced by retrograde flow into the segmental arteries to reach the spinal cord by anterograde flow. The vis a tergo should be supplied by high intraluminal pressure. Barz's pathogenetic hypothesis, pointing at the arteries of the vertebral body as entry site of the emboli, allows a coherent explanation of the subsequent events, only his assumption of high intraluminal pressure as source of the vis a tergo being unconvincing. The intraluminal pressure must abruptly decrease after nucleus pulposus extrusion and could hardly support the progression of symptoms. The source of the propulsive force is more likely to be increased intraspinal pressure due to forced intrusion of disc material into the marrow spaces of a non-dilatable vertebral body. A cadaveric experiment by Yoganandan et al. reproduced this mechanism. A functional unit consisting of two lumbar vertebrae with the interposed disc was excised. Radio-opaque dye was injected into the nucleus pulposus and its movements were monitored under fluoroscopy. Transducers were inserted into the vertebrae to record intraspinal pressure. Progressive loading was applied until injury occurred. Before reaching the limiting load and before any radiologically demonstrable fracture, one of the endplates buckled and contrast medium moved into the spongiosa, while the intraspinal pressure rapidly increased in comparison with the pressure in the vertebral body with intact end plates.

Acute symptomatic intraosseous disc herniation without involvement of the spinal cord has been demonstrated on radiographs after bony reaction; MRI was more sensitive showing prompt loss of signal intensity in the affected intervertebral disc space, confirmed later by changes in the underlying cancellous bone. Acute herniation into a vertebral body must lead to increased intraspinal pressure, according to Yoganandan et al. At lower levels of increase in pressure, disc material remains in situ or may be pushed into the venous system with subclinical embolisation to the lungs, this being the usual outcome. A retrograde flow of emboli to the spinal veins may remain asymptomatic as well. At unusually high pressures, disc material can be forced not only into the veins but also into the arteries of the vertebral body, as shown by Barz and Barz and Hackebeli. Only in cases where the intraspinal pressure is persistently high enough to cause a lasting arterial reversal flow.
can a progressive embolisation of the spinal cord occur (fig 4B). This condition may account for the rarity of the event. The infarction is due to embolic arterial occlusion, whereas venous emboli, mostly asymptomatic, are an accessory finding. This explains the fact that the spinal infarction in FCE is always of the arterial type, even when both arterial and venous emboli are present. The involvement of the territory of the anterior spinal artery in most cases, and of several spinal segments in each case, is explained by the anatomy of the spinal vessels (fig 4B). An arterial microembolisation is also explained by the clinical course of FCE by comparison with thrombotic or embolic infarction. The spinal cord is well protected by extensive arterial anastomoses and the occlusion of larger arterial branches may cause an abrupt onset of signs and symptoms but allows a functional recovery in most cases. The progressive occlusion of the end flow system of the intrinsic spinal arteries must cause definitive damage. Finally, the envisaged pathogenetic mechanism allows some therapeutic prospects. Measurements of intraosseous vertebral pressure can be performed in vivo and elevates from which could be found as a way to stop the progression of embolism. Drugs with a lytic effect on fibrocartilaginous emboli could also be conceived. Of course, "a firm clinical diagnosis" is needed first. An obstacle may be the tendency to consider FCE as an odd disease, a "lusus naturae", which it is not. After the first description in a human, FCE was described in the dog. Since then there have been numerous reports of this condition in dogs, as well as isolated cases in horses, pigs, cats, and lambs. In the dog the mechanism cannot be formation of Schmorl's nodes, these being almost unknown in relation to the different loading pattern of quadruped posture; a direct passage of disc material into the vessels is the most accepted explanation. In any case, the comparative pathology demonstrates that FCE is a pathological pattern common to various species of vertebrates, with differences reflecting the course of evolution.

13 Lyspvky AM. Embolias spondalnog mozgo (kutanu meszczonowisko dioka: embolism of spinal vessels by tissue of the intervertebral disc), Z Neurochir Plikatnom Korahov 1969:8:1151-1153.
34 Griffiths IR. Spinal cord infarction due to emboli arising from the intervertebral disc in the dog. J Comp Pathol 1979;83: 225-32.