Journal of Spinal Disorders
Vol. 7, No. 2, pp 111–119

Pathogenesis of Uncus Deformation and Vertebral Artery Compression: Histologic Investigations of the Uncus and Dynamic Angiography of the Vertebral Artery in the Cadaveric Cervical Spine

Francesco Benazzo, *Alberto Araujo Alvarez, †Darcio Nalli, Alberto Pio, and ‡Jose Laredo Filho

*Istituto di Clinica Ortopedica e Traumatologica della Università di Pavia, Policlinico S. Matteo, IRCCS, Pavia, Italy; *Hospital Americano, Lima, Peru; and the †Radiologic Service and ‡Orthopaedic Department, Hospital Sao Paulo, Escola Paulista de Medicina, Sao Paulo, Brazil*

Summary: Twenty-one cervical spines were collected from fresh cadavers (12 male, nine female), their ages ranging from 10 to 90 years (mean 49.47). After removing muscle debris from the spines, they were mounted and tested on a device to passively reproduce the main movements of the spine. The degree of motion in flexion–extension and lateral bending significantly decreased from group A (ages 10–49 years) to group B (51–90 years) ($p < 0.005$) and was directly correlated with the amount of cervical spine degenerative alterations. The incidence of these alterations, classified according to Lysell (1969), was highest at C5–6. On the testing machine, dynamic angiography of the vertebral artery showed an impingement with extrinsic compression of the vessels in four of 28 successful injections. The histologic serial sections of the uncus showed a characteristic pattern of ossification–deformation: a newly formed cartilaginous tissue tipping the apex of the uncus, forming a double protruding contour of the apex, rapidly ossifying, and appearing to deform outward together with the disk degeneration and consequently decreasing in height. **Key Words:** Uncus—Vertebral artery impingement—Cartilage.

Degenerative alterations of the neurocentral (or uncovertebral) joints, which were studied in detail by Luschka (20), are one of the very early changes in cervical spondylosis. Moreover, these changes are of marked clinical relevance because they may be responsible for syndromes caused by vertebral artery compression and/or irritation, nerve root compression, or both (17,18,22,27).

Address correspondence and reprint requests to Francesco Benazzo, Istituto di Clinica Ortopedica e Traumatologica della Università di Pavia, Via Taramelli 3, 27100 Pavia, Italy.

Degeneration of the cervical spine units, including these processes, is common in the general population, even if frequently asymptomatic (10). This degeneration is mainly due to the wide range of motion of the cervical spine, given its anatomic conformation, and mainly by the apophyseal joints. Moreover, the unci preserve and support the spine's pattern of motion (especially rotation; 12), and protect the disk (23) in a form of functional adaptation (24). This role exposes the unci to early degeneration, as noted in anatomic studies on large series of spines from cadavers (13). However, the process of uncus deformation and its

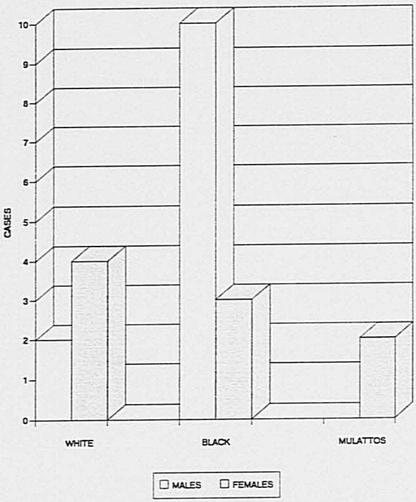


FIG. 1. Race and sex distribution: Men and balcks were prevalent.

role in causing progressive arterial and/or neural compression has not yet been completely clarified.

The aim of this article is to specifically investigate this pathologic process from the morphologic point of view and to study the characteristics of vertebral artery compression with dynamic angiography in a series of spines obtained from cadavers.

