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The neurocentral vertebral cartilage: anatomy, physiology and physiopathology

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Summary. The neurocentral cartilage (NCC) described by Schmorl [14] as an intermediate cartilage has aroused discussion among numerous authors as to its role, its age of closure and its possible involvment in the genesis of scoliosis. The authors have attempted to define these problems on the basis of a histologic study of 20 vertebral specimens of different ages and a scanographic study of 25 children. The NCC remains open until adolescence and even beyond, but its maximal activity is probably around 5-6 years. Part of its function is to ensure growth of the posterior arch. Finally, the scanograms of scoliosis show the NCC to be more widely open on the concave side, as if this remained active for a longer period.

Cartilage neurocentral vertébral : anatomie, physiologie et physiopathologie

Résumé. Le cartilage neurocentral (CNC) décrit par Schmorl [14] comme cartilage intermédiaire a suscité des discussions entre de nombreux auteurs quant à son rôle, son âge de fermeture et son intervention probable dans la genèse de la scoliose. Les auteurs ont voulu préciser ces interrogations grâce, d'une part, à une étude histologique de 20 pièces vertébrales d'âges différents et, d'autre part, grâce à une étude scanographique de 25 enfants. Ainsi, le CNC reste ouvert jusqu'à l'adolescence et même au-delà, mais son activité maximale est probable aux alentours de 5-6 ans. Il agit en assurant, en partie, la croissance de l'arc postérieur. Enfin, les scanographies de scoliose montrent, du côté concave, un CNC plus largement ouvert comme si ce dernier était actif plus longtemps.

Key words : NCC — Scoliosis

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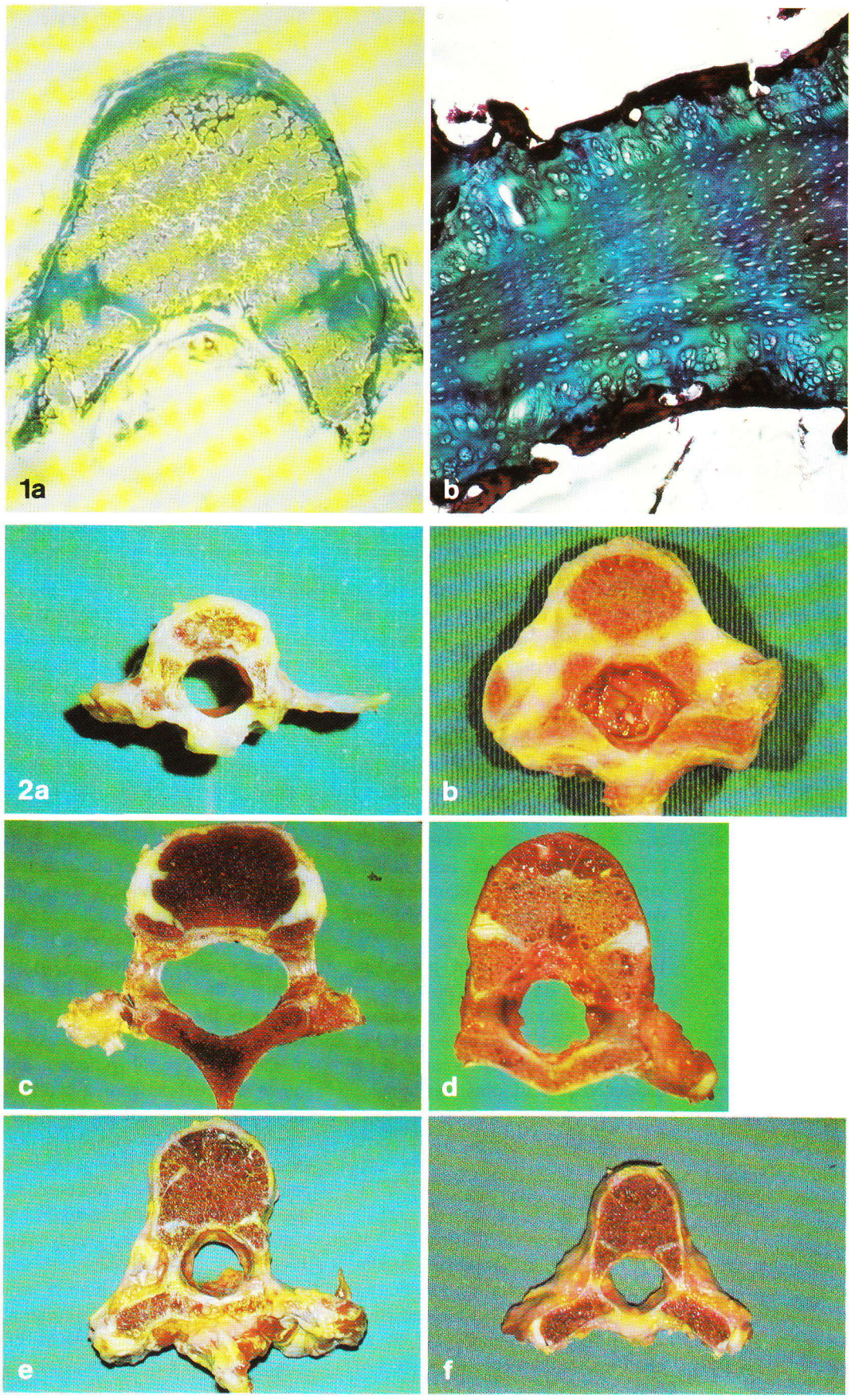
The neurocentral cartilage (NCC) is a growth cartilage appearing secondarily and situated at the junction of the vertebral body and the pedicles. Described by Schmorl [14] as an intermediate cartilage, the results of clinical observations and animal experiments have led many authors to consider it as predominantly involved in the genesis of scoliosis. The present study reviews previous work on the NCC and makes use of a histologic and scanographic study of vertebrae of different ages, normal and pathologic, to answer the following questions: up to what age is the NCC active? What is its function in spinal growth? Is there a real asymmetry of the NCCs on the concave and convex sides at the level of a scoliotic vertebra?

