International Orthopaedics (SICOT) 3, 317–321 (1980)

International
Orthopaedics

Experimental Scoliosis by Epiphysiodesis in Pigs

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Summary. *Using two-month-old pigs selective epiphysiodesis of the neurocentral cartilage was performed using cancellous screws inserted to achieve effective compression. The operation was performed on eight experimental animals, on the right side, involving four or five vertebrae at the mid thoracic level. The procedure consistently caused structural scoliosis, convex on the side of operation. The radiographic, macroscopic and microscopic findings in the experimental animals are described. In other animals so treated at ages when the neurocentral cartilage is not active rotational deformity did not occur.*

Résumé. *Une épiphysiodèse sélective du cartilage neurocentral a été pratiquée sur des porcs de deux mois à l'aide de vis à spongieux mises en place afin de réaliser une compression efficace. L'opération a été effectuée sur huit animaux d'expérience, du côté droit, et a porté sur quatre ou cinq vertèbres, à l'étage dorsal moyen. Cette technique entraîne régulièrement une scoliose structurale à convexité du côté opéré. Description des constatations radiographiques, macroscopiques et microscopiques, faites sur les animaux d'expérience. Chez d'autres animaux, ayant subi la même opération à un âge où le cartilage neurocentral n'est plus actif, la déformation en rotation ne s'est pas produite.*

Key words: *Scoliosis, Epiphysiodesis, Pigs, Neurocentral cartilage*

It is known from work by Langenskiöld and Michelsson [7, 8, 10] that resection of the vertebral ends of the ribs or a more extensive resection with costotransversectomy is an effective method of inducing experimental scoliosis in the rabbit and in the pig. This technique has since been confirmed by many other authors [9, 14, 18].

We were interested to try and confirm the finding in subjects with a bipedal stance and so we carried out costotransversectomy in rats that had been made bipeds using the technique described by Goff [4]. We found, however, that structural scoliosis with rotation did not develop but only wedging of the vertebral bodies occurred [1].

Further enquiry revealed that in rabbits the neurocentral cartilages in the thoracic spine fuse between the 10th and 14th week of life, whereas in the rat fusion occurs between the 3rd and 4th week of life. We believe that the lack of rotation observed in our experimental rats was due to the absence of neurocentral cartilage at the age when the operation was performed. As confirmation of this belief it is known that in the rabbit experimentally induced scoliosis proceeds for some weeks after the operation but then ceases at a time that coincides with natural fusion of the neurocentral cartilage, eventhough the epiphyseal cartilages of the vertebral bodies remain active after this time. Other animals in which the neurocentral cartilages fuse at an early age, hamsters and guinea pigs, were also subjected to costotransversectomy and produced results identical with those obtained in our experimental rats. These results lead us to believe that the neurocentral cartilages could be important in connection with the pathology of scoliosis and that alteration in the symmetry of their growth influences the morphology of the spine. In this connection we know only of the work by Ottander [13] who performed unilateral epiphysiodesis in one lumbar vertebra and obtained slight scoliosis thereby.

Materials and Method

We chose the pig as our experimental animal for the following reasons. The neurocentral cartilages of the thoracic spine are active for a long period, more than one year. Due to the size of the animal

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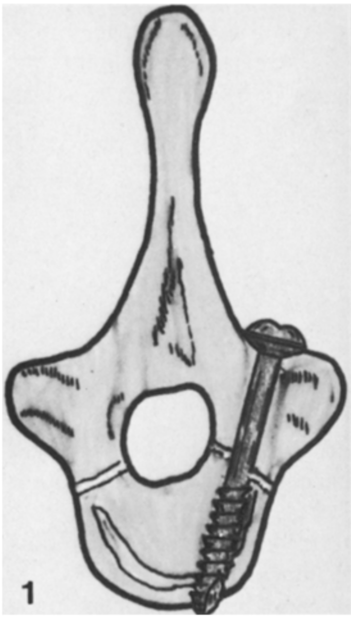