MATERIALS AND METHODS

Twenty-one cervical spines (C1–C7) were collected from fresh cadavers at the Service of Pathologic Anatomy of the Hospital Sao Paulo, Escola Paulista de Medicina, Sao Paulo, Brazil. Twelve were male and nine female. Race and age distribution is shown in Figs. 1 and 2. The mean age was 49.47 years (49.41 for males, 50.22 for females).

Death was caused by infectious diseases (pneumonia, meningitis, hepatitis) in younger subjects; by heart disease (also with pulmonary complications) in middle aged and old females and males; and by cirrhosis of the liver and pancreatitis in middle aged males. The subjects visibly affected by acquired immunodeficiency disease were excluded, as were those whose death was caused by traumatic events.

Withdrawal Technique

The spines were removed via the anterior approach. Subclavian arteries were isolated after ablation of the esophagus and trachea, and the vertebral arteries were resected with part of the former vessels. C7 and D1 were divided with an osteotome inserted into the disk space; all muscle tissue was removed from the vertebral bodies up to the lateral masses of C1. The osteotome was then inserted from each side above the arch of C1, and the occipital condyles were detached from the base of the skull.

Radiographic and Dynamic Investigations

The spines were immediately cleaned of any muscular debris, and the vertebral arteries were washed with

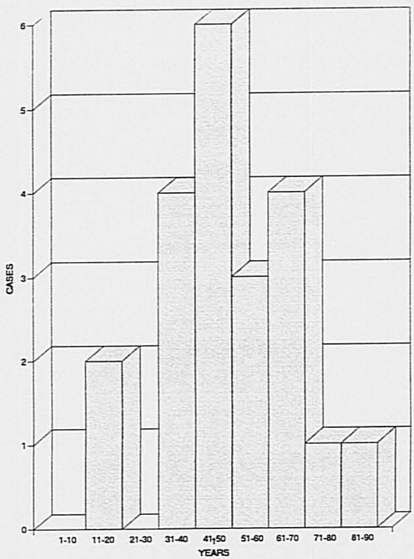


FIG. 2. Age distribution: Decades between 31 and 70 yr were the most represented.

A,B

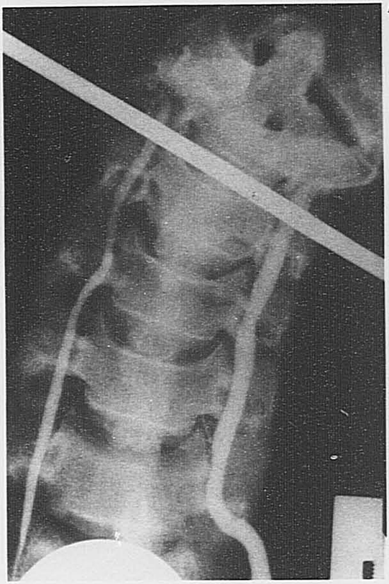


FIG. 3. The specially built device (**A**) allows a manual progressive motion of the fresh cervical spines in different directions by pulling with a graduated winch a pin inserted through the body of C2 in the sagittal plane for flexion and extension, and in the frontal plane for lateral bending; dynamic angiography of the vertebral arteries was realized in these phases (**B**).

saline solution. Standard radiographs were taken in anteroposterior (AP) and lateral views. Each spine was then tested on a specially designed device that reproduced flexion–extension and lateral bending (Fig. 3A and B). Each movement was started from the neutral position naturally assumed by the spine when unloaded and deprived of muscles and was realized with the maximum intensity allowed by the device. The maximum force that was allowed by the device before breaking of the reflexion girdles was 220 N; we obtained our range of motion of the cervical spine with a couple of 8 Nm. This force was applied in the three directions (flexion, extension, and inclination). The spine was photographed in each different position; the range of motion was measured in vivo and on the films.

Using the same device, the vertebral arteries were injected with contrast medium (Iopamiro), which was retained by clamping the arteries at the base of the spine before their entrance in the intertransverse space, and radiographs were taken in AP views with left and right inclination to visualize the vertebral arteries and any possible impingement caused by deformed unci. After completion of the dynamic and radiographic studies on fresh spines, the specimens were fixed by immersion in buffered formol (10%).

