A PATHOLOGICAL STUDY ON DEFORMATION OF THE VERTEBRAL COLUMN IN THE "SHORT-SPINE DOG"

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INTRODUCTION

The deformity of dogs which should belong to the so-called "short-spine" category discovered by MOHR & WRIEDT was found, in 1949, by SUU in Gifu Prefecture in Japan. After continuous investigations, SUU,[6] in 1956, discussed the origin and reproduction of thirteen dogs obtained and reported that the length of the life of these dogs was practically not different from that of normal dogs. Regarding ten of the 13 dogs, SUU & UESHIMA[7,8] reported on their external appearance and on their posture and movement, in 1957 and 1958, respectively. The external appearance of "short-spine dogs" was characteristic and very odd owing to the fact that length of the body was less than its height due to extreme shortening of the vertebral column and thorax in contrast with the almost normal length of the head and extremities. The common external appearance of "short-spine dogs" was as follows:

1) Head: Almost normal except for slight lateral inclination.

2) Dorsal line: Wavy appearance of the vertebral column due to striking kyphosis in the anterior part of the thoracic segment and in the lumbar segment; alternate scoliosis in several parts with a slight inclination of the pelvic region.

3) Cervical region: Neckless appearance due to the extreme shortening and closeness of the manubrium sterni to the larynx and of the shoulder joint to the caudal part of the mandibula.

4) Lumbar region: Shortening, and sinking of the tail-root and its adjacent region.

5) Anal orifice: Opening to the dorso-posterior direction in comparison with that of normal dogs.

6) Abdomen: Shortening, and distension of the cranial abdominal part.

7) Tail: Shortening and twisting. Tufty tail hair.

8) Extremities: Almost normal with the exception of the abnormal postures

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due to shortening of the trunk. The forelimbs:—approaching of the shoulder joint to the head, slight abduction of the elbow, and wide outstretching of branches and "down in pastern" of their distal portions. The hind limbs:—poor condition of growth, unilateral or bilateral abduction of the stifle joints and the shanks opened outwards.

MOHR & WRIEDT, in 1930, discovered the vertebral deformity occurring among several calves of the Oplandske mountain breed in Norway and named this deformity "short-spine". Since that time, ASMUNDSON, in 1942, among turkeys and WEBER, in 1943, in a goat reported deformities of this kind respectively.

MOHR & WRIEDT observed an individual of "short-spine calves" which, as a rule, are stillborn or die immediately after birth, as representative in all essential respects. The external appearance of this individual was very strange due to extreme shortening of the entire vertebral column, which contrasted strikingly with the normal head and normal length of the extremities, whilst the vertebral column showed distinct or slight kyphosis, lordosis and scoliosis in several regions. In the vertebrae, there were irregularity in number, shape and order, irregular fusion of the adjacent vertebrae and reduction in number of the vertebrae coccygeae. In the ribs, there were extreme reduction in number, abnormality in shape and mutual fusion with the neighbouring ones; in the sternum, extreme shortening and thickness were seen. MOHR & WRIEDT concluded that from the viewpoint of heredity this deformity was produced by a new recessive lethal gene; they concluded on the basis of comparison between these deformities and those of the "amputated calf" that the respective deformities were essentially analogous, though the deformed portions varied, and that the shortening of the vertebral column arose from aplasia or reduction in size with irregular fusion or irregular amalgamation of the adjacent bony rudiments during the processes of development.

ASMUNDSON found "short-spined turkeys" in turkey embryos that failed to hatch; he undertook a brief macroscopic observation. It was his opinion that the shortening of the body was due to crowding together of the vertebrae and that this deformity was a single autosomal recessive lethal mutation. In addition, he stated that the percentage of ash was less in the scapula, ilium and ischium than in corresponding bones of normal embryos.

WEBER reported a congenital abnormality in a goat; in spite of the fact that its head and extremities were normal, the vertebral column was very short, the vertebrae cervicales, from the 3rd to 6th, fused at their centers, the vertebrae coccygeae were lacking and the ribs were reduced in number. WEBER stated that this case was possibly similar to the calf of MOHR & WRIEDT in respect to the recessive factor causing the shortening of the spine.

As above mentioned, since MOHR & WRIEDT discovered these deformities, the

so-called "short-spine", vertebral deformities of this kind have been examined from the viewpoint of heredity or somatology but not of pathology. Therefore, the pathological investigations on the "short-spine dog" were undertaken as described below in this paper.

MATERIALS AND METHODS

Materials for this research were four "short-spine dogs" bred in Gifu City and its environs (Table 1).

TABLE 1. *Materials*

CASE NO.	BREED	SEX	AGE (year)	TERMINATION
1	Japanese native breed	female	1	†
2	Japanese native breed (mixing Shepherd-blood)	male	1	†
3	Japanese native breed	male	1.3	† (motor-car accident)
4	Japanese native breed	male	5.3	† (motor-car accident)

Materials were fixed in 10% formalin. After fixing, the specimens of the visceral organs were embedded in paraffin and stained with hematoxylin-eosin (H.-E.); the specimens of the skeleton were decalcified, embedded in celloidin and stained with H.-E. The skeletal specimens were from the vertebral column, ribs, mandibula, os coxae, femur and tibia.

Excepting case No. 3, the vertebral column was divided into 4 parts in case No. 1, into 5 parts in case No. 2 and into 3 parts in case No. 4; these parts were sagittally sectioned in either sinister or dexter side of the vertebrae. In addition, the vertebral column was intermittently cross-sectioned, in such a manner as to include whole or unilateral (dexter or sinister) cross section of the vertebrae, in as many regions and as much as possible at a right angle to the axis of the vertebral column in all cases.

MACROSCOPICAL FINDINGS

The Skeleton

Skull : A slight inclination to the right side was observed in all cases except case No. 4 in which, as there existed a severe fracture of the skull, such a condition could not to be distinctly observed. In case No. 3, the foramen magnum inclined slightly to the right side and the right condylus occipitalis was situated somewhat more ventrally than the left one. With the exception of these points, the skulls were almost normal.

Vertebral column : The extreme shortening of the entire vertebral column was notable in all cases; the length of each part of the column was as shown in table 2.

The dorsal line was strikingly abnormal due to kyphosis, lordosis and scoliosis. In the thoracico-lumbar region, abrupt severe kyphosis was observed in all cases except case No. 2 in which slight kyphosis in the caudal region of the vertebrae thoracicae and abrupt kyphosis

TABLE 2. *The Length of Each Part of the Vertebral Column*

CASE NO.	TOTAL LENGTH (except the coccygeal part) (cm)	CERVICAL PART (cm)	THORACIC PART (cm)	LUMBAR PART (cm)	SACRAL PART (cm)	COCCYGEAL PART (cm)
1	22.8	7.5	6.0	7.0	2.3	5.0
2	36.0	12.0	10.5	10.5	3.0	8.0
3	32.5	9.0	9.0	12.0	2.5	7.0
4	27.0	9.5	9.0	6.0	2.5	7.0

centering in the 2nd lumbar vertebrae were observed. Lordosis in the caudal region of the vertebrae lumbales and lumbo-sacral region and kyphosis in the sacro-coccygeal region were found in all cases. Scoliosis irregularly showed in several portions in all cases.

In the vertebrae, the greatest morphological abnormalities were seen in the portion between the caudal region of the cervical segment and the cranial region of the lumbar segment and in the os sacrum.

The atlas inclined to the left-caudal side in cases Nos. 1, 2 and 4, while in case No. 3, the inclination was to the right-caudal side. In the atlas, shortening of itself and bifidity of the arcus ventralis and dorsalis were seen in case No. 1; the right fovea articularis cranialis in case No. 2 was changed to present a condylar feature.

In all cases, the axis was shortened; in the proc. articularis cranialis of the axis of case No. 3, the promination of the left one and retrocession of the right one respectively were observed.

The vertebrae cervicales excepting the atlas and axis were shorter than the atlas plus axis in length due to their extreme shortening. Furthermore, the vertebrae cervicales did not exhibit distinct division between the vertebra due to their conglomeration ; the corpus vertebrae, arcus vertebrae and proc. spinosus showed cleft; also, at the end of the proc. costotransversus of the caudal region of the vertebrae cervicales in case No. 2, cleft was found. In the vertebrae thoracicae, complete or incomplete bifidities of the corpus vertebrae and bifidity of the arcus vertebrae and cleft of the proc. spinosus were recognized; the divisions between the vertebrae were extremely indistinct. The procc. spinosi in the cranial region of the vertebrae thoracicae inclined forwards in all cases. In some of the procc. spinosi, fork-like features had resulted from the fusion of the neighbouring divisions; in case No. 1, only 10 procc. spinosi were found because of the reduction in number.

In the vertebrae lumbales, each vertebra was shortened and somewhat indistinct in division. Bifidities of the corpus vertebrae of the vertebrae lumbales were commonly present in the cranial and caudal regions. In the cranial region of the vertebrae lumbales in case No. 4, fusion of all the vertebrae spreading over 3.5 cm was recognized. The procc. transversi of the vertebrae lumbales were of various shapes and sizes and irregular in interspaces; moreover, in cases Nos. 1 and 3, the caudalmost proc. transversus showed fusion with the ilium.

The length of the os sacrum was less than its width in all cases due to its extreme shortening. Clefts of the corpus vertebrae, arcus vertebrae and proc. spinosus of the os sacrum

were markedly exhibited in all cases.