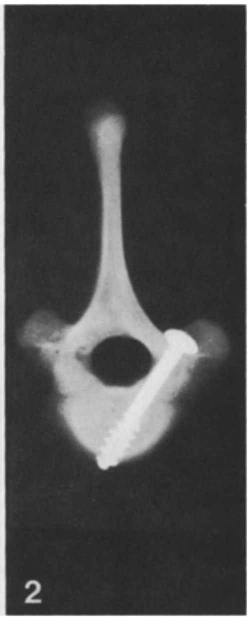

Fig. 1. This drawing represents the direction of the screw, introduced from the posterior part, passing through the pedicle and the neurocentral cartilage up to the anterior part of the vertebral body

Fig. 2. Radiologic follow-up of a thoracic vertebral body of a two-month-old pig. It can be seen that it is possible to introduce the screw across the neurocentral cartilage

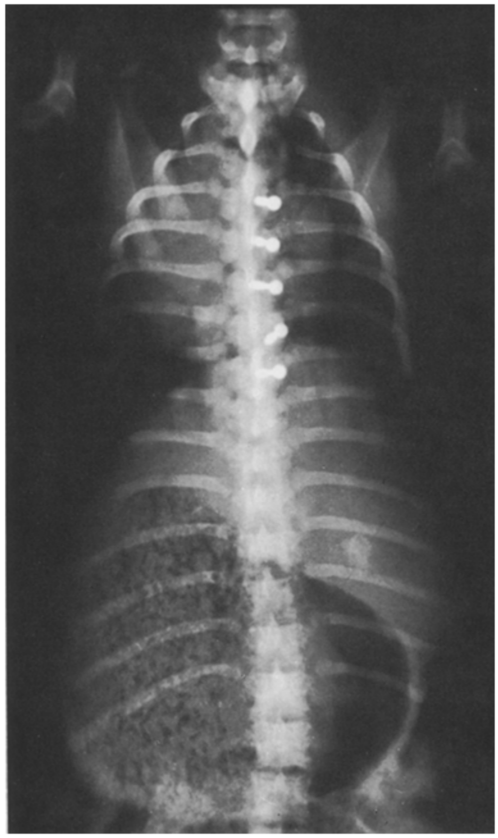

Fig. 3. Radiologic follow-up, performed with the animal already awake, after the placement of 5 screws in the right side of the spine. No alteration is observed in its alignment

it is technically possible to introduce a screw across the neurocentral cartilages using a posterior approach without injuring adjacent structures (Figs. 1 and 2).

The operation was carried out under general anaesthesia, when the animals were about two months old. The paraspinal canal was exposed on both sides and on the right side, at the middle of the thoracic region, one screw was placed in four or five successive vertebrae. Eight animals were operated on in this manner and there were no postoperative complications. The animals were subsequently sacrificed between 4 and 12 months postoperatively.

Radiological studies were carried out immediately after the operation and again on the dead animal at the end of the experimental period. The vertebral bodies were then extracted and studied macroscopically, radiologically and histologically.

Results

No immediate postoperative curves developed (Fig. 3), but at the end of the experimental period all the animals presented structural scoliosis varying between 10° and 80° (Cobb) with the convexity on the operated side (Fig. 4). All the curves were sited at the level of the operated segments and there were no appreciable compensatory curves.

In the animal which presented the least deformity (pig No. 2), there were defects in our technique which had caused interference with the activity of the neurocentral cartilage of only one vertebra. All the other pigs, except one, presented curves of approximately 30° (Cobb) and in these animals there was evident deformity of the vertebral bodies with rotation (Fig. 5) and wedging (Fig. 6).