The degree of degenerative changes was assessed radiographically based on the classification adopted by Lysell (21) (Table 1) (which assigned a score from 0 to 3 for normal to severely degenerated spines) to calculate the range of motion in the presence of arthrotic changes and to correlate the two aforementioned parameters.

TABLE 1. *Radiographic changes*

0	Normal height, no osteophytes
1	Slight reduction of the disk level Minimal to small osteophytes
2	Pronounced reduction of disk level Moderate osteophytes Slight subcondral sclerosis
3	Pronounced to total reduction of the disk level Large osteophytes

TABLE 2. *Mean motion of 21 spines (C2–C6)*

Flexion	15.48 ± 1.61°	36.91
Extension	21.43 ± 2.016°	
Inclination (R)	12.05 ± 1.372°	22.10
Inclination (L)	10.52 ± 0.812°	

Macroscopic and Histologic Investigations

After fixation, each spine was cut with a bone saw in the sagittal plane through the center of the bodies, and the two halves were examined and photographed to observe disk degeneration. A frontal cut passing through the unci also was made. These specimens were also observed and photographed. Some of these specimens were decalcified and included in paraffin, and some were included in resin without decalcification. These specimens were abraded with a grinding Exakta device down to a thickness of ~10 μm. Four unci from each spine were observed (C3, C4, C5, C6). Serial slices were collected and stained with hematoxylin and eosin, alcian blue, safranin orange, and von Kossa.

RESULTS

Dynamic Investigations

Degrees of spinal motion are shown in Tables 2 (mean motion of 21 spines), 3 (group A, ages 10–49 years, 11 subjects), and 4 (group B, ages 50–90, 10 subjects). The difference in range of motion (flexion and extension) between groups A and B is significantly different from a statistic point of view (Student's t test) ($p < 0.005$).

Degenerative changes are shown in Figs. 4 (21 spines), 5 (group A), and 6 (group B). Most of the degenerative changes were found in disk space C5–6 in all groups considered. This interspace was involved in 100% of older subjects, with various degrees of degeneration.

TABLE 3. *Mean motion, group A[a] (C2–C6)*

Flexion	19.09 ± 2.32°	45.45
Extension	26.36 ± 2.02°	
Inclination (R)	13.64 ± 2.34°	25.26
Inclination (L)	11.64 ± 1.26°	

[a] Patients in group A were 12–49 years of age.

TABLE 4. *Mean motion, group B[a] (C2–C6)*

Flexion	11.5 ± 1.50°	27.5
Extension	16.0 ± 2.77°	
Inclination (R)	10.30 ± 1.19°	16.3
Inclination (L)	9.0 ± 0.91°	

[a] Patients in group B were 50–90 years of age.

Radiographic Investigations

Dynamic angiography was performed in 28 vertebral arteries (in six cases monolaterally). In the remaining 14, angiography was not successful due to technical difficulties in the withdrawal of the vertebral arteries, occlusion due to atheromas, or unknown reasons.

Results are reported in Table 5. Deviation and impingement due to uncus deformation was found in four cases (14%): at C5–6 on the right side in one subject (66 years of age) (Fig. 7), at C4–5 in the other cases (in one subject bilaterally, 57 years of age; in the other subject on the right side, 70 years of age).

Impingement was markedly increased in dynamic passive maneuvers at C5–6 and the increase was less evident at C4–5 in the 57-year-old subject.

Microscopic Investigations

Histologic examination of the unci was systematically conducted on all serial slices of each specimen, presenting as normal to severely altered uncal processes.

The normal unci differed in height according to the disk level and level of section in the frontal plane (they appear higher in the lower cervical spine and at the posterior edge of the vertebral body). The general architecture was similar: the lateral side of the disk was interposed between the apex of each uncus and the opposite "echancrure" of the upper vertebral body. The disk was not contained by true anterior and posterior intervertebral ligaments.

