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Intraspongious disc herniation (Schmorl's node) in *Phocoena phocoena* and *Lagenorhynchus albirostris* (Mammalia: Cetacea, Odontoceti)

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In this article five cases of intraspongious vertebral herniation of the nucleus pulposus (Schmorl's node) in harbour porpoises *Phocoena phocoena* and one in a white-beaked dolphin *Lagenorhynchus albirostris* are described. This condition has not previously been described for any cetacean species. Its etiology is most probably post-traumatic.

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INTRODUCTION

Although pathological changes of the vertebrae in Cetacea are well known from cleaned skeletons in museum collections (see for an overview Kompanje 1999), proven pathological changes of the intervertebral disc have been described only once when evidence of disc degeneration with secondary discarthrosis was observed during autopsy in white-beaked dolphins *Lagenorhynchus albirostris* (Kompanje 1995a, 1996). Conditions like spondarthritis (spondyloarthropathy), infectious spondylitis and discarthrosis/zygarthrosis (spondylosis deformans) have been recognized in some species of Mysticeti and Odontoceti (Kompanje 1995b, 1999). None of these conditions is however common.

Vertebral disc protrusion, a well-known condition in man and wild and domesticated terrestrial mammals, has not previously been described for any cetacean species. In general, disc herniation is defined as a localized protrusion of part of the intervertebral disc beyond its normal boundaries: a protrusion of the nucleus pulposus and/or annulus fibrosus and/or cartilage through a defect in the annulus and eventually the perivertebral ligaments (François *et al.* 1995). Vertebral disc protrusion can occur as a dorsal, ventral or ventrolateral prolapse. Moreover, there are prolapses which are directed in anterior or posterior direction, e.g. into the spongiosa of the vertebral body. There seems to be an anatomical predisposition for the latter kind of protrusion: a funnel-shaped indentation is found into each cartilage layer at the location where the former notochordal track went through the cartilage plate. These indentations constitute central weak points in the cartilage plate through which herniations from the nucleus into the vertebral spongiosa frequently occur in man. Such herniations are named Schmorl's nodes, after their first description in human spines in 1927 (Schmorl 1927; Schmorl & Junghanns 1932).

A way to find such a disc protrusion in cetaceans is during autopsy. Inspecting every intervertebral space during this procedure is very time-consuming and sometimes difficult. However, intraspongious protrusion of the intervertebral disc can sometimes also be diagnosed in cleaned vertebrae, depending on the nature of the pathological changes in the vertebral end plate and the vertebral body.

This article describes six cases of vertical intraspongious disc protrusion in five harbour porpoises *Phocoena phocoena* and one white-beaked dolphin *Lagenorhynchus albirostris* found stranded on the Dutch coast.

CASE REPORTS

Case 1 A dead female harbour porpoise was found on 20 November 1995 on the beach near Monster, province of Zuid-Holland, the Netherlands. The length of the pregnant animal was 138 cm, the weight 44 kg. During autopsy all vertebrae and intervertebral discs were studied for abnormalities. The 11th and 12th thoracic vertebrae were fused by a smooth, ventrally protruding ankylosis. None of the other vertebrae showed any abnormal features. The intervertebral discs between the 5th and 6th and between the 6th and 7th thoracic vertebrae showed signs of disc degeneration (the nucleus pulposus was found to be solid, dry, non-turgescent and showed a brown coloration). Yet the adjacent vertebrae showed no sign of discarthrosis. The 10th-13th thoracic vertebrae were removed en bloc and kept deep-frozen. These were subjected to radiological examination. After that they were divided longitudinally and fixed in alcohol 70%. The skull, pelvic bones and the described vertebrae were collected and kept in the Natural History Museum Rotterdam (NMR 999000170). On the divided vertebrae, large intraspongious disc protrusions (Schmorl's nodes) were found in the corpora of the 11th and 12th thoracic vertebra (Fig. 1). The intervertebral disc was calcified after secondary degeneration. The Schmorl's nodes were not demonstrated by radiography, but the calcification of the degenerated disc was clearly visible. The intervertebral spaces next to the lesion between the 10th and 11th and between the 12th and 13th thoracic vertebra were normal.