Historically, Schmorl [14] is certainly the author to have best describeb the NCC. Before him, Nicoladoni [9] in 1864 had spoken of the neurocentral junction and shown a vertebra from a scoliotic child where the cartilage was more open on the side of the concavity. Ottander [10], in 1963, made a precise histologic and morphologic study of the growth cartilage of bipolar appearance, with two directly opposed series of cell columns. Mineiro [8], in 1965, in a work on the vertebral column, showed numerous specimens of different ages. But it was particularly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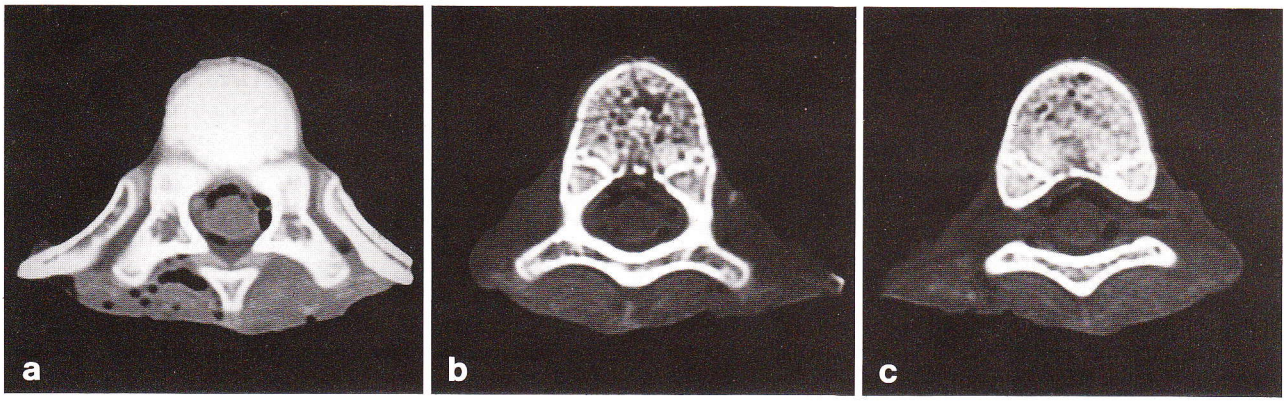

Fig. 3 a-c
CT sections of vertebra of a child of 6 years: **a** at discal level **b** at pedicular level **c** at foraminal level

Coupes tomodensitométriques de vertèbre d'enfant de 6 ans : **a** au niveau discal **b** au niveau pédiculaire **c** au niveau foraminal

the team of Cañadell [3] which published numerous articles on the subject in the 1970s, especially on experimental aspects (Pique-Vidal [11], Beguiristain [1]).