We found many longitudinal, multiple clefts extending medially to laterally that were probably responsible for an early decrease in thickness of the lateral portion of the disk, which can mostly be independent from that of the central part (Fig. 8A and B). The

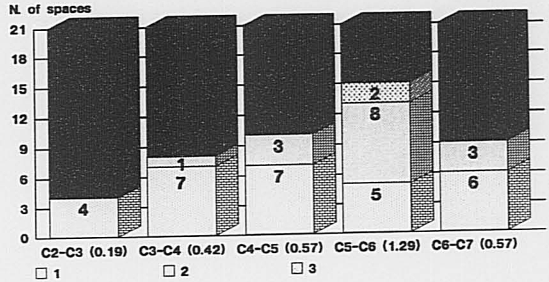


FIG. 4. Degenerative alteration of the spines according to Lysell (1969). (0 = black) All cases.

most lateral portions of the disk bulged outward from the narrowed uncovertebral joint and above the apex of the uncus, mainly because of the above-mentioned lack of a true intervertebral ligament.

The apex of each uncus showed a cartilaginous tip, probably of the same nature of the vertebral plate, usually of small dimensions (Fig. 9A). This island of cartilage clearly appeared to be stimulated with cloning and production of new, rapidly ossifying matrix, together with the above-described alterations of the lateral disk. This newly formed tissue formed a double protruding contour of the apex of the uncus, whose bony shape did not change in this first phase but increased in height (Fig. 9B and C). This neo-uncus appeared to progressively deform itself outward (Fig. 9D).

In some cases, fusion of the fibrocartilaginous front with the protruded disk was observed, creating a bulging tissue first composed of cartilaginous, and then calcified, islands, thus creating the deformed osteophytelike uncus. In many cases, the already deformed uncus appeared to be still covered by fibrocartilaginous tissue. Therefore, its size is probably greater than that calculated on radiographs (Fig. 9E).

Abnormality of the bony trabeculae of the uncus in the later stages, in the form of microfractures and reabsorption with formation of geodeticlike cavities, was also observed (Fig. 10A and B).

DISCUSSION

Many investigations on degenerative changes of the cervical spine due to aging and spondilouncoarthrosis have been performed. The purpose of this article was to focus attention on the deformation of the uncus, furnishing additional information to many previously published data (3–7). The device used for the dynamic trials was specially designed to investigate the vertebral arteries during motion, thus simulating the

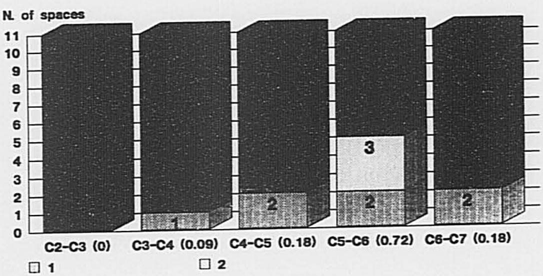


FIG. 5. Degenerative alteration of the spines. Group A: 12–49 years of age.

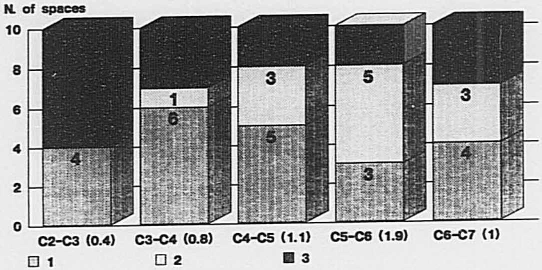


FIG. 6. Degenerative alteration of the spines. Group B: 50–90 years of age.

biomechanical conditions occurring in vivo and reproducing compression of the arteries in the presence of uncus deformation.