EPIPHYSIODESIS OF THE NEUROCENTRAL CARTILAGE IN PIGS - Results

PIG nº	AGE	LEVEL SCREWS	EVOLUTION TIME	INTENSITY CURVE
1	2 Mths	Th_3 - Th_7	5 Mths	28° Cobb
2	2 Mths	Th_{10} - Th_{13}	5 Mths	10° Cobb
3	2 Mths	Th_4 - Th_8	4 Mths	20° Cobb
4	2 Mths	Th_4 - Th_8	5 Mths	30° Cobb
5	2 Mths	Th_5 - Th_9	6 Mths	36° Cobb
12	2 Mths	Th_6 - Th_9	8 Mths	29° Cobb
13	2 Mths	Th_5 - Th_9	12 Mths	80° Cobb
14	2 Mths	Th_6 - Th_{10}	8 Mths	28° Cobb

Fig. 4. Total number of animals operated upon and the result at the end of the follow-up period

The animal which presented the greatest curve (80° Cobb) had the longest follow-up period of 12 months. The fusion of the neurocentral cartilage on the convex side of the curve, and the deformity of the vertebral bodies were evident (Figs. 7, 8 and 9).

We noted that the vertebral bodies were wedged with a reduced height on the side of the concavity but without appreciable alteration in the thickness of the epiphyseal cartilage.

Discussion

Our experiments demonstrated that selective epiphysiodesis of the neurocentral cartilage at four or five vertebral levels consistently produces a structural scoliosis in the pig's spine with rotation and wedging of the vertebral bodies and convexity on the side of screw fixation.

The mechanism of production of the scoliosis is more difficult to explain especially since the convexity lies on the operated side. We believe, that under normal conditions, there exists an equilibrium between the growth of the neurocentral cartilages on each side of the vertebral bodies. If for any reason the neurocentral cartilage on one side ceases activity as, for example, under the effect of compression with a screw, the growth of the neurocentral cartilage on the opposite side is unopposed so that a greater quantity of bone tissue develops on the unoperated side of the vertebral body. This would induce rotation of the spine towards the side of the convexity.

Greater activity of the neurocentral cartilage on the side of concavity in subjects with scoliosis has already been reported by Nicoladoni in 1909 [12] who considered that the vertebral torsion was due to premature cessation of growth in the neurocentral synchondrosis of the convex side. Michelsson [10] also has stated that in some animals the neurocentral cartilage was fused on the convex side but remained open on the concave side. This has since been confirmed by observation of the increased activity of the neurocentral cartilage on the concave side of the curve using Tetracycline marker studies [6] and also during investigation of the effect of vascular lesions in the causation of scoliosis [16].

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Fig. 5. Transversal histologic section of T4. It was operated 5 months earlier, placing 5 screws from T3 to T7. It presented a curve of 28° Cobb with the convexity towards the right side. Disappearance of the neurocentral cartilage can be seen on the rigth side, the operated side; the neurocentral cartilage of the concavity remaining open. There is evident rotation towards the side of the convexity