It is our intention here to describe the anatomy of the NCC on the basis of a histologic study of 20 spinal specimens of different ages, to recognize this cartilage in the scanographic images of 25 vertebrae in children, and to assess any asymmetry in the context of scoliosis.

In the discussion, we compare these results with those of authors who have studied this cartilage histoligically and experimentally. This may provide a better understanding of the physiology and physiopathology of the NCC.

Anatomic study (Table 1)

Twenty vertebral specimens from children of different ages without evidence of vertebral anomaly were examined (Dr Reparaz, Dr Rivel).

Tableau 1. Anatomic specimens

No.	Age	Sex
1	Fetus (18 weeks)	M
3	Newborn	2 F, 1M
1	3 months	M
1	11 months	M
2	2 years	F, M
2	3 years	2 M
1	4 years	F
2	5 years	2 F
1	6 years	M
1	7 years	M
1	9 years	F
1	11 years	M
1	12 years	M
1	14 years	F
1	16 years	M
Total 20		12 M, 8 F

These were: an 18-week fetus (male), 3 newborn (2 female, one male), an infant of 3 months (m), and children of 11 months (1 m), 2 years (1 m, 1 f), 3 years (2 f), 4 years (1 f), 5 years (2 f), 6 years (1 m), 7 years (1 m), 9 years (1 f), 11 years (1 m), 12 years (1 m), 14 years (1 f) and 16 years (1 m).

The cartilage is effectively bipolar and we have specified its thickness and topography related to age (Figs. 1, 2).

The thickness of the NCC decreases noticeably after 5-6 years, the date at which it is probably most active. At the histologic level it is fully organized at this age. We consider that this structure is related to the junction of the two primary centers of ossification for the body and posterior arch, which join at this level.

Scanograhic study

Cases

Twenty-five vertebral columns of 6 to 20 years were examined (10 male patients and 15 female). There were

Figs. 1, 2
1 Histologic section of thoracic vertebra of 6 years **(a)** with enlargement of the NCC **(b),** showing the bipolar appearance of this cartilage **2** Anatomic specimens of thoracic vertebrae of different ages: note the thinning of the NCC, its apparent retraction and its more or less transverse character. **a** 2 days **b** 3 months **c** 2 years **d** 3 years **e** 9 years **f** 11 years

1 Coupe histologique de vertèbre thoracique de 6 ans **(a)** avec grossissement du CNC en **(b)** montrant l'aspect bipolaire de ce cartilage **2** Pièces anatomiques de vertèbres thoraciques d'âges différents : observer l'amincissement du CNC, son apparent recul, son caractère de plus en plus transversal. **a** 2 jours **b** 3 mois **c** 2 ans **d** 3 ans **e** 9 ans **f** 11 ans

10 normal cases with routine section passing through T8. The 15 abnormal cases included 10 scolioses (4 congenital), 3 hollow backs and 2 kyphoses subsequent to Scheuermann's disease.

Technique

For each vertebra examined, the following were specified:

- *The thickness of the NCC,* depending on the window used. The window at 1600 Hounsfield units seemed the best (Fig. 3). In the scoliotic children, in order to obtain a perfectly horizontal section in relation to the two pedicles of the apical vertebra, the child was laid on the side of the convexity to obliterate the deformity as much as possible. The scout lateral view then provided a frontal image on which the inclination of the section was programmed.

- *The position of the NCC* in the anteroposterior direction was defined in terms of the ratio $\frac{AC}{BC}$, where A is the ventral border of the vertebral body; B is the junction of the two laminae; and C is the perpendicular projection of the medial extremity of the NCC on the straight line A B.

Thus, the greater the recession of the NCC, the greater the ratio. In actuality, this relationship is partly falsified by the fact that point A moves away under the influence of the growth of the vertebral body which is predominant after 5 years according to Knutsson [6]

- *The direction of the NCC,* whether more or less transverse.