In the 28 vertebral arteries investigated with this technique, we observed many anomalies, such as hypoplasia, anomaly of entrance, and tortuosity with a loop into the vertebral bodies, as well as pathologic conditions such as intrinsic atherosclerotic narrowing. Deviation with impingement of the vertebral artery was demonstrated in four cases (14.3%). Passive motion increased the degree of compression, with a filling defect of the vessels. This impingement can cause clinical symptoms (cervicocephalic syndrome; 18). This percentage (14.3%) can be considered high; no other comparable data were available. In any case, the degree of spondylosis of our specimens (Figs. 4–6) was similar to that described in a normal asymptomatic population in the age range 20–65 years by Gore et al. (10). However, information on possible clinical symptomatology in our subjects, when alive, was not available.

Furthermore, the device also calculated the passive motion in flexion, extension, and lateral inclination of the segment C2–C6. Some degree of rotation has been associated with lateral flexion (9,23,25). However, technical reasons impeded calculation of rotation in our specimens; therefore, inclination was calculated as a pure movement. Measurements began from the neutral position (Eigenform; 8), assumed by the specimens when unloaded and deprived of the muscles. The purpose of these measurements was only to establish whether increasing age created a difference in the amount of motion. Our studies showed a range of motion similar to those found by Lysell (21) and much lower than that reported by other investigators (1,14,15). However, our flexibility and stiffness coefficients (data not presented in this article) are similar to those reported by White and Panjaby (26). These differences could be due to technical reasons (different measurement techniques and/or intrinsic defects of the machine) and to intrinsic differences of the specimens. However, we were able to demonstrate a statistically significant reduction in mobility with increasing age (Tables 3 and 4 and Figs. 5 and 6), according to the findings of Ball and Mejiers (1), Blanchard and Kottke (2), and Jones (16), but contrary to the findings of Fielding (9), Hadley (11), and Lysell (21). We wish to underline that a lack of full motion in vivo, caused by degenerative changes, actually decreases the possibility of true impingement of the vertebral arteries, even if deviated by uncus deformity.

In our specimens, we found wide fissurations of the lateral portion of the disk interposed between the apex of the uncus and the opposite vertebral body (Fig. 8A and B). These fissurations were also present in the youngest subjects and are due to the high stress forces applied by inclination and rotation movements in this area together with the areolar synovial-like tissue

TABLE 5. *Angiographic results*

	No. of cases
Normal pathway; normal diameter	12
Normal pathway; hypoplasia or small diameter	6
Deviation and impingement (extrinsic)	4
Tortuosity with normal diameter	1
Tortuosity with irregular diameter (intrinsic narrowing) due to arteriopathy	3
Normal pathway with irregular lumen (narrowing) due to arteriopathy	2
Anomaly of entrance	1

that penetrates from the outer portion of the vertebral bodies (13,19).

The changes and the deformation of the uncus appear in the first phases (youngest subjects) to be independent from the narrowing of the central portion of the disk space, whereas the lateral portion of the intervertebral disk interposed between the uncus and the upper vertebral body shows large fissures and clefts (as also demonstrated by Lysell; 21), resulting in a decreased buffering action of the forces created by inclination and rotation. Two normal cervical vertebrae show a pattern of motion of concentric gliding in lateral bending; therefore, the moments applied to the unci must be calculated from the geometric center of rotation of the vertebral body. In a degenerated vertebra, the moment of the uncus should be calculated at the opposite edge because the gliding motion is substituted by a hinge motion, which implies a considerably higher reaction force due to the lengthening of the lever arm (26). However, we should remember that "there are at the present no convincing estimates of the instantaneous axial rotation center for lateral bending in the cervical spine" (26).