In the vertebrae coccygeae, there were extreme shortening and abrupt bending or twisting. The vertebrae coccygeae were strikingly reduced in number and counted only eight in cases Nos. 1 and 3, seven in case No. 2 and six in case No. 4. In the cranial region of the vertebrae coccygeae, bifidities of the corpus vertebrae were recognized in all cases except case No. 2.

The thorax was extremely shortened. Therefore, the spatia intercostalia were very narrow and especially the dorsal parts of the costae were crowded together. The curve connected with the junctions of the os costale and cartilago costalis tended upwards at an acute angle in the region of the costae spuriae.

Reduction in number of the costae was observed in all cases except case No. 2, viz., 9 in each side in case No. 1; 12 in the left side in case No. 3, and 12 in the left side in case No. 4. The costae were strikingly close together and in some places, there was almost no spatium intercostale. In some costae, abnormality in size and also fusion of the neighbouring 2 or 3 costae were recognized. Because of the promination outwards and depression inwards of the costae, unevenness of the breast wall resulted. In the right 1st costa in case No. 1, left 1st and right 13th costae in case No. 2 and right 5th costa in case No. 3, there existed only the cartilago costalis with defect of the os costale. The dorsalmost part of the right 6th costa in case No. 1 was very slender and was separated from the corresponding vertebra without any articulation.

The sternebrae were reduced in number in cases Nos. 1 and 3 counting only 6 in each case. In the sternum, slight shortening and twisting were found and in some places the juncture with the cartilago costalis was asymmetrical.

The os coxae was almost parallel to the level of the columna vertebralis lumbalis.

Bones of the fore and hind limbs except the os coxae did not show any significant abnormalities.

HISTOLOGICAL FINDINGS

1. Case No. 1

In the vertebral column, as the spaces between respective corpora vertebrarum except the parts of the articulationes atlanto-axiales mediana and lateralis were occupied by the annulus fibrosus (a. f.) of the intervertebral discs, cartilaginous structures, in the composition of the column, were quantitatively relatively abundant; in addition they were more numerous than those of normal dogs, in spite of the extreme shortening of the vertebral column.

The epiphyseal cartilaginous plates and cartilaginous fragments in the corpus vertebrae were found on most cut surfaces of the vertebrae cervicales, thoracicae and lumbales; cartilaginous fragments in the arcus vertebrae were recognized in the central and caudal regions of the vertebrae thoracicae.

In the intervertebral discs, nuclei pulposi (n. p.) were found between the axis and the 3rd vertebra cervicalis and in the cranial regions of the vertebrae lumbales and coccygeae. Although the fact that the boundary of the n. p. situated between the axis and the 3rd vertebra cervicalis was indistinct due to the invasion of the perinuclear cartilaginous tissues into the n. p., the boundaries of the other n. p. were distinct. The structureless substances in the spaces of the n.p. were poor in all n. p.; they were stained light-reddish or light-blueish with

H.-E. Tissue debris of the chorda dorsalis was, though poor, found in the n. p.; it consisted of vesicular cell elements. Though all n. p. were invaded by cartilaginous tissues, this invasion was poor in the n. p. excepting the one situated between the axis and the 3rd vertebra cervicalis. These cartilage cells which had invaded the n. p. were round, and only in the n. p. of the cranial region of the vertebrae thoracicae, were degenerative features of these cartilaginous tissues observed.

In the a. f., cell groups consisting of two to scores of round, comparatively large cartilage cells were found scatteringly on most cut surfaces; they were principally recognized in the interior of the a. f., interior of bifid areas of the corpus vertebrae and innermost-ventral portions of incompletely bifid areas of the corpus vertebrae. In the peripheries of all n. p. excepting the one of the vertebrae coccygeae, these cell groups were usually found; they were especially strongly developed in the periphery of the n. p. of the cranial region of the vertebrae lumbales. Furthermore, in the caudal region of the vertebrae cervicales, such cartilage cell groups as just noted above were scattered in the left-dorsal margin of the incompletely bifid areas of the corpus vertebrae. In the areas of these cartilage cell groups attached to the corpus vertebreae, pictures of ossification were usually seen and, also, the process of transition to fibrocartilaginous tissues was occasionally recognized.

In the a. f. of fibrocartilaginous tissues, fish-bone patterned structures were sometimes irregular due to the complicated morphological abnormalities of the corpus vertebrae and degenerative changes of cartilaginous tissues.

On some cut surfaces, the cartilaginous plates of the corpus vertebrae consisting of hyaline cartilaginous tissues were found scattered on the central surfaces of the epiphysis of the corpus vertebrae and in such parts of the corpus vertebrae as to face toward the n. p. and toward the central portions of the bifidities of the corpus vertebrae.

In the a. f. of almost all cut surfaces, there were numerous degenerative territories which were various in size and shape, stained in light red, red, red-violet, blue-violet, deep blue and light blue tones with H.-E. and either localized or diffused. These degenerative changes of the a. f. were principally observed in their interiors. In the perinuclear layers, also, the same foci of degeneration were usually found and, especially, they were conspicuous in those of the cranial region of the vertebrae lumbales. Both in such portions as where cartilage cell groups were scattered and in the portions consisting of fibrocartilaginous tissues, such foci of degeneration were found and especially in the former they were quite frequently observed. In the innermost ventral areas of incomplete bifidities of the corpus vertebrae, the same degenerative changes were frequently recognizable. In the central narrow areas of bifidities of the corpora vertebrarum which existed in the caudal region of the vertebrae thoracicae and cranial region of the vertebrae lumbales and in the dorsal portion of the fissure-form bifidity of the corpus vertebrae of the cranial region of the os sacrum, also, degeneration of all portions of the cartilaginous structures was observed and their calcified zones were lost. Furthermore, in the areas of the a. f. which were in contact with the corpus vertebrae, degenerative changes of cartilaginous tissues being accompanied by lack of the calcified zones of cartilaginous tissues were visible on many cut surfaces. Unrelated with degeneration of cartilaginous tissues, there were areas which exhibited loss of calcified zones in the a. f. in the caudal region of the vertebrae lumbales and in both the cranial and the caudal regions of the os sacrum. In the

bifid area of the arcus ventralis of the atlas, the calcified zone of the cartilaginous tissues was lost having important relation, or not, to the degenerative changes of cartilaginous tissues. There was no degeneration in the cartilaginous plates of the corpus vertebrae.

In the a.f., free isolated new-formed bone tissues were scatteringly found, viz., in the dorsal periphery of the a.f. and area of the a.f. adjacent to the n.p. in the cranial region of the vertebrae cervicales, in the dorsal periphery of the a.f. in the caudal region of the vertebrae cervicales, and in the lateral periphery of the a.f. in the caudalmost region of the vertebrae thoracicae. New-formed bone tissues deposited periostally in the corpus vertebrae were found scatteringly through the entire columna vertebralis; they existed usually in the ventral margin of the corpus.

In the caudal region of the vertebrae cervicales, dorsal halves of two corpora vertebrarum were fused, but this process was different from that caused by new formation of bone tissues.

The area of bifidity of the arcus ventralis of the atlas was occupied by cartilaginous tissues in which the degenerative changes were observed as well as in the a.f. Moreover, new-formed bone tissues were deposited in the left ventral margin of the bifid area of the arcus ventralis.

In the cranial region of the vertebrae cervicales, lymphocytes were accumulated in the ventral portion of the a.f.

In the epiphyseal cartilaginous plates and cartilaginous fragments found in the corpus vertebrae, small foci of degeneration were usually recognized. In the cartilaginous fragments which appeared in the arcus vertebrae, foci of degeneration were poor in general, and a mere few foci were found only in the fragment in the caudal region of the vertebrae thoracicae.

Bifidities of the arcus vertebrae were scatteringly found; such areas were occupied by cartilaginous or fibrous tissues or both. In all these cartilaginous tissues, foci of degeneration were recognized.

The areas of cleft of the proc. spinosus were also occupied, as in those of the arcus vertebrae, by cartilaginous or fibrous tissues or both; foci of degeneration were recognized in those cartilaginous tissues.

The area of bifidity of the arcus dorsalis of the atlas was occupied by fibrous tissues.

The articulationes atlanto-axiales mediana and lateralis were histologically normal.

Degenerative changes of articular cartilages of the articulatio intervertebralis were comparatively slight in general. In some joints, there was entire or partial unification of the articular surfaces. In the caudal regions of the vertebrae cervicales and lumbales and between the os sacrum and the vertebrae coccygeae, degenerative changes of the articular cartilages appeared in the left joints; similar changes appeared in the left joints between the vertebrae lumbales and the os sacrum and of the cranial region of the vertebrae coccygeae. In the right joints of the caudal region of the vertebrae cervicales and between the os sacrum and the vertebrae coccygeae, also in the left one between the vertebrae lumbales and the os sacrum, entire unification of the articular surfaces showed; in addition, in the right joints between the os sacrum and the vertebrae coccygeae, ossification was found in a part of the unified articular cartilage. In the right joint of the caudal region of the vertebrae cervicales, left one of the cranial region of the vertebrae lumbales and right and left ones between the os sacrum and the vertebrae coccygeae, partial unification of articular surfaces was found. Foci of degeneration were observed in the articular cartilages of these almost unified joints. In the left joint

of the cranial region of the vertebrae lumbales, new-formed bone tissues deposited in the proc. articularis.