Results

Normal cases (Fig. 4). The *thickness* of the NCC decreases with age, but it was sometimes visible very late, as in 2 young adult vertebrae (20 years). In the same subject, this closure takes place first in the lumbar, then in the thoracic and finally in the cervical region. The NCC progressively moves back actually, the medial extremity of this NCC still projects at the level of the posterior wall of the vertebral body, but the growth of the vertebral body is greater than that of the posterior arch. Finally, the NCC becomes more and more transverse.

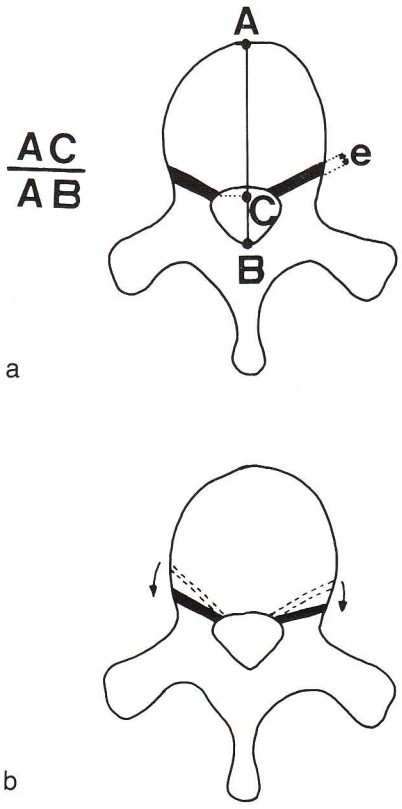

Fig. 4
a Assessment on CT sections of the thickness *(e)* (which decreases with age) and of the position in the horizontal plane by means of the ratio (which increases with age)

b Progressive orientation of the NCC, which becomes more transverse in the horizontal plane

a Appréciation sur les coupes scanographiques de l'épaisseur *(e)* (qui diminue avec l'âge) et de la situation dans le plan horizontal grâce au rapport $\frac{AC}{AB}$ (qui augmente avec l'âge) **b** Evolution de l'orientation du CNC qui devient dans le plan horizontal plus transversal

Pathologic cases. The *scanogram* is the best evidence of the degree of rotation of the vertebrae and the shape of the pedicles, which are narrower and longer on the concave side of an advanced scoliosis. There is no notable asymmetry in thickness or situation between the concave and convex sides in the early stage of a slowly developing scoliosis. On the other hand, such asymmetry does exist at the end of growth, where the NCC is seen to be still open on the concave side, rather as if it were prolonging the elongation of the posterior arch on this concave side. Moreover, in progressive juvenile scolioses there may be noted a difference in thickness of the cartilages, that on the convex side being narrower than that on the concave side (Figs. 5, 6). There were too few cases of kyphosis or abnormal lordosis to define the special progressive criteria of the NCC. One can only say that it is rather anterior in the lordo-scolioses and rather posterior in the kyphoses.

Discussion

Here, we must compare our histologic and scanographic findings with those of various authors who have studied the neurocentral cartilage on the basis of histologic, histopathologic or experimental investigations. A comparison of these different results must aim to define the 3 following points: the age of closure and maximal activity; its role in vertebral growth; and its possible role in the genesis of idiopathic scoliosis.

Divergent opinions

Opinions are extremely divergent as to the date of closure of the NCC. It is given as between 3 and 6 years by Knutsson [6], 5 years by Nicoladoni [9], 10 years by Ottander [10], 14 years by Bouillet [2], 15 years by Mineiro [8] and 16 years by

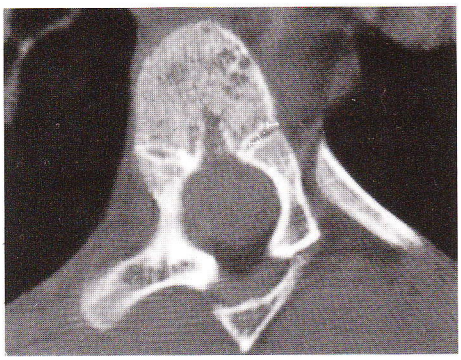

Fig. 5
CT section in child of 6 years with thoracic scoliosis and rotation towards the left-sided convexity; on the convex side the CNC is more compact

Coupe scanographique d'enfant de 6 ans présentant une scoliose thoracique avec rotation vers la convexité à gauche : du côté convexe, le CNC est plus serré