From the histologic point of view, the chondroid tissue tipping the apex appears to react by proliferation and with formation of a second, higher cartilaginous uncus (chondrophyte), presenting growing is-

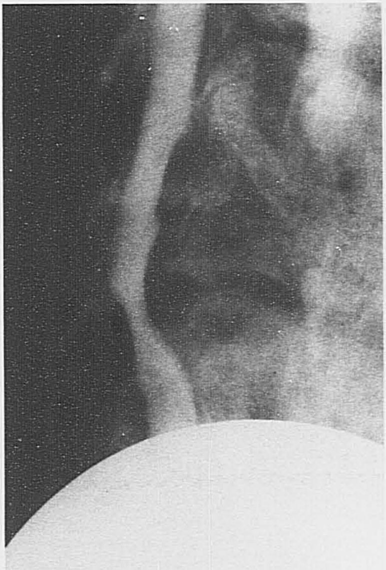


FIG. 7. The dynamic angiography shows a clear extrinsic impingement of the vertebral artery at C5–6 in a 66-year-old subject (arrows).

A

B

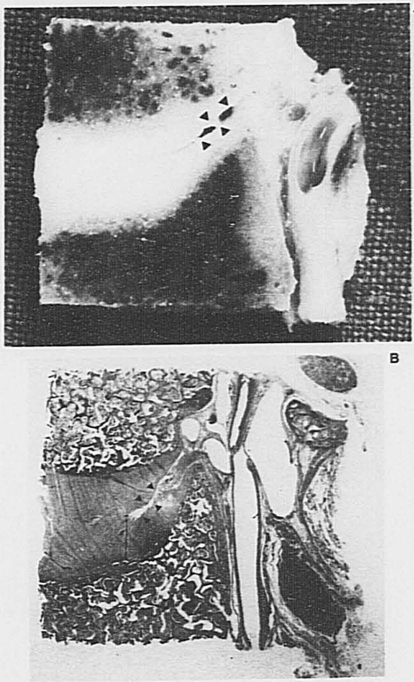


FIG. 8. After the radiographic investigations, the spines were prepared for histology. The frontal cut was made at the level of the anterior wall of the vertebral artery. The serial histologic slices included the full area of contiguity between the uncus and the vessel. The presence of large clefts in the lateral portion of the disks was constantly seen both macroscopically (**A**) and histologically (**B**) (hematoxylin and eosin, original magnification ×3) (arrows).

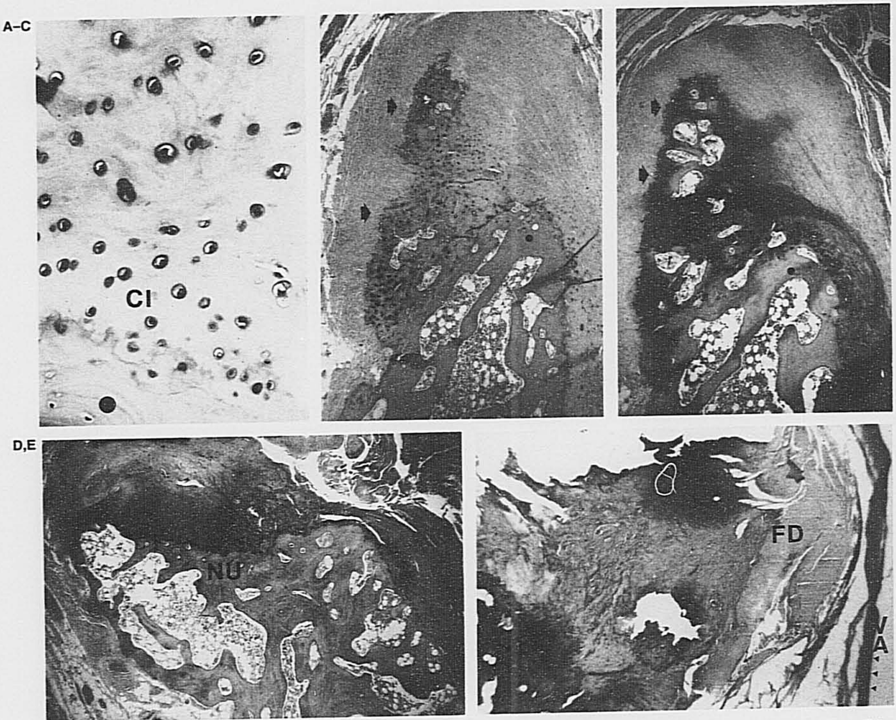
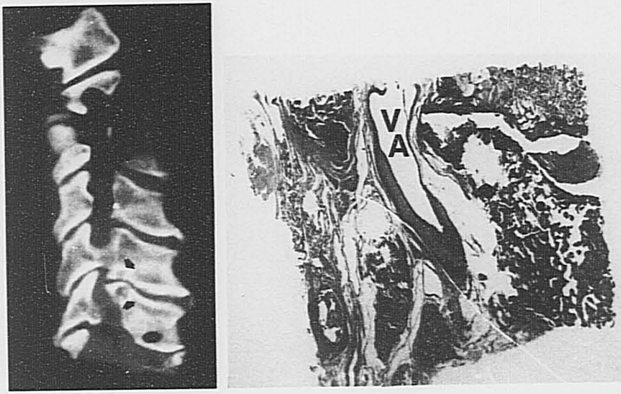