Degenerative changes of the articular cartilages of the articulatio costo-vertebralis were observed in the caudal and caudalmost regions of the vertebrae thoracicae. The articular surfaces of the right joint of the caudal region of the vertebrae thoracicae was wholly unified while such surfaces of the left joint of the caudal region and right joint of the caudalmost region of the vertebrae thoracicae were partially unified.

Degenerative changes of the articular cartilages of the articulatio sacro-iliaca existed extensively, but there was no unification of the articular surfaces. Periostally new-formed bone tissues were deposited extensively in the medial surface of the os ilium.

In the ligament in the cranial region of the vertebrae coccygeae, new-formed hyaline cartilaginous tissues were found.

In the margin of the bone tissues which were in contact with the periosteum of the vertebrae, os coxae, femur and os frontale, many serrated defective areas were recognized in some places, the bone marrow seemed to have come into contact with the periosteum. In these areas, there were fibrocytes, pale nuclear cells and multi-nuclear giant cells.

In the periosteum of the vertebrae, foci of infiltration and proliferation of lymphocytes and histiocytic elements were rather extensively recognized.

The bone marrow was almost normal.

In the costo-chondral junctions of some of the costae, degenerative changes of the cartilaginous tissues were recognized. The intersternebral cartilages, parts of the cartilago costalis near the articulationes sternocostales and articular cartilages of the acetabulum and caput femoris were normal.

In the caudal portion of the axis, new-formed bone tissues were found in the ventral part of the dura mater spinalis.

In the ganglia spinalia in the vertebral canal throughout almost the whole vertebral column, slight proliferation of capsular cells and slight infiltration of round cells were observed. Partial degeneration and loss of nerve fibers were observed in some of the nerve bundles of the root spinal nerves in the vertebral canal, also.

As the principal findings on the visceral organs, the picture of bronchopneumonia was observed and eosinophilic intracytoplasmic inclusion bodies were recognized in the epithelial cells of the renal pelvis.

2. Case No. 2

In the vertebral column, as the spaces between the respective corpora vertebrarum except the parts of the articulationes atlanto-axiales mediana and lateralis were occupied by the a.f. of the intervertebral discs, cartilaginous structures, in point of the composition, were relatively abundant quantitatively. In addition, such structures were more than those of normal dogs, in spite of the extreme shortening of the vertebral column.

The epiphyseal cartilaginous plates and cartilaginous fragments, in the corpus vertebrae, were extensively found on the cut surfaces from the caudal region of the vertebrae cervicales to the central region of the vertebrae lumbales and on those of the os sacrum and vertebrae coccygeae. Cartilaginous fragments in the arcus vertebrae were found in the caudal region of the vertebrae cervicales, cranial region of the vertebrae thoracicae and central region of

the vertebrae lumbales.

The n.p. in the intervertebral discs were found on fairly many cut surfaces from the caudal region of the vertebrae cervicales to the os sacrum and about one half of them were indistinct in their boundaries to the a.f. due to the invasion of the perinuclear cartilage cells into the n.p. In the spaces of the n.p. except some ones completely occupied by cartilage cells, there were structureless substances stained in light-reddish or light-blueish color with H.-E. and some tissue debris of the chorda dorsalis. Such tissue debris was generally poor in volume; it consisted or reticular elements. The spaces of all n.p., except the ones in the vertebrae coccygeae, were invaded by cartilage cells of the perinuclear layers of the a.f. In the n.p. conspicuously invaded by cartilage cells, the tissue debris of the chorda dorsalis seemed to be pushed away to the margin of the spaces. In the n.p. in the cranial and central regions of the vertebrae lumbales and cranial region of the os sacrum, no tissue debris of the chorda dorsalis was observed and the spaces of these n.p. were completely occupied by cartilage cells. The invaded cartilage cells were round and all of these certilaginous tissues possessed foci of degeneration.

In the a.f., such cell groups as to be constituted of two to scores of round, comparatively large cartilage cells were seen on many cut surfaces. These cell groups were found principally in the interior of the a.f. and especially in the almost perinuclear layers of the a.f.; furthermore, the spaces of the n.p. were invaded by these cartilage cells of the perinuclear layers. In these cell groups in the central region of the vertebrae lumbales and in the perinuclear layer of the cranial region of the vertebrae coccygeae, transition to fibrocartilaginous tissues was found. Furthermore, there were massive hyaline-cartilaginous tissues in the a.f. in the caudal region of the vertebrae thoracicae and central region of the vertebrae lumbales. In such areas of the a.f. as these, cartilage cell groups were in contact with the corpus vertebrae, picutures of slight ossification were recognized.

In the a.f. constituted of fibrocartilaginous tissues, fish-bone patterned structures were sometimes irregular due to the complicated morphological abnormalities of the corpus vertebrae and degenerative changes of cartilaginous tissues, which were similar to the findings in case No. 1.

The cartilaginous plates of the corpus vertebrae constituted of hyaline cartilaginous tissues were recognized on the central surfaces of the epiphysis of the corpus vertebrae and in the parts of the corpus vertebrae facing the n.p.

The degenerative changes of the a.f. were similar to those in case No. 1. In all perinuclear layers of the a.f., except those in the cranial regions of the vertebrae thoracicae and coccygeae, foci of degeneration were observed. Furthermore, they were also observed both in scattered portions of cartilage cell groups and in the portions constituted of fibrocartilaginous tissues; especially, they were usually recognized in the former. In the central area of the bifidity of the corpus vertebrae found in the central region of the os sacrum, degeneration of all the cartilaginous structures was observed. In the areas of the a.f. adjacent to the corpus vertebrae and in the cartilaginous plates of the corpus vertebrae, localized foci of degeneration were also found; the calcified zones in these degenerated portions were lost. Though the lack of the calcified zones in cartilaginous tissues adjacent to the corpus vertebrae was principally due to degeneration of the cartilaginous tissues, the calcified zones were lost without any con-

nection with degeneration in some parts of the a.f. which were adjacent to the corpus vertebrae in the caudal region of the vertebrae thoracicae, central region of the vertebrae lumbales and cranial regions of the os sacrum and vertebrae coccygeae.

In the a.f., scattered new-formed bone tissues were observed. In the interior of the a.f. adjacent to the n.p. in the caudal region of the vertebrae cervicales and in the peripheries of the a.f. in the caudal region of the vertebrae thoracicae and cranial and central regions of the vertebrae lumbales, isolated new-formed bone tissues were found. New-formed bone tissues deposited periostally in the corpus vertebrae were observed in the central region of the vertebrae lumbales and central and caudal regions of the os sacrum.

Histiocytic elements and lymphocytes had accumulated perivascularly in the ventral part of the a.f. in the central region of the vertebrae lumbales.

In a majority of the epiphyseal cartilaginous plates and cartilaginous fragments which existed in the corpus vertebrae, small foci of degeneration were observed. In the cartilaginous fragments existing in the arcus vertebrae similar foci were found only in the central region of the vertebrae lumbales.

The areas of the bifidities of the arcus vertebrae in the central region of the vertebrae lumbales and caudal region of the os sacrum were occupied by cartilaginous tissues in which foci of degeneration were recognized. The other areas of bifidities of the arcus vertebrae were occupied by fibrous tissues.

In the central region of the vertebrae lumbales, the area of the bifidity of the proc. spinosus was occupied by cartilaginous tissues possessing foci of degeneration and the other areas of bifidities were occupied by fibrous tissues.

The bifidity of the procc. costotransversus was found in the caudal region of the vertebrae cervicales and this area was occupied by cartilaginous tissues in which a focus of degeneration was found.

New-formed bone tissues were deposited periostally in the right dorsal part of the arcus vertebrae in the caudal region of the vertebrae cervicales.

Histologically the articulationes atlanto-axiales mediana and lateralis showed no abnormalities.

The foci of degeneration in the articular cartilages of the articulatio intervertebralis were comparatively numerous being found in about half the cartilages. In about half the articulatio intervertebralis, whole or partial unification of the articular surfaces was observed; in the articular cartilages of almost of the unified joints, foci of degeneration were found.

Degenerative changes of the articular cartilages of the articulartio costovertebralis were found only in the left joint of the central region of the vertebrae thoracicae; only in this joint and the left one of the central region of the vertebrae thoracicae, there existed partial unification of their articular surfaces.

In the articulatio sacro-iliaca, degenerative changes of the articular cartilages were extensively observed and in some parts of this joint, the unification of the articular surfaces was recognized.

Periostally new-formed bone tissues were visible on the medial surface of the os ilium, and one case of isolated new-formed bone tissues was respectively recognized in the ventral periphery of the articular cartilage of the left articulatio sacro-iliaca and in the ligament ventral to this joint.

As regards serrated defective processes and others observed in the margin of the bone tissues which were in contact with the periosteum in many bones including the vertebrae, the findings were similar to those of case No. 1.

The bone marrow was normal.

In some costo-chondral junctions, degenerative changes of cartilaginous tissues were recognized. Histologically the intersternebral cartilages and the articular cartilages of the acetabulum and caput femoris showed no abnormalities.

The changes of the ganglia spinalia and nerve bundles of the root part of the nervus spinalis in the vertebral canal were similar to what was seen in case No. 1, although they were slight in general.