Canadell [3]. Actually, this divergence can be explained by the confusion that has often existed between the age of closure of this cartilage and that of its maximum activity. Our scanographic study showed the cartilage to be still visible in young adults although it had lost much of its thickness after adolescence (which explains the lessened importance of scanography after 15-16 years of age). The histologic specimens showed a bipolar growth cartilage, perfectly organized at the age of 5-6 years. This activity subsequently decreases until the end of growth, as already reported by Mineiro [8]. Depending on the level of its position in the vertebral column, the NCC does not evolve at the same speed: it first closes in the lumbar region, then at the thoracic and finally at the cervical level.

Role in vertebral growth

Most of the classical authors (Poirier [12], Testut [15]) agree in believing that the NCC controls the growth of the posterior third of the vertebral body (the remainder being ensured in great part by the primary center of ossification of the body) and especially the growth of the posterior arch, and this in symmetric fashion. Bilateral screwing of the pedicles in the growing pig by Professor Canadell's team yielded narrowed canals with short pedicles. Knutsson [6], who studied the growth of the spinal canal after birth, also showed a growth peak at around 5 years (the presumed age of maximal activity of the NCC).

Moreover, according to some authors, the NCC controls the growth in height of the posterior third of the vertebral body. This effect seems more debatable, as in the experiment previously described no decrease in height towards the back of the vertebral bodies (absence of lordosis) was noted after bilateral screwing of the pedicles.

Possible role of the NCC in idiopathic scoliosis

The role of the NCC in scoliosis has been approached in 2 ways: either by observation of scoliostic vertebrae in man or animals or by experiment acting directly on the NCC.

In scoliotic vertebrae, the NCC are asymmetric as has been well shown by Nicoladoni [9] in 4 children aged 1 to 6 years, and by Karaharju [5] and Michelsson [7] in animals. The NCC on the side of the convexity seems to have developed more rapidly and is narrower. The pedicle on the convex side is therefore shorter in the anteroposterior direction and wider than on the concave side. In actuality, it may be asked if the NCC is not the histologic image of the opposition occurring at the level of the pedicles between the two primary centers of ossification of the body and neural arch from the 3rd month of intrauterine life.

At the same time, numerous — notably Spanish — experimenters (Pique Vidal [11]), Beguiristain [1]) have attempted to produce scoliosis by acting in asymmetric manner on the NCC of growing animals. The vertebrae most nearly approaching the scoliotic model as observed in man have been obtained by Beguiristain. The scoliotic convexity was observed on the screwed side and the vertebrae were rotated. This experiment would tend to show the predominance of rotation in scoliosis.

Roaf [13] has very much stressed this phenomenon of rotation as the initator of scoliosis, in opposition to Dickson [4] who rather insists on a lordosis at the apex of the scoliosis as the starting-point of the deformity. To return to Beguiristain's experiment, screwing of the convex side of the NCC produces shortening of the pedicle on this side and more marked growth on the opposite side, thus promoting rotation towards the convexity (Fig. 6).

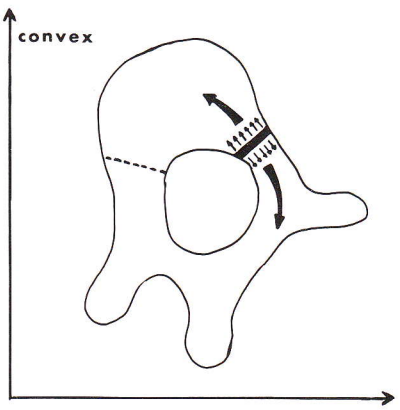

Fig. 6
Scoliotic vertebra with NCC on concave side more active than on convex side, thus producing rotation

Vertèbre scoliotique avec CNC du côté concave plus actif que le convexe et entraînant ainsi la rotation

This asymmetry in closure of the NCC has been found in CT scans of scoliotics: the NCC on the convex side undergoes involution and closes more rapidly than that on the concave side. Two questions then arise: Is the NCC the factor that determines the scoliosis by its asymmetry, or is it only the effector of an asymmetry of a muscular or neurologic nature? Does the possibility exist of effectively treating an idiopathic scoliosis seen to be progressive from 5-6 years of age by local early fusion of the NCC on the concave side?

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