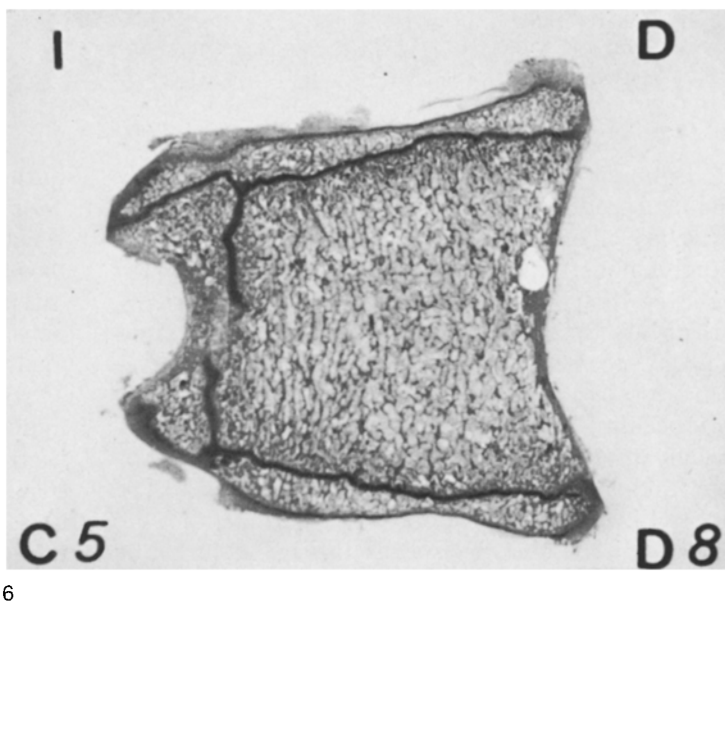

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Fig. 6. Longitudinal histologic section of T8. It was operated 6 months before, placing 5 screws from T5 to T9. At the end of the follow-up period it presented a curve of 36° Cobb, with the convexity towards the right side. Wedging of the vertebral bodies can be observed, being of lesser height at the side of the concavity of the curve. There is no alteration in the epiphyseal cartilages. The neurocentral cartilage of the operated side, the right, has fused, that of the concavity remaining open

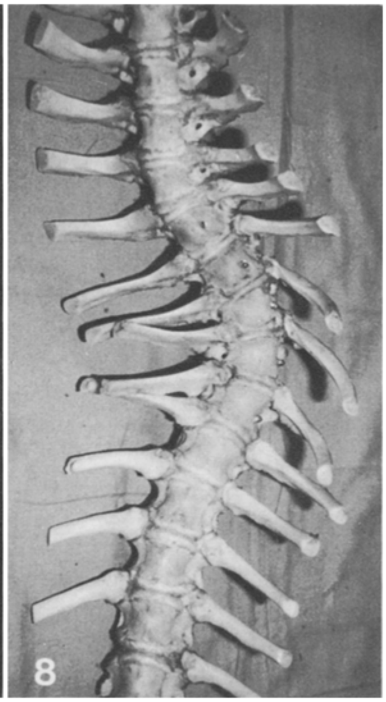

Fig. 7. The follow-up radiograph of the spine of the animal that presented 80° Cobb (pig no. 13). The curve is with the convexity towards the operated side

Fig. 8. Macroscopic appearance of the spine of the same animal. There is evident scoliosis, located at the level of the operated segment, with convexity towards the operated side. Compensating curves are not observed

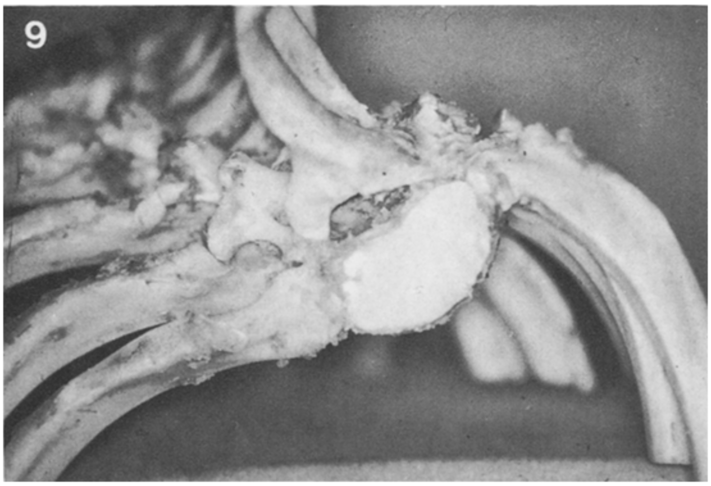

Fig. 9 Macroscopic axial view of the spine of the same animal as in Figures 7 and 8. Evident rotation of the vertebral body towards the operated side can be appreciated, the right side, with posterior displacement of the ribs on that side (hunch). Asymmetry of the spinal canal. The spinous processes are deviated towards the concavity of the curve

In human scoliosis, however, the role played by the neurocentral cartilage is very controversial since there is lack of agreement on the age at which fusion occurs under normal circumstances. Roaf [15] believes that the neurocentral cartilage usually disappears by the age of six years and is therefore unlikely to be cause of scoliosis after this age. Schmorl and Junghans [17] also agreeing that the neurocentral cartilage or neurocentral synchondrosis usually disappears between the third and sixth year of age, find that exceptionally it may persist up to the age of 14 years or even later.

