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Columna Vertebralis in a Dolphin (*Globicephala meleana*)

Erdal Ozmen
Department of Anatomy, Faculty of Veterinary Medicine,
Mustafa Kemal University, Hatay, Turkey

Abstract: This study describes the vertebral column of a long-finned pilot whale, a member of the dolphin family using material from a dead specimen. The vertebral bones were separated from the soft tissues and investigated anatomically. A dolphin's vertebral column is formed of 62 bones: 7 cervical, 12 thoracic, 17 lumbar and 26 caudal vertebrae. There are 5 visible cervical vertebrae (1st and 2nd are fused as are 5th and 6th). The first four thoracic vertebrae have 2 articular faces for ribs located at the tips of the transverse processes while the others have only one. The vertebral canal through the lumbar vertebrae has a triangular cross-section. The caudal vertebrae have various shapes. Although, the first 20 caudal vertebrae are not fully developed, they do have complete anatomical structures such as transverse and spinous processes and the last 19 have 2 symmetrically disposed foramina in their bodies. The vertebral foramen extends from the 1st cervical to the 17th caudal vertebra. Sacral vertebrae were not identified.

Key words: Anatomy, columna vertebralis, dolphin, ribs, caudal, Turkey

INTRODUCTION

Dolphins are marine mammals of the order cetacea, suborder Odontoceti, family Delphinidae, subfamily Delphininae (Perin, 2002). Buchholtz *et al*. (2005) report that there are 17-19 genera and 34-36 species in the subfamily. Researchers (Buchholtz and Schur, 2004; Boszczyk *et al*., 2001) describe the vertebral column of the dolphin as a flexible structure and its functional property as one of the moving organs. In domestic mammals, the vertebral column is composed of the cervical, thoracic, lumbar, sacral and caudal (coccygeal) segments (Dursun, 2001). The cited literatures (Buchholtz and Schur, 2004; Buchholtz *et al*., 2005; Fettucia and Lopes, 2004) show that the vertebral column of the dolphin exhibits all the same segments as land mammals except the sacral segment. Numbers of vertebrae per segment vary among Delphinidae species, except for the cervical (Long *et al*., 1997; Buchholtz and Schur, 2004; Fettucia and Lopes, 2004; Buchholtz *et al*., 2005).

There are 7 cervical vertebrae in dolphins (Long *et al*., 1997; Buchholtz and Schur, 2004; Fettucia and Lopes, 2004; Buchholtz *et al*., 2005) as in land mammals (Dursun, 2001) but because of the fusion of the atlas and axis. Fettucia and Lopes (2004) report the number of the cervical vertebrae as 6 in *Sotalia guianensis*. This fusion is partial or total in all cetaceans (Buchholtz and Schur, 2004) and the first 4 vertebrae are fused in *Lagenorhynchus acutus* (Buchholtz *et al*., 2005). Fettucia and Lopes (2004) point out that the archus of the cervical vertebrae is not fused dorsally and describe a bilateral vertebral foramen. The number of thoracic vertebrae is 13 in *Delphinus delphis* (Long *et al*., 1997) and 14 in *Lagenorhynchus acutus* with variation between 13 and 16. In other dolphin species generally, the number of thoracic vertebrae is stated as 12 but may be any number from 8-17 (Buchholtz *et al*., 2005). Fettucia and Lopes (2004) in their study, point out that there were 12 thoracic vertebrae in 26 of 27 samples in *Sotalia guianensis* but 11 in the 27th. In *Lagenorhynchus acutus* (Buchholtz *et al*., 2005) and *Sotalia guianensis* (Fettucia and Lopes, 2004), articular faces are recorded in all thoracic vertebrae for articulation with the ribs. Buchholtz *et al*. (2005) describe parapophyseally located second articular faces also forming joints with the ribs on the thoracic vertebrae. Fettucia and Lopes (2004) report that the spinous process of the thoracic vertebrae arise backwards in *Sotalia guianensis* while Buchholtz *et al*. (2005) describe them as decumbent caudally. While Boszczyk *et al*. (2001) record the zygopophyseal articular face as far back as the seventh vertebrea in *Tursiops truncatus*. Fettucia and Lopes (2004) register metapophyseal articular faces appearing on the cranial border of spinous processes on thoracic vertebrae in *Sotalia guianensis*.

There is a wide difference in the numbers of lumbar vertebrae both among and within the species in dolphins (Buchholtz and Schur, 2004; Fettucia and Lopes, 2004; Buchholtz *et al*., 2005). The number of lumbar vertebrae are stated as 10-12 in *Sotalia guianensis* (Fettucia and Lopes, 2004), 20-25 in *Lagenorhynchus acutus* (Buchholtz *et al*., 2005) and in other species the number ranges from 7-33 (Fettucia and Lopes, 2004). Fettucia and Lopes (2004) show metapophyseal processes (processus mammillaris) on the spinous processes of lumbar vertebrae in *Sotalia guianensis* appearing to embrace the preceding vertebrea. Buchholtz *et al*. (2005) describe zygopophyseal articular faces on initial lumbar vertebrae in *Lagenorhynchus acutus*. The numbers of caudal vertebrae are 30-40 in *Lagenorhynchus acutus* (Buchholtz *et al*., 2005) and 23-25 in *Sotalia guianensis* (Fettucia and Lopes, 2004). The spinous and transverse processes were determined to be vertical to the vertebral body with the spinous process shortened, thickened and curved cranially after the synclinal vertebrea. Dorsoventrally directed symmetrical foramina (canalis vertebralis) are located on the last few caudal vertebrae (Buchholtz *et al*., 2005). Fettucia and Lopes (2004) described Y-shaped haemal bones forming joints with the ventral parts of the caudal vertebrae to form the haemal archus that carries the aorta. The aim of this report is to describe the anatomy of the vertebral column of the dolphin (*Globicephala melaena*).