The principal changes of the visceral organs were hemothorax, marked congestive edema of the lungs and a picture of bronchopneumonia.

3. Case No. 3

In the vertebral column, as the spaces between the respective corpora vertebrarum except the parts of the articulationes atlanto-axiales mediana and lateralis were occupied by the a.f. of the intervertebral discs, cartilaginous structures, in point of the composition, were quantitatively relatively abundant; in addition there were more such structures than those of normal dogs, in spite of the extreme shortening of the vertebral column.

The epiphyseal cartilaginous plates and cartilaginous fragments in the corpus vertebrae were extensively found on many cut surfaces from the caudal region of the vertebrae cervicales to the vertebrae lumbales. Cartilaginous fragments in the arcus vertebrae were found in the cranial and caudal regions of the vertebrae thoracicae and caudal region of the os sacrum.

The n.p. in the intervertebral discs were comparatively numerous and found on the cut surfaces from the caudal region of the vertebrae cervicales to the cranial region of the vertebrae lumbales and on those from the cranial region of the vertebrae coccygeae. In the other n.p. except the ones which existed in the caudalmost region of the vertebrae cervicales and in the cranial region of the vertebrae coccygeae, the boundaries to the a.f. were indistinct because of the invasion of the perinuclear cartilage cells into the n.p. The structureless substances in the spaces of the n.p. were stained in light-reddish or light-blueish color with H.-E. Tissue debris of the chorda dorsalis in the n.p. were generally scanty. While such debris in the n.p. in the caudal region of the vertebrae cervicales consisted of both vesicular and reticular elements, that in all the other n.p. were made up of reticular elements. The spaces of all n.p. were invaded by cartilage cells, and this invasion process was conspicuous in the majority of n.p. These cartilage cells were round and many of them showed degenerating pictures.

In the a.f., cell groups constituted of two to scores of round, comparatively large cartilage cells were scattered on most cut surfaces. These cartilage cell groups were principally found in such a interior of the a.f. as to contain a perinuclear layer over the whole circumference and also, were found in the innermost-ventral areas of incomplete bifidities of the corpus vertebrae, in areas of the a.f. adjacent to the corpus vertebrae and in peripheries of the a.f. In these cartilaginous tissues found in the areas of the a.f. adjacent to the corpus vertebrae, pictures of slight ossification were observed. In the caudalmost region of the vertebrae cervicales, cranial and caudal regions of the vertebrae thoracicae and cranial region of the vertebrae coccygeae, transition of these cartilaginous tissues to fibrocartilaginous tissues was

observed. In addition, the n.p. were invaded by these cartilage cells of the perinuclear layers. Large massive hyaline cartilaginous tissues were recognized respectively in the left dorsal portion of the dorsal incomplete bifidity of the corpus vertebrae in the caudal region of the vertebrae thoracicae and in the perinuclear layer of the cranial region of the vertebrae lumbales. In some parts of the a.f. constituted of fibrocartilaginous tissues, fish-bone patterned structures were sometimes irregular due to the complicated morphological abnormalities of the corpus vertebrae and degenerative changes of cartilaginous tissues, which were the same as in case No. 1 as described above.

On some cut surfaces, the cartilaginous plates of the corpus vertebrae constituted of hyaline cartilaginous tissues were recognized in the central surfaces of the epiphysis of the corpus vertebrae and such part as those facing the central portions of bifidities of the corpus vertebrae.

The degenerative changes of the a.f. in the intervertebral discs were similar to those of case No. 1. In perinuclear layer of all the a.f., foci of degeneration of cartilaginous tissues were found. Both in scattered portions of cartilage cell groups and in the portions constituted of fibrocartilaginous tissues, foci of degeneration were seen to be scattered; especially, they were usually observed in the former. In the areas of the a.f. adjacent to the corpus vertebrae and in the cartilaginous plates of the corpus vertebrae, foci of degeneration were found; in these degenerated portions the calcified zones were lost. The cartilaginous tissues of the central portion of the bifidity of the corpus vertebrae in the caudalmost region of the vertebrae lumbales were almost entirely degenerated; their calcified zones had quite disappeared. The loss of the calcified zones of the cartilages adjacent to the corpus vertebrae was principally due to degeneration of cartilaginous tissues. However, in some parts of the a.f. of the caudal regions of the vertebrae cervicales and thoracicae and cranial region of the vertebrae lumbales and in a part of the cartilaginous plates of the corpus vertebrae of the caudalmost region of the vertebrae lumbales, the calcified zones were lost without any relation to degeneration of the cartilaginous tissues.

In the a.f., new-formed bone tissues were scatteringly observed. Free new-formed bone tissues were found in the interior of the a.f. in the caudalmost region of the vertebrae cervicales, also in the ventral peripheries of the a.f. in the central region of the vertebrae thoracicae and cranial region of the vertebrae lumbales. Furthermore, in the caudalmost regions of the vertebrae cervicales and lumbales, new-formed bone tissues were periostally deposited in the corpus vertebrae.

In all of the epiphyseal cartilaginous plates and all of cartilaginous fragments found in the corpus vertebrae, small foci of degeneration were recognized. In the cartilaginous fragments found in the arcus vertebrae in the cranial region of the vertebrae thoracicae and caudal region of the os sacrum, degenerative changes were found, but not in the fragment in the caudal region of the vertebrae thoracicae.

Bifidities of the arcus vertebrae were observed in the axis and caudal region of the vertebrae cervicales. The bifid area of the arcus vertebrae in the axis was occupied by new-formed bone tissues. The bifid area of the arcus vertebrae in the caudal region of the vertebrae cervicales was occupied by cartilaginous tissues and its periphery showed a picture of ossification. In the caudalmost region of the vertebrae cervicales and cranial and caudalmost regions

of the vertebrae lumbales, new-formed bone tissues were deposited periostally in the arcus vertebrae.

Bifidities of the proc. spinosus were recognized in the caudal and caudalmost regions of the vertebrae cervicales; such bifid areas were occupied by fibrous tissues.

The articlationes atlanto-axiales mediana and lateralis were histologically normal.

Degenerative changes of the articular cartilages of the articulatio intervertebralis were slight. Such changes were found only in the left joint of the central region of the vertebrae lumbales and in the left and right joints of the cranial region of the vertebrae coccygeae. The articular surfaces of the left joint in the cranial region of the vertebrae coccygeae were wholly unified.

Degenerative changes in the articular cartilages of the articulatio costovertebralis were observed in all the joints excepting the left joint of the central region of the vertebrae thoracicae. The articular surfaces of all the right joints and of the left joint in the central region of the vertebrae thoracicae were entirely unified. In the left side of the caudal region of the vertebrae thoracicae, the area of bifidity of the corpus vertebrae was deeply invaded by the capitulum costae; in the area, except the ventral part of this area, between this capitulum costae and corpus vertebrae, there existed synchondrosis without the formation of any joint. In the left joint of the central region of the vertebrae thoracicae, new-formed bone tissues were found in the ventral part of the articular cartilage.

The articular cartilage of the articulatio sacro-iliaca possessed foci of degeneration. Moreover, the articular surfaces were unified in the caudal part of the left joint. New-formed bone tissues were found in the ligament ventral to the left joint and new-formed bone tissues were periostally deposited on the medial surface of the os ilium.

The findings of serrated defective areas in the margin of the bone tissues adjacent to the periosteum, which were noted in many bones including the vertebrae, were similar to those of case No. 1.

In the bone marrow of all the vertebrae, hemorrhages were commonly observed to have happened.

In the right 5th cartilago costae freed in the intercostal muscles, pictures of ossification and degeneration were seen in its interior. In the costo-chondral junctions, there were foci of degeneration of cartilaginous tissues. The intersternebral cartilages and articular cartilages of the acetabulum and caput femoris were histologically normal.

There was neither proliferation of capsular cells nor infiltration of round cells in the ganglia spinalia in the vertebral canal. The changes of the nerve bundles of the root part of the nervus spinalis in the vertebral canal were similar to those in case No. 1.

The principal changes of visceral organs were hemorrhages in the liver, spleen, kidneys, myocardium, lungs, submeningeal areas of the brain and spinal cord, and canalis centralis.

4. Case No. 4

In the vertebral column, as the spaces between the respective corpora vertebrarum except the parts of the articulationes atlanto-axiales mediana and lateralis were occupied by the a.f. of the intervertebral discs, cartilaginous structures, in point of the composition, were quantitatively relatively abundant; in addition they were more numerous than those of normal dogs, in spite of the extreme shortening of the vertebral column.

The cartilaginous fragments in the corpus vertebrae corresponding to a part of the

epiphyseal cartilaginous plates were, though poor, recognized in the cranialmost region of the vertebrae thoracicae and cranial region of the vertebrae lumbales. Cartilaginous fragments in the arcus vertebrae were found in the cranial regions of the vertebrae thoracicae and lumbales.