Epstein [5] does not specify the age of fusion of the cartilage but only states that they are present during the first few years of life. Mineiro [11] when describing the normal development of the cartilage, which he called 'neurosomatic cartilages', said that they begin to ossify as from four years but that ossification may be very irregular and the cartilage may persist to the age of 15 years although ossification normally occurs between the fourth and nineth years.

The present authors' experience of studying anatomical specimens confirms that up to the age of 11 years all the neurocentral cartilages in the thoracic spine may be active, and some cartilage may still be present at the age of 14 years; but only at the mid thoracic level [3], the most frequent site of idiopathic scoliosis.

Our experimental results and observations lead us to believe that if symmetry of growth in the neurocentral cartilages of the spine is disturbed this leads to rotation of the vertebral body which in turn can alter the rate of growth of the epiphyseal cartilage giving rise to structural scoliosis and it is anatomically possible for this process to operate even up to adolescence.

References

1. Beguiristain, J. L.: Escoliosis experimental en ratas bidedas. Rev. Ortop. Traum. **18,** 367–380 (1974)
2. Beguiristain, J. L., Gili, J. R.: Influencia de la fisis neurocentral en la patogenia de la excoliosis experimental. Gac. Med. Bilbao **74,** 995–1018 (1977)
3. Cañadell, J., Beguiristain, J. L., Gonzalez Iturri, J., Gili, J. R.: Escoliosis experimental. Rev. Med. Univ. Navarra **18,** 99–111 (1974)
4. Goff, Ch. W., Landmesser, W.: Bipedal rats and mice. J. Bone Joint Surg. [Am.] **39,** 616–622 (1957)
5. Epstein, B. S.: The spine. A radiological text and atlas, p. 23. London: Henry Kimpton 1955
6. Karaharju, E. O.: Deformation of vertebrae in experimental scoliosis. Acta Orthop. Scand. (Suppl.) **105** (1967)
7. Langenskiöld, A., Michelsson, J. E.: Experimental progressive scoliosis in the rabbit. J. Bone Joint Surg. [Br.] **43,** 116–120 (1961)
8. Langenskiöld, A., Michelsson, J. E.: The pathogenesis of experimental progressive scoliosis. Acta Orthop. Scand. (Suppl.) **59** (1962)
9. Manning, C. W.: Experimental scoliosis. Proc. 2nd Symposium on Scoliosis: Causation, ed. by P. A. Zorab, pp. 11–14. Edinburgh: Livingstone 1968
10. Michelsson, J. E.: The development of spinal deformity in experimental scoliosis. Acta Orthop. Scand. (Suppl.) **81** (1965)
11. Mineiro, J. C.: Coluna vertebral humana. Alguns aspectos da sua estrutura e vascularizaçao. Lisboa: Sociedade Industrial Grafica 1965
12. Nicoladoni, C.: Anatomie und Mechanismus der Skoliose. München, Berlin, Wien: Urban and Schwarzenberg 1909
13. Ottander H. G.: Experimental progressive scoliosis in a pig. Acta Orthop. Scand. **33,** 91–97 (1963)
14. Piggott, H.: Posterior rib resection in scoliosis. J. Bone Joint Surg. [Br.] 663–671 (1971)
15. Roaf, R.: Scoliosis, Vol. 41. Edinburgh, London: Livingstone 1966
16. De Salis Amaral, J. A.: Escoliosis experimental por lesiôn vascular. M. D. Thesis, Universidad de Navarra, Pamplona 1977
17. Schmorl, G., Junghanns, H.: Die gesunde und die kranke Wirbelsäule. Stuttgart: Georg Thieme Verlag 1932
18. Tresserra, J.: Escoliosis experimental. Rev. Ortop. Traum. **31,** 739–800 (1969)