FIG. 9. The cartilaginous islands (CI) tipping the apex of the normal unci (dot) **(A)** can proliferate with production of progressively ossifying cartilage spurs (arrows), which increase the size of the unci (dots) **(B and C)**. The degeneration of the disks and the consequent decrease in its thickness cause the outward deformation of the ossifying neo-uncus (NU) **(D)**. Fragments of the disk (FD) may accompany the outward deformation of the uncus, further increasing the size of the spur, possibly causing functional impingement of the vertebral artery (VA; wall of the vessel) **(E)** (A, B, D, E, hematoxylin and eosin; C, safranin-orange).

lands of ossification. The presence of fibrocartilaginous tissue covering the progressively deforming uncus suggests that its size is larger than that calculated on radiographs; consequently, it can impinge the vertebral artery before complete deformation and ossification (Fig. 9E). Bony mechanical failure can finally explain the geodeticlike cavities of the deformed uncus.

CONCLUSIONS

In this series, vertebral artery impingement was demonstrated in four cases (14.3%), whereas uncus deformation was much more common with increasing age range (group B, Fig. 6). Uncus modifications begin with a deformed chondrophyte (not visible on radiographics), which rapidly ossifies and protrudes outward as the thickness of the central portion of the disk decreases. The bulging connective tissue overwhelming the deformed uncus may increase the possibility and the degree of arterial compression. Bony failure in the form of geodeticlike cavities in the final stage of the progressive alterations of the uncus region is a consequence of the exertion forces acting on the lateral edges of the vertebral bodies.



A,B

FIG. 10. The computed tomography scans, realized in eight cervical spines (data not presented here) were able to show geodeticlike lytic areas at the base of the unci, as well as at the edge of the upper vertebral bodies (**A**, arrows). Histologically, these areas show lack of the bone trabeculae (**B**) (hematoxylin and eosin, original magnification ×3). Compression of the vertebral artery appears to be caused by the deformed uncus (dot) together with the edge of the above vertebra, and by soft tissue interposed.

Further investigations with sialoprotein are in progress in order to clarify this particular process of bone formation.