The n.p. which existed in the intervertebral discs were found in the cranial and central regions of the vertebrae thoracicae and cranial regions of the os sacrum and vertebrae coccygeae; the boundaries between the a.f. and the n.p. were distinct except those in the cranial region of the os sacrum. In the spaces of the n.p. other than the ones occupied by catilaginous tissues, there were structureless substances stained in light reddish, light red-violet or light blueish color with H.-E. and also tissue debris of the chorda dorsalis; the tissue debris consisted of reticular elements. Such debris in the cranial region of the os sacrum seemed to have been pushed away to the margin of the space by the invading cartilage cells. Though invasion of the cartilage cells into the spaces of the n.p. in the cranial region of the vertebrae coccygeae was poor in degree, such invasion was conspicuous in the other n.p. The spaces of the n.p. in the cranial and central regions of the vertebrae thoracicae were completely occupied by cartilage cells; all of the invading cartilage cells were round; tissue debris of the chorda dorsalis had disappeared. In the cartilaginous tissues there existed foci of degeneration.

In the a.f. of the intervertebral discs, cell groups constituted of two to scores of round, comparatively large cartilage cells were scatteringly observed on many cut surfaces. These cell groups were principally found in the interior of the a.f. The spaces of the n.p. in the cranial and central regions of the vertebrae thoracicae were invaded by these cell groups appearing in the perinuclear layers of the a.f. These cell groups were also recognized in the peripheries of the a.f. and in the areas of the a.f. adjacent to the corpus vertebrae. Pictures of generally slight ossification were found in the areas of these cell groups adjacent to the corpus vertebrae. In addition, these cell groups showed transition to fibrocartilaginous tissues in the caudal region of the vertebrae thoracicae and central region of the vertebrae lumbales. On the cut surface of the cranial region of the os sacrum, a large mass of hyaline cartilaginous tissues was found in the periphery of the a.f.

In the a.f. constituted of fibrocartilaginous tissue, fish-bone patterned structures were sometimes irregular due to the complicated morphological abnormalities of the corpus vertebrae and degenerative changes of cartilaginous tissue, while they were similar to the findings in case No. 1.

The cartilaginous plates of the corpus vertebrae constituted of hyaline cartilaginous tissues were observed on the central surfaces of the epiphysis of the corpus vertebrae and in the parts facing the central portions of bifidities of the corpus vertebrae on some cut surfaces.

Degenerative changes of the a.f. were similar to those of case No. 1. Such changes in the interiors of the a.f. were recognized on almost all cut surfaces; foci of degeneration were observed in the perinuclear layers of all the a.f. In scattered portions of cartilage cell groups, degenerative foci commonly existed, and also were found in the peripheries and other areas of the a.f. In the a.f. constituted of fibrocartilaginous tissues, foci of degeneration were also found. In addition, in the areas of the a.f. adjacent to the corpus vertebrae and in the cartilaginous plates of the corpus vertebrae, focal degeneration was observed and the calcified zones in these degenerated portions were lost. Though the loss of the calcified zones of

cartilaginous tissues adjacent to the corpus vertebrae was principally resultant from degeneration of the cartilaginous tissues themselves, in some parts of the a.f. found in the caudal region of the vertebrae thoracicae and cranial and central regions of the vertebrae lumbales, the calcified zones of cartilaginous tissue adjacent to the corpus vertebrae had disappeared without there being any relationship with degeneration.

In the a.f., isolated new-formed bone tissues and new bone tissues periostally deposited in the corpus vertebrae were scanty in general. Isolated new-formed bone tissues were found in the peripheries of the a.f. in the cranial region of the vertebrae thoracicae and central region of the vertebrae lumbales, and new bone tissues periostally deposited in the corpus vertebrae were observable in the caudal region of the os sacrum. In the cranial region of the vertebrae lumbales, all the vertebrae were fused extending over about 3.5 cm with no division.

In all the cartilaginous fragments found in the corpus vertebrae and arcus vertebrae, foci of degeneration were found.

Bifidities of the arcus vertebrae were observed in the caudal regions of the vertebrae cervicales and thoracicae and cranial region of the vertebrae lumbales; these areas, except those of the cranial region of the vertebrae lumbales which were filled with connective tissues, were occupied by cartilaginous tissues in which foci of degeneration were found.

The articulationes atlanto-axiales mediana and lateralis were histologically normal.

In the articular cartilages of the majority of the articulationes intervertebrales, foci of degeneration were observed. The articular surfaces of the left joint in the central region of the vertebrae lumbales and same side one caudal to the os sacrum were respectively partially unified, whilst the articular surfaces of the right joint caudal to the os sacrum were wholly grown together.

Degenerative changes of the articular cartilages of the articulatio costovertebralis were conspicuous; foci of degeneration were observed in the articular cartilages of all the joints except the right joint in the cranial region of the vertebrae thoracicae and left one in the central region of the vertebrae thoracicae. In the left joints of the cranial and caudal regions of the vertebrae thoracicae and both the left and right joints of the central region of the vertebrae thoracicae, complete unification of the articular surfaces was observed, whilst in the right joint of the caudal region of the vertebrae thoracicae, partial unification of those surfaces was observed.

Periostally new-formed bone tissues were found on the medial surface of the os ilium.

The findings of serrated defective areas in the margin of the bone tissues adjacent to the periosteum in many bones including the vertebrae, were similar to those of case No. 1.

In the periosteum of the vertebrae cervicales, hemorrhages and infiltration of lymphocytes and proliferation of histiocytic elements were occasionally observed.

The bone marrow was almost normal.

In the cranial region of the vertebrae thoracicae, the dorsal ends of the left six costae were mutually articulated. In all these joints, foci of degeneration of the articular cartilages were found and these articular surfaces, except those in the caudalmost joint, were respectively partially unified. In each of the joints, there were a few free new-formed bone tissue fragments and periostally new-formed bone tissues. Both the costo-chondral junctions and the inter-

sternebral cartilages had foci of degeneration. The articular cartilages of the acetabulum and caput femoris were histologically normal.

Though the changes of the ganglia spinalia and nerve bundles of the root part of the nervus spinalis in the vertebral canal were generally slight just as in case No. 1, some nerve bundles in the cranial region of the vertebrae lumbales, passing through the foramen intervertebrale of the fused vertebrae, showed severe degeneration and loss of nerve fibers.

The main findings on the visceral organs were hemorrhages in the lungs and cavum thoracis.

DISCUSSION

In the vertebral column, there were such complicated features as clefts of the corpus vertebrae, arcus vertebrae and proc. spinosus, etc. The spaces between each of the corpora vertebrarum, and areas of bifidity of the corpus vertebrae were occupied by the annulus fibrosus (a.f.) of the intervertebral discs. It is very noteworthy the cartilaginous structures, in point of the elements composing the vertebral column, were quantitatively more abundant relatively than those of normal dogs. In addition, the epiphyseal cartilaginous plates or cartilaginous fragments corresponding with the epiphyseal cartilaginous plates or other cartilaginous fragments in the corpus vertebrae and the cartilaginous fragments in the arcus vertebrae and proc. spinosus, more usually found in such portions as morphological abnormalities of the vertebral column, were most conspicuous between caudal regions of the vertebrae cervicales and thoracicae. Even in case No. 4 (5 years old), the existence of these cartilaginous fragments was confirmed (Table 3). These features suggest that ossification of the vertebrae may have been disturbed.

TABLE 3. *Distribution of Cartilaginous Tissues in the Corpus Vertebrae, Arcus Vertebrae and Proc. Spinosus*

CASE NO.	VERTEBRAE CERVICALES		VERTEBRAE THORACICAE			VERTEBRAE LUMBALES			OS SACRUM		VERTEBRAE COCCYGEAE
	cran.	caud.	cran.	centr.	caud.	cran.	centr.	caud.	cran.	centr. caud.	cran.
1	○	○	○	○	○	○	○	○			
				●	●						
2		○	○	○	○	○	○		○	○	○
		●	●				●				
3		○	○	○	○			○		●	
			●		●						
4			○			○					
			●			●					

Notes: ○—Cartilaginous tissues in the corpus vertebrae.
● —Cartilaginous tissues in the arcus vertebrae and proc. spinosus.

The boundaries of the nuclei pulposi (n.p.) in the intervertebral discs were indistinct in some cases due to the invasion of cartilage cells into the space of the n.p. as a result of the progressive changes of the perinuclear cartilaginous tissues. Except the n.p. occupied by invaded cartilage cells, tissue debris of the chorda dorsalis in the n.p. was comparatively scanty; the debris consisted of vesicular cell-elements in all the n.p. in case No. 1, complexes of vesicular and reticular cell-elements in the n.p. of the caudal region of the vertebrae cervicales in case No. 3 and reticular cell-elements in all the other n.p. The invasion of cartilage cells into the spaces of the n.p. was found in almost all of them. Except for the n.p. of case No. 1, there were many suffering from conspicuous invasion of cartilage cells in other cases; in some of the n.p., the debris of the chorda dorsalis seemed to be pushed away to the margin of the spaces of the n.p. by the invading cartilage cells; especially, some of the n.p. in cases Nos. 2 and 4 were completely occupied by cartilage cells and the debris had entirely disappeared. These invading cartilage cells were round. In a majority of the n.p., pictures of degeneration were observed in the cartilaginous tissues.