Case 2 On 5 January 1982 a male harbour porpoise was beached alive at Camperduin, province of Noord-Holland, the Netherlands. The animal was taken to the Marine Mammal Park Harderwijk where it died the same day. Detailed autopsy was not performed. The length and weight were not taken. The complete skeleton of this porpoise is in the National Museum of Natural History, Leiden (RMNH 33036). The 6th, 7th and 8th caudal vertebrae show pathological changes. Beside irregular marginal osteophytes, the 7th caudal vertebra shows an imploded area on the caudal epiphysis; on the caudal epiphysis of the 6th caudal vertebra, sclerosis is visible. This sclerosis and the reactive marginal osteophytes on the 6th, 7th and 8th caudal vertebra are due to secondary degeneration. All other vertebrae were normal. A diagnosis of intraspongious disc protrusion with secondary bone changes seems very probable.

Case 3 Two fused caudal vertebrae of an adult harbour porpoise were dredged in 1996 together with bones of Pleistocene mammals and recent cetacean bones during trawler fishery in the southern North Sea. The gross appearance of the pathological changes was very similar to the fused vertebrae of case 1. Longitudinal division of the fused vertebrae revealed a calcified central intraspongious

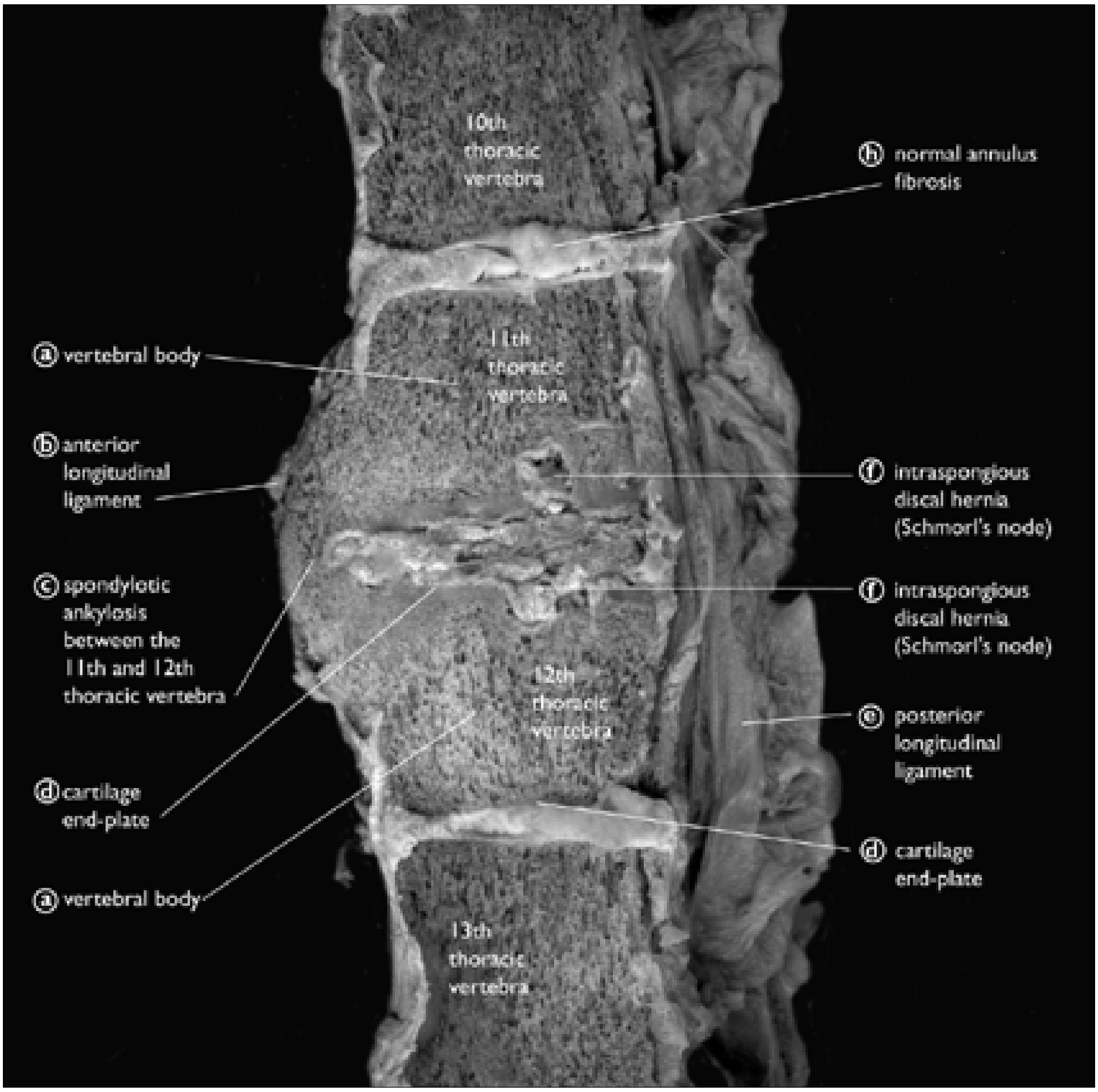

Figure 1 Longitudinally divided thoracic vertebrae of *Phocoena phocoena* (NMR 9990-00170), case 1. [photo: Jaap van Leeuwen]

disc protrusion. The vertebrae are kept in the Natural History Museum Rotterdam (NMR 999000474).