MATERIALS AND METHODS

The material of the report was a dolphin (*Globicephala melaena*). Soft tissues were removed from the bones by burying the carcass for 18 months. On disinterment, the bones were coded and labeled before exposure to 5% sodium hypochlorite for a week for whitening. The bones were then ordered, evaluated and photographed.

RESULTS AND DISCUSSION

About 62 vertebrae were counted, consisting of seven cervical, 12 thoracic, 16 lumbar and 27 caudal sacral vertebrae were seen to be absent. The first two vertebrae, atlas and axis, appeared as a single bone because they were fused (Fig. 1-3). Two bilaterally positioned shallow articular faces were seen, forming joints with the occipital

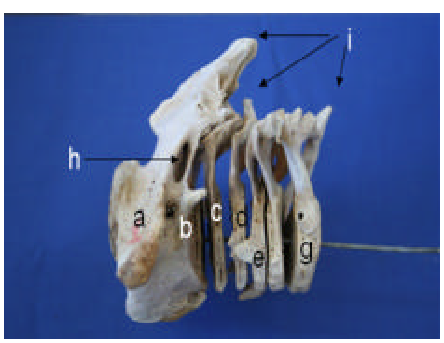

Fig. 1: Lateral appearance of cervical vertebras; a; Atlas, b; Axis, c; 3rd cervical vertebra, d; 4th cervical vertebra, e; 5th cervical vertebra , f; 6th cervical vertebra, g; 7th cervical vertebra, h; foramen between Atlas and axis, i; spinal processus

bone, cranial to these two fused bones. It was determined that the vertebral foramen was dorsoventrally flattened and wide, the transverse processes were horizontal and distinctive and the spinous processes were caudally directed and strongly constructed. In the border of the 2 used vertebrae, at the inosculation point of the vertebral arch and body, intervertebral foramina were observed (Fig. 1 and 3). The transverse process of the axis which fused with the atlas was easily determined. The length of the vertebral body of the two fused vertebrae was 3.5 cm. A rough caudal articular process was seen on the vertebral arch. The C3 and looked alike but the body of the 3rd was shorter than that of the 4th (Fig. 1 and 2). The arch of the 4th cervical vertebrea was not fused dorsally.

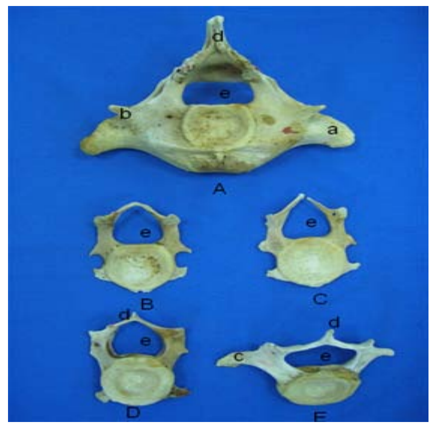

Fig. 2: Caudal appearance of cervical vertebras. A; atlas and axis, B; 3rd cervical vertebra, C; 4th cervical vertebra D; 5th and 6th cervical vertebra E; 7th cervical vertebra, a; transversal process belongs to Atlas, b; transversal process belongs to Axis c; transvers process, d; spinal process, e; vertebral foramen

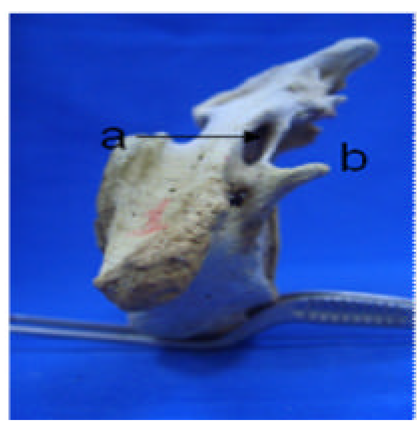

Fig. 3: Left side appearance of the atlas and axis, a; Foramen between atlas and axis b; Tranversal process belong to axis

Fig. 4: Fused 4th and 5th cervical vertebrae

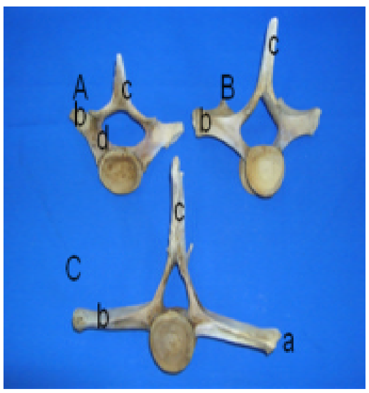

Fig. 5: Caudal appearance of thoracal vertebras. A; 1st thoracic vertebra, B; 6th thoracic vertebra, C; 12th thoracic vertebra, a; articular face for rib on the transversal process (fovea costalis processus transversi), b-transversal process, c; spinal process, d