In the a.f., principally in their interior, there were scattered cartilage cell groups constituted of two to scores of round, comparatively large cells. The spaces of the n.p. were invaded by these cell groups in the perinuclear areas. These events may be recognized as indicating active proliferation of the low-differentiated cartilage cells. These low-differentiated cartilaginous tissues were scatteringly recognized in many portions as well as in perinuclear layers of the a.f., that is in the innermost areas of incomplete bifidities of the corpus vertebrae and peripheral areas of the a.f. Transition of these cartilaginous tissues to fibrocartilaginous tissues was found in some regions. In addition, pictures of generally slight ossification were recognized in the areas adjacent to the corpus vertebrae. Moreover, massive hyaline cartilaginous tissues were occasionally found in the a.f. in all cases except case No. 1; these pictures are suggestive that the differentiation of cartilages in the a.f. may be not a little low. Upon this, the author would like, with deep interest, to refer to what HANSEN[2,3] has stated, in his report on so-called "chondrodystrophoid breed" in dogs, that the low-differentiated cartilage cell groups were scattered in the perinuclear layers of the a.f. and according to the invasion of these cells into the n.p., the spaces of the n.p. came to be occupied by cartilaginous tissues.

In the present observations, in the a.f. constituted of fibrocartilaginous tissues, fish-bone patterned structures were seen to be irregular, depending upon the localization, due to morphological abnormalities of the corpus vertebrae and degenerative changes of cartilaginous tissues.

In the a.f., features of degeneration of the various stadia were seen on most cut surfaces; they stained in light reddish, reddish, red-violet, deep blueish and

light blueish tones with H.-E. stain. Such degenerative areas were localized or diffussed and various in size. They were also recognized in all portions such as cartilage cell groups and were scattered in the regions constituted of fibrocartilaginous tissues. Degenerative changes of the a.f. were found principally in such an interior part of the a.f. as the perinuclear layer. They were also found in many of the other regions, viz., the peripheral parts of the a.f., innermost-ventral areas of incomplete bifidities of the corpus vertebrae and areas adjacent to the corpus vertebrae etc. In the areas where the bone tissues were close to each other, such as the narrow areas of bifidities of the corpus vertebrae, all the a.f. showed degenerative changes. The cartilaginous plates of the corpus vertebrae were seen on the central surfaces of the epiphysis of the corpus vertebrae, accompanied by similar foci of degeneration which occurred scatteringly, also. According to degeneration of the a.f. adjacent to the corpus vertebrae and cartilaginous plates, the calcified zones of the cartilages were lost in some places. Though the losses of the calcified zones of the cartilages were principally resultant from degenerative changes of cartilaginous tissues, in some places, losses which had occurred without participation of degenerative changes were also observed. It may be considered that this phenomenon exerts considerably strong influences upon the growth of the corpus vertebrae.

In the present "short-spine dogs", though the invasion of cartilage cells into the n.p. showed earlier than in normal dogs, the filling up of the n.p. by cartilage cells required more than one year after birth; such a filling up has been not necessarily completed, even if the animal was 5 years old, and no calcification in the a.f. was found. Thus, degeneration of the a.f. is not a secondary result due to the loss of plasticity of the n.p., but may be due to existence of the plenty of cartilaginous tissues resulting from low-capacity of ossification in the vertebrae and to progressive change of the cartilages. As to this point, the author would like to refer to the interesting statement of HANSEN[2,3] that in "chondrodystrophoid" dogs, the cartilage cells of the perinuclear layers of the a.f. showed active proliferation, that is progressive change, and that the n.p. were replaced with cartilaginous tissues in about one-year-old animals due to invasion of cartilage cells. Then HANSEN[2,3] expressed the opinion that the loss of plasticity of the n.p. and degenerative changes of the a.f. arose from progressive changes of cartilaginous tissues and that there was close relation between the degenerative changes of the a.f. and the protrusion of the intervertebral discs into the vertebral canal. In addition, HANSEN[2,3] considered that calcification of both interior and periphery of the n.p. played an important part in this protrusion.

In addition, the present author, in his "short-spine dogs", did not find protrusion of the intervertebral disc into the vertebral canal and adhesion of the a.f. to the

dura mater spinalis, just as the observation of MOHR & WRIEDT in their "short-spine calf". Accordingly, direct influence upon the spinal cord could not be considered in the present cases. In this connection, HANSEN[2,3] and HOERLEIN have stated in their respective reports that degeneration of the a.f. was the cause of protrusion of the intervertebral disc into the vertebral canal.

In the interior and more frequently in the periphery of the a.f., free new-formed bone tissues and periostally new-formed bone tissues which were deposited in the corpus vertebrae, though not so conspicuous, were scatteringly observed in each of the four cases.

In the dorsal halves of two corpora vertebrarum in the caudal region of the vertebrae cervicales in case No. 1 and in the entire vertebrae spreading over 3.5 cm in the cranial region of the vertebrae lumbales in case No. 4, there was a fusion, respectively. As to the embryological mechanism of such synostoses a further investigation is to be performed.

In the majority of the epiphyseal cartilaginous plates and cartilaginous fragments in the corpus vertebrae, foci of degeneration were seen. In keeping with these degenerative changes, the normality of the growth of the corpus vertebrae may be disturbed. In the cartilaginous fragments in the arcus vertebrae, foci of degeneration were poor in general.

The areas of clefts of the arcus vertebrae and proc. spinosus were occupied by cartilaginous or fibrous tissues or both; in most of these cartilaginous tissues, foci of degeneration were found. The area of the bifidity of the arcus vertebrae in the axis in case No. 3 was occupied by new-formed bone tissues; the area of the bifidity of the arcus vertebrae in the caudal region of the vertebrae cervicales in the same case was occupied by cartilaginous tissue, and in the peripheral area of this bifidity the picture of ossification was seen. These pictures may be understood to reflect reparative processes to clefts.

The articulationes atlanto-axiales mediana and lateralis were histologically normal. In the articulatio intervertebralis, such joints as the articular cartilages showing degeneration were comparatively few in cases Nos. 1 and 3, but more numerous in cases Nos. 2 and 4. In addition, entire or partial unification of the articular surfaces was seen in these joints. In the joint between the os sacrum and the vertebrae coccygeae in case No. 1, the picture of ossification in the peripheral part of the joint, as well as entire unification, was seen; it may be understood as a step in the osseous fusion of the joint. In the articulatio costovertebralis, degenerative changes of the articular cartilages were observed in a majority of the joints; moreover, entire or partial unification of the articular surfaces was extensively observed; only case No. 2 had feeble degenerative and unified changes in the joints. In the left side of the caudal region of the vertebrae thoracicae in case No. 3, the

area of bifidity of the corpus vertebrae was invaded by the costa; synchondrosis was shown between the costa and corpus vertebrae, except in the ventral part. It is conceivable that these changes of the articulatio costovertebralis have to do with greater morphological abnormalities of the vertebrae thoracicae. In the articulatio sacro-iliaca also, similar degenerative changes were observed in the articular cartilages and partial unification of the articular surfaces was recognized in three cases other than No. 1. It may be considered that degenerative changes of the articular cartilages and unification of the articular surfaces in the joints of the vertebral column originate from mechanical factors and indicate processes which are occurring in the direction of synostosis.

In the ganglia spinalia in the vertebral canal, slight proliferation of capsular cells and infiltration of round cells were observed, and in the nerve bundles of the nervi spinales in the vertebral canal, partial degeneration and loss of nerve fibers were found occasionally. The relation between the morphological abnormalities of the vertebral column and these changes must be the subject of further research.

In the costae, foci of degeneration of cartilaginous tissues were observed in the costo-chondral junctions in all cases. In the cranial region of the vertebrae thoracicae in case No. 4, the dorsal ends of the six costae were articulated with each other; foci of degeneration were seen in the articular cartilages of each of the joints and partial unification of the articular surfaces was recognized in most of them. In addition, in each of the joints there were a few free new-formed bone tissue fragments and periostally new-formed bone tissues. In case No. 4, a focus of degeneration was found in the intersternebral cartilaginous tissue. Accordingly, it may be considered that these morphological abnormalities of the costae are derived, as a secondary result, from the deformities of the vertebral column.

In the other bones except the vertebral column, costae, sternum and os coxae and in the visceral organs, there was no finding directly associated with deformation of the vertebral column.

SUMMARY AND CONCLUSIONS

The four available "short-spine dogs" were investigated pathologically; the results obtained may be summarized as follows.

1. The cartilaginous tissues in the vertebral column, in point of composition of the column, were quantitatively more abundant than those of normal dogs. In addition, the epiphyseal cartilaginous plates remained for a long period of time and especially cartilaginous fragments in the arcus vertebrae were recognized in all cases. These phenomena are suggesive of the probability that ossification of the vertebrae is feeble during the developmental process and also after birth.

2. The tissue debris of the chorda dorsalis in the spaces of the nuclei pulposi

(n.p.) began to disappear during considerably early stages after birth, and the spaces of the n.p. were gradually invaded by low-differentiated cartilage cells of the perinuclear layer of the annulus fibrosus (a.f.) and were—entirely in some instances—occupied by the cartilaginous structures. On that occasion, even in the 5-year-old dog, there sometimes existed such n.p. as the replacing by cartilaginous tissues had not been perfectly occurred.

3. In the a.f., according to the progressive changes of the low-differentiated cartilage cells, the formation of many groups constituted of these cells was recognized. These cell groups were found chiefly in the interior but also in the peripheral portion of the a.f.; moreover, massive hyaline cartilaginous tissues were scatteringly found in the a.f. That is to say, in the a.f. pretty extensively low-differentiated and progressive changes were seen simultaneously. In addition to these changes, degeneration of cartilaginous tissues was recognized in various portions of the a.f. and especially, usually found in scattered portions of the cartilage cell groups. It may be understood that these pictures are highly significant in respect to the deformation of the vertebral column in the developmental process and moreover, after birth.

4. In the parts of the a.f. constituted of fibrocartilaginous tissue, fish-bone patterned structures were irregular in some places due to the morphological abnormalities of the corpus vertebrae and degenerative changes of the cartilaginous tissue.

5. In the a.f. adjacent to the corpus vertebrae and in the cartilaginous plates adjacent to the corpus vertebrae which were seen on the central surfaces of the epiphysis of the corpus vertebrae and in the parts facing the central portions of bifidities of the corpus vertebrae, the loss of the calcified zones of cartilage was seen in some places, as a result of the degenerative changes of cartilaginous tissue principally, though occasionally, in having no relation to such changes. In the majority of the epiphyseal cartilaginous plates, foci of degeneration were recognized. It may be considered that these changes exert considerable interference in the growth of the corpus vertebrae.

6. In the a.f., free new-formed bone tissues and periostally new-formed bone tissues deposited in the corpus vertebrae were observed here and there.

7. In one place respectively in cases Nos. 1 and 4, fusion of a part of the corpus vertebrae and of the entire vertebrae was recognized. As to the embryological mechanism of these changes further investigation needs to be performed.

8. The areas of clefts of the arcus vertebrae and proc. spinosus were occupied by cartilaginous or fibrous or both; in these cartilaginous tissues, pictures of degeneration were found. Furthermore, as shown in the vertebrae cervicales in case No. 3, there were bifidities of the arcus vertebrae which had been repaired with new-formed bone tissues.

9. In the articulationes intervertebralis, costovertebralis and sacro-iliaca, both degeneration of the articular cartilages and unification of the articular surfaces were observed in many of the joints. A picture of ossification was observable in the peripheral part of the unified articulatio intervertebralis between the os sacrum and the vertebrae coccygeae in case No. 1. It may be understood that in the joints of the vertebral column, degeneration of the articular cartilages and unification of the articular surfaces arise from mechanical factors and, sometimes, that osseous fusion occurs in these joints.

10. The relation between the changes of the ganglia spinalia and nerve bundles of the nervi spinales in the vertebral canal and the deformity of the vertebral column must be a subject for further research.

11. In the costo-chondral junctions foci of degeneration were found in all cases. In case No. 4, the dorsal ends of some costae were articulated with each other. Moreover, in these joints, there were degeneration of articular cartilages, unification of articular surfaces, formation of free new-formed bone tissue and periostal apposition of new bone tissue. It may be considered that the morphological abnormalities of the costae have occurred as secondary results of deformities of the vertebral column.

12. In the bones other than the vertebral column, costae, sternum and os coxae, and in the visceral organs, there was no finding directly related with deformation of the vertebral column.

Thus, on the basis of the present pathological findings concerning the "short-spine dogs", the following conclusions may be drawn. It may be regarded that in the vertebral column, low differentiation, progressive changes and degeneration of cartilaginous tissue in the a.f. as well as low accomplishment of ossification occurred in the developmental process and after birth. It may be understood that these processes are principal causes of deformation of the vertebral column and that the morphological abnormalities of the arcus vertebrae and other portions can be induced secondarily.

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REFERENCES

1) ASMUNDSON, V. S. (1942): *Proc. Soc. exp. Biol., N. Y.*, **50**, 120.
2) HANSEN, H.-J. (1951): *Acta orthopaed scand.*, **20**, 280.
3) HANSEN, H.-J. (1952): *Ibid.*, Suppl. No. 11.
4) HOERLEIN, B. F. (1953): *Amer. J. vet. Res.*, **14**, 260.
5) MOHR, O. L. & C. WRIEDT (1930): *J. Genet.*, **22**, 279.
6) SUU, S. (1956): *Res. Bull. Fac. Agr. Gifu Univ.*, **7**, 127 (in Japanese with English summary).
7) SUU, S. & T. UESHIMA (1957): *Ibid.*, **8**, 112 (in Japanese with English summary).
8) SUU, S. & T. UESHIMA (1958): *Ibid.*, **9**, 178 (in Japanese with English summary).
9) WEBER, W. (1943): *Schweiz. Arch. Tierheilk.*, **85**, 472. [*Vet. Bull., Weybridge*, **17**, 323 (1947)].

EXPLANATION OF PLATES

Notes common to figures of the pictures of the cut surfaces.

Thick line: Boundary of bone tissues
Thin line in bones: Boundary of new-formed bone tissues
Light black part: Cartilaginous tissues
Part surrounded by thin line in cartilaginous tissues: Nucleus pulposus (n.p.)
Dot in cartilaginous tissues: Location of a focus of degeneration

PLATE I

Fig. 1. Case No. 2

Fig. 2. Case No. 3

Fig. 3. X-ray photograph of case No. 4, dorsoventrally. Cervico-thoracic portion. × 0.5

Fig. 4. X-ray photograph of case No. 4, dorsoventrally. Lumbo-sacral portion. × 0.5

Fig. 5. Sagittal cut surface, somewhat right from the median line of the vertebral column, through the caudal region of the vertebrae cervicales and cranial region of the vertebrae thoracicae in case No. 2. Left is cranial. Cartilaginous tissues are shown to be abundant compared with bone tissues. × 1.2

PLATE II

Fig. 6. Cross-sectioned surface through the central region of the vertebrae thoracicae in case No. 4. Shows bifidity of the corpus vertebrae. × 1.2

Fig. 7. Nucleus pulposus (n.p.) of fig. 6. Space of the n.p. occupied by cartilaginous tissues shows partial degeneration and foci of degeneration of the perinuclear layer of the a.f. Hematoxylin-eosin stain (H.-E.). × 17

Fig. 8. Cross-sectioned cut surface through the cranial region of the vertebrae lumbales in case No. 2. Shows bifidity of the corpus vertebrae. Arrow indicates the portion photographed in fig. 9. × 1.2

Fig. 9. Portion showing the scattered low-differentiated cartilage cell groups. Shows foci of degeneration. H.-E. × 55

Fig. 10. Cross-sectioned cut surface through the caudalmost region of the vertebrae lumbales in case No. 3. Shows bifidity of the corpus vertebrae. Arrow indicates the portion photographed in fig. 11. × 1.2

Fig. 11. Portion showing the scattered low-differentiated cartilage cell groups. Shows foci of degeneration. H.-E. × 55

Fig. 12. Sagittal cut surface of the corpora vertebrarum, somewhat right from the median line, through the caudal region of the vertebrae thoracicae and cranial region of the vertebrae lumbales in case No. 2. Left is cranial. The cartilaginous tissues are shown to be abundant compared with bone tissues; irregularities of the corpus vertebrae in shape and order are shown. Arrow indicates the portion photographed in fig. 13. × 1.2

Fig. 13. Foci of degeneration in the area constituted of fibrocartilaginous tissue in the a.f. H.-E. × 55

PLATE III

Fig. 14. Cross-sectioned cut surface of the right half through the caudal part of the axis in case No. 3. Arrow indicates the portion photographed in fig. 15 showing bifidity of the arcus vertebrae repaired with new-formed bone tissue. × 1.2

Fig. 15. New-formed bone tissue occupying the area of bifidity of the arcus vertebrae. H.-E. × 22

Fig. 16. Cross-sectioned cut surface through the central region of the vertebrae thoracicae in case No. 4. Arrow indicates the articulatio costovertebralis photographed in fig. 17. × 1.2

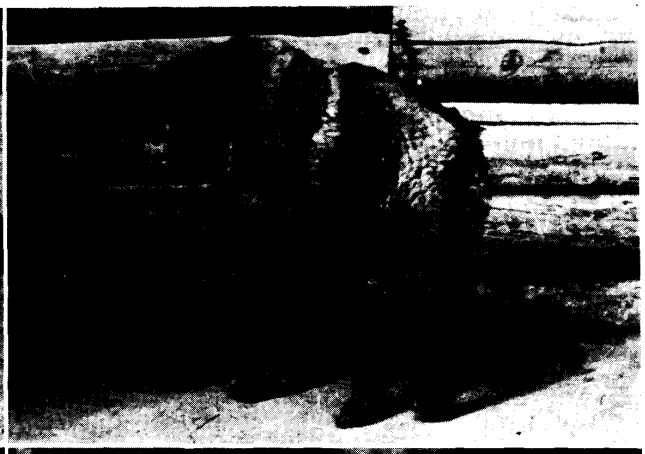
Fig. 17. Degeneration of the articular surface of the articulatio costovertebralis. H.-E. × 55

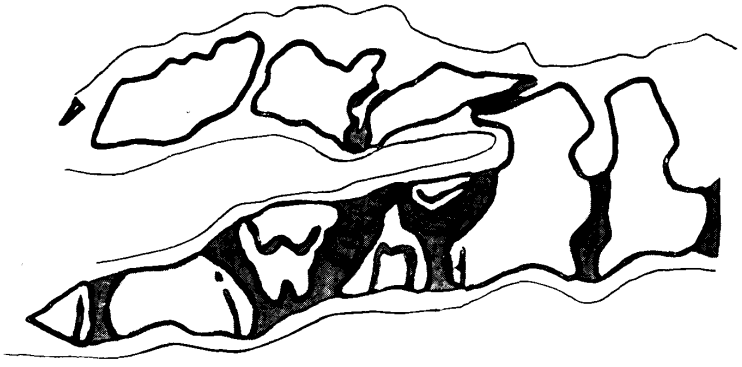
Fig. 18. Cross-sectioned cut surface through the caudal region of the os sacrum in case No. 3. Arrow indicates the articulatio sacro-iliaca photographed in fig. 19. × 1.2