REFERENCES

1. Ball J, Mejiers KAE: On cervical mobility. *Ann Rheum Dis* 23:429, 1964
2. Blanchard RS, Kottke FJ: A study of degenerative changes of the cervical spine and relation to age. *Bull Univ Minn* 24:470, 1953
3. Boni M: Considerazioni anatomo-patologiche e cliniche sulle potrusioni del disco del rachide cervicale. Abstract presented at "Atti LI Congresso della Società Italiana di Ortopedia e Traumatologia," Catania, October 1966
4. Boni M, Ceciliani L: Anatomo-clinical correlations of cervical spondylosis and the elderly. 52nd annual meeting of the AAOS, 1985, 200
5. Boni M, Cherubino P, Denaro V: Aging and degenerative changes in the cervical spine. Presented at the international meeting for the updating of pathology and surgery of cervical spine, Pavia, 1982, 21–3
6. Ceciliani L, Pazzaglia UE, Mora R: Artrosi del rachide. Patologia. Presented at the Relazione al III Corso di Aggiornamento sulla Radiodiagnostica dello Scheletro, Reggio Calabria, April 14–15, 1983, pp. 1–8
7. Ceciliani L, Pedrotti L, Benazzo F, Pazzaglia UE: Spondylosis of the cervical spine: formation of the osteophytes. *Cervical Spine II*, ed by R Louis, A Weidner, New York, Springer-Verlag, 1989, p 183
8. Fick R: *Handbuch der Anatomie und Mechanik der Gelenke unter Beruecksichtigung der bewegenden Muskeln*, T.3., Fischer, Jena, 1911
9. Fielding JW: Normal and selected abnormal motion of the cervical spine from the second cervical vertebra based on cineroentgenography. *J Bone Joint Surg [Am]* 46:1779, 1964
10. Gore RD, Sepic SB, Gardner GM: Roengtenographic findings of the cervical spine in asymptomatic people. *Spine* 11:521, 1986
11. Hadley LA: *The Spine*, Springfield, IL, Thomas, 1965
12. Hall MC: *Luschka's Joint*, Springfield, IL, Thomas, 1965
13. Hirsch C, Schajowicz F, Galante J: Structural changes in the cervical spine—a study on autopsy specimens in different age groups. *Acta Orthop Scand Suppl* 109:34–41, 1967
14. Hjortsjo CH: *Roerelsapparaten*, Lund, Sweden, Gleerups, 1959
15. Joefe MH, White AA, Panjabi MM: Clinically relevant kinematics of the cervical spine. In: *The Cervical Spine*, 2nd ed., Philadelphia, PA, JB Lippincott, 1989, p 57
16. Jones MD: Cineradiographic studies of the normal cervical spine. *Calif Med* 93:293, 1960
17. Jung A, Kehr P: Patologia dell'arteria vertebrale e delle radici nervose. *Ermes Med*, pp. 16–41
18. Kehr P: Syndromes de l'artere vertebral et cervicobrachialgie par uncarthrose et apres traumatisme du rachis cervical. Presented at the international meeting for the updating on pathology and surgery of the cervical spine. Pavia, 1982, pp. 171–188
19. Krogdahl T, Torgensen O: Die "unco-vertebral gelenke" und die "Arthrosis deformans unco-vertebralis." *Acta Radiol* 21:231, 1940
20. Luschka H: *Die Halbgelenke des menschlichen Koerpers*, Berlin, Reimer, 1858
21. Lysell E: Motion in the cervical spine. An experimental study on autopsy specimens. *Acta Orthop Scand Suppl* 123:54, 1969
22. MacNab I: Degenerative disorders—symptoms in cervical disc degeneration. In: *The Cervical Spine*, 2nd ed., Philadelphia, PA, JB Lippincott, 1989, p 599
23. Penning L. Physiology and biomechanics—functional anatomy of joints and discs. In: *The Cervical Spine*, 2nd ed., Philadelphia, PA, JB Lippincott, 1989, p 33
24. Tondury G: *Entwicklungsgeschicte und Fehlbildungen der Halswirberl saeule*, Stuttgart, Hippokrates Verlag, 1958, p 87
25. White AA III, Panjabi MM: *Clinic Biomechanics of the Spine*, Philadelphia, PA, JB Lippincott, 1978
26. White AA III, Panjaby MM: *Clinic Biomechanics of the Spine*, 2nd edition, Philadelphia, PA, JB Lippincott, 1990, Chap. 1, p 51; Chap. 2, p 102
27. Xq C, Bo S, Zhong SZ: Nerves accompanying the vertebral artery and their clinical relevance. *Spine* 13:1360–4, 1988