Case 4 On 29 January 1998 a dead female harbour porpoise was found on De Hors on the island of Texel, province of Noord-Holland, the Netherlands. The length of the animal was 153 cm, the weight 42 kg. During autopsy all vertebrae and intervertebral discs were studied for abnormalities. The 2nd and 3rd lumbal vertebrae were fused by a smooth, ventrally protruding ankylosis. None of the other vertebrae showed any abnormality. The intervertebral space between the first and second lumbal vertebra measured 8.5 mm in width, between the second and third 4 mm and between the third and fourth 8 mm. The first four lumbal vertebrae were removed en bloc and fixed in formalin. These vertebrae are kept in the Natural History Museum Rotterdam (NMR 999001054). This bloc was longitudinally divided, after which a vertical intraspongious disc protrusion in the corpus of the second and third lumbal vertebra became visible. The intervertebral discs of these articulations showed severe degeneration and calcification.

Case 5 On 21 July 1999 a dead female harbour porpoise was found on the beach near Zandvoort, province of Noord-Holland, the Netherlands. The length of the animal was 155 cm, the weight 32 kg. During autopsy all vertebrae and intervertebral discs were studied for pathological changes. The 13th and 14th lumbal vertebrae were fused by a smooth ventrally protruding ankylosis. None of the other vertebrae showed any abnormality. The two ankylosed vertebrae were longitudinally divided, after which small vertical intraspongious disc protrusions in both vertebrae became visible. The intervertebral disc showed an advanced stage of degeneration. The divided vertebrae were fixed in formalin and preserved with the rest of the skeleton in the collection of the Natural History Museum Rotterdam (NMR 999000298).

Case 6 On the 23 December 1999 an adult female white-beaked dolphin was stranded alive on the mudflats near Den Helder, province of Noord Holland, were she died the same day. The length of the animal was 251 cm. During autopsy all vertebrae and vertebral ligaments were studied for abnormalities. The 2nd and the 3th lumbal vertebrae were fused by a smooth ventrally protruding ankylosis. None of the other vertebrae showed any abnormality. The last thoracic up to and including the third lumbar vertebrae were removed en bloc and the vertebral bodies were divided longitudinally, after which intraspongious disc protrusions in the corpora of the first, second and third lumbar vertebra became visible. The intervertebral discs were calcified after secondary degeneration (Fig. 2). The vertebrae were fixed in formalin and are kept in the Natural History Museum Rotterdam (NMR 999000475).

DISCUSSION

It is well-known that some mammal species are more vulnerable than others to either traumatic or degenerative conditions of the intervertebral disc. In the domestic dog *Canis familiaris*, there are great differences between breeds, with disc degeneration and disc herniation being especially prevalent in chondrodystrophoid breeds (Hoerlein 1987). But whereas disc protrusions in the transversal body plane are well documented for domestic animals, intraspongious disc protrusions into the adjacent vertebra through the cartilage end plate are considered rare (Palmer 1992). In man, this condition is however rather common: some authors report an incidence of no less than 76% in human spines examined during autopsy (Hilton *et al.* 1976).

Intraspongious discal herniation as described here has not been reported previously for any cetacean species. The occurrence of this lesion in cetacean species has not been established, but examination of 658 cleaned skeletons of 47 species of Odontoceti and 44 cleaned skeletons of Mysticeti in museums (Kompanje 1999) and 231 spinal columns of seven species of Odontoceti during autopsy by the first author revealed only the six cases described here, suggesting that the incidence is low. It should be noted, however, that a full examination of the vertebral column, its intervertebral discs and the cartilage end plates of the vertebrae is very time-consuming and not part of most standard dissection protocols for small cetaceans (Kuiken & Garcia Hartmann 1993). This may explain why this lesion has gone unreported so far.