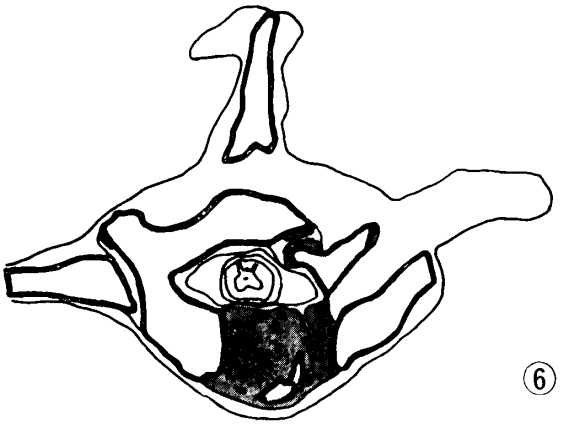
Fig. 19. Degeneration and unification of the articular surfaces of the articulatio sacro-iliaca. H.-E. × 17

Fig. 20. Cross-sectioned cut surface through the caudal region of the os sacrum in case No. 1. Bifidity of the corpus vertebrae is shown. Arrow indicates the articulatio intervertebralis between the os sacrum and the vertebrae coccygeae photographed in fig. 21. × 1.2

Fig. 21. Degeneration and unification of the articular surfaces and ossification of its periphery appearing in the articulatio intervertebralis. H.-E. × 55







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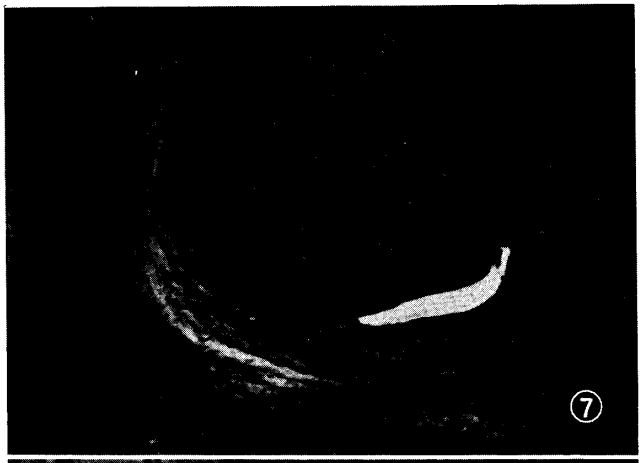

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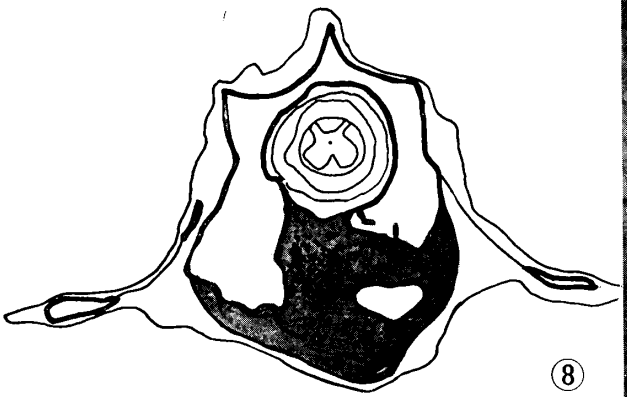

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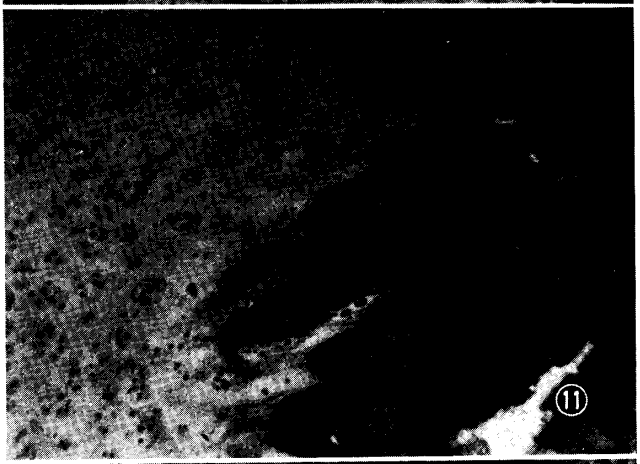

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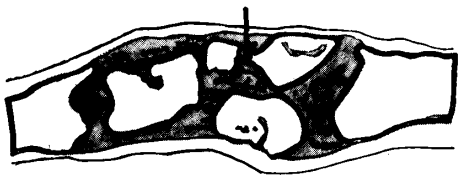

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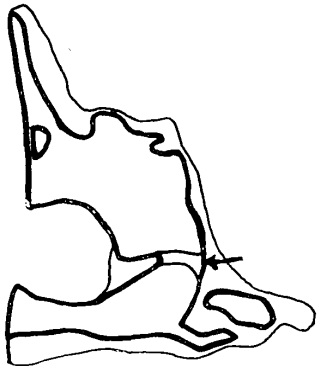

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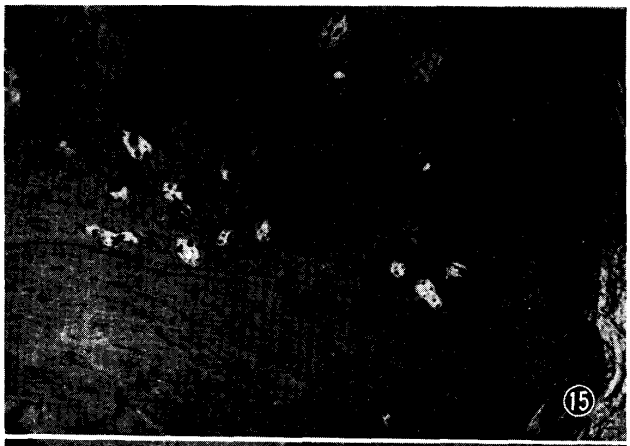

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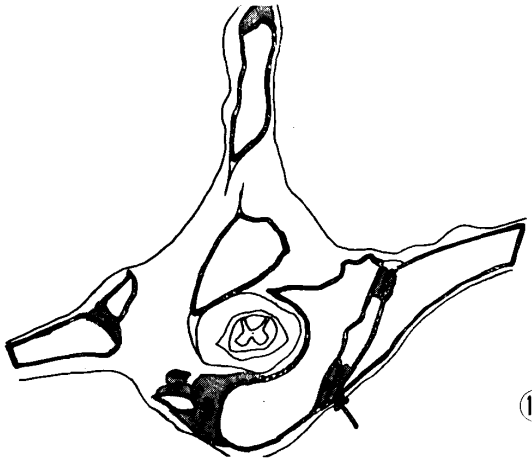

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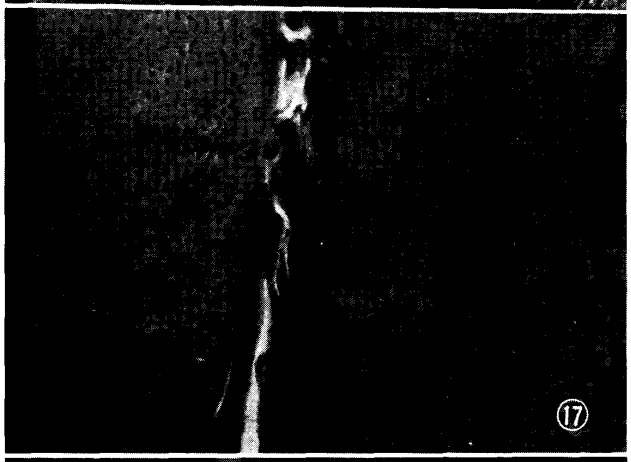

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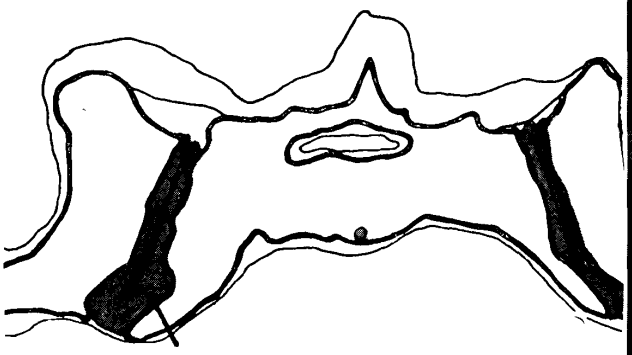

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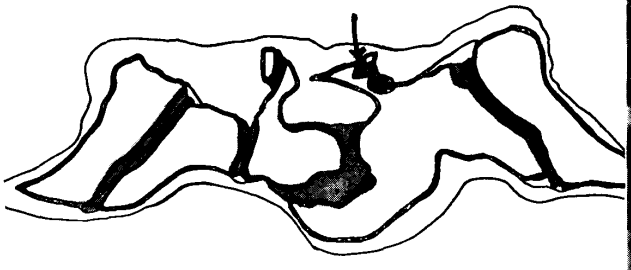

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