The presence of this lesion in two species of odontocetes and in man, and its very low incidence in other mammals (Palmer 1992), might indicate that similar strains on the vertebral column occur in species with a locomotion different from that of quadrupedal mammals. Therefore, the direction of forces acting on the vertebral column may be an important predisposition for the frequency of

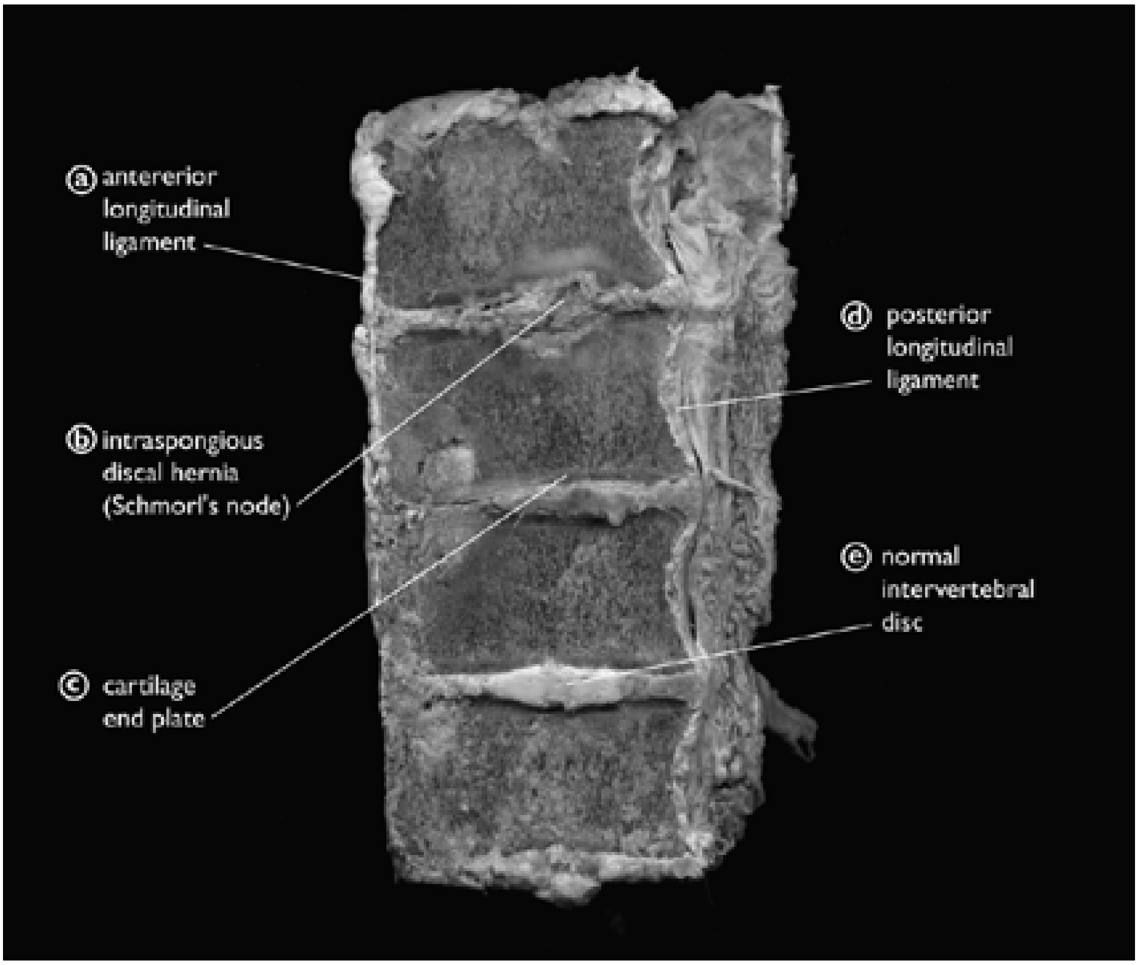

Figure 2 Longitudinally divided lumbar vertebræ of *Lagenorhynchus albirostris* (NMR 9990-00475), case 6.
[photo: Jaap van Leeuwen]

occurrence of Schmorl's nodes: man, with its vertical vertebral column, and cetaceans, which use their vertebral column as locomotion organ causing stress in the same three-dimensional direction as in man, may be examples of more vulnerable species. This has already been hypothetically suggested for cetaceans (Klima 1992; Kompanje 1995). Our finding of Schmorl's nodes in the cases described above seems to corroborate this hypothesis for these two odontocete species.

In man, blood vessels of the cartilage plate gradually disappear at about 25 years of age. In the adult, relatively few blood vessels from the spongiosa perforate the calcified cartilage layer connecting the cartilage plate to the bony vertebra. In childhood and adolescence, the sites of these blood vessels are occupied with plugs of soft fibrocartilage. Deformations of the nuclei pulposi of children have been described opposite the sites of these cartilage degeneration zones. These weak points in the cartilage plates seems to predispose to herniations forming Schmorl's nodes (Taylor & Twomey 1988). Under normal circumstances the cartilage end plates and the annulus fibrosus are strong enough to prevent displacement of the nucleus even under stressful circumstances. Yet, if the nucleus pulposus becomes displaced, there are two anatomical sites where the herniation is most likely to occur: (1) if pressure forces act in the longitudinal axis of the vertebral column, herniation may occur at the cartilage end plate which is supported by a thin subchondral bone plate; and (2) at the dorsal segments and immediately adjacent area of the annulus fibrosus (posterior or dorsal herniation), because of this being its thinnest parts in the transversal axis of the vertebral column. Additional factors of influence, like the support provided by the dorsal longitudinal ligament and the intercapital ligaments in the thoracic region and the moment of bending stresses at the same time as the compressive force, may determine the site of protrusion/extrusion (Toombs & Bauer 1993; Adams *et al.* 1993).

Although the exact etiology of Schmorl's nodes is unknown, there is evidence that in man the main cause is traumatic, with the existence of predisposing anatomical features and frequent secondary degeneration. The hypothesis that traumatic events may be the main cause of Schmorl's nodes is plausible (Adams *et al.* 1993) and the majority of these lesions is probably present from an early age and only a small percentage is formed in adult life. This is in agreement with the concept that herniation is more likely to occur at an age when the nucleus is in a semifluid state. Schmorl's nodes in man are particularly common in athletes and swimmers who subject their spines to high impulsive forces (Adams *et al.* 1993; 1997). Vertebrae and discs with Schmorl's nodes tend to exhibit advanced degenerative changes at an early age and, in some instances, at least the earliest degenerative changes are in the region of the herniation (Vernon-Roberts 1988). The latter is also evident in the cases described here for cetaceans. The age of the harbour porpoises with Schmorl's nodes is unknown, but based on the known age-length relationship in the Dutch harbour porpoise population (Addink & Smeenk 1999) and the maturity of the skeletons examined, they are classified as adults. The white-beaked dolphin with the Schmorl's nodes described here was an old adult.

Suggestive for traumatic origin in humans is the localization of the lesions, which are more common and more severe in the dorsolumbar (Th10-L1) than in the lower lumbar region, which is more prone to degenerative lesions. Identical dorsolumbar locations were found in two harbour porpoises and the white-beaked dolphin (case 1, 4 and 6).

It has been found in man that congenital as well as aquired defects of the cartilage may be predisposing factors for the occurrence of Schmorl's nodes (Vernon-Roberts 1988). The nucleus pulposus is subject to a large array of mechanical forces during movements of the vertebral column. Degeneration of its components, for instance the nucleus pulposus and, to a lesser degree the annulus fibrosus, have also been found to play a role in other disc protrusions in mammals (Dahme 1988). In man, disc degeneration occurs more frequently in discs with Schmorl's nodes. However, it is considered that most degenerative processes are secondary to the initially traumatic origin of the Schmorl's nodes.The fact that Schmorl's nodes are demonstrable by radiography in only 13.5% of the cases in man (Schmorl & Junghans 1971) indicates that protrusions are small and that they are not surrounded by reactive cartilaginous or osseous casing. In some cases, fibrosis, calcification and ossification of the protruded nuclear material follow the intraspongious disc protrusion, initiating further degenerative changes. In our case 3 the calcified protruded material was still present in dregded cleaned vertebrae. On the vertebrae of the harbour porpoises and the white-beaked dolphin described here, secondary degenerative changes are clearly visible: excessive formation of marginal osteophytes and sclerosis of the epiphysis in case 2, ankylosis in cases 1, 3, 4, 5 and 6 and ossification of the protruding material is found in cases 1, 3 and 6. Since they concern mainly single intervertebral events rather than several joints being affected, we believe that it is most likely that these degenerative features have developed only after the intraspongious discal herniation.

CONCLUSIONS

(1) Most probably, single or repeated traumatic events, possible at a young age, have been the origin of ruptures or tears in the cartilage end plate which led to the intraspongious herniation (Schmorl's node) in the odontocetes described. (2) An isolated ankylosis found during autopsy in two adjacent vertebrae in an otherwise normal vertebral column can be an indication for secondary disc degeneration with discarthrosis after an intraspongious discal herniation. A longitudinal division of the fused vertebrae can demonstrate the presence of a Schmorl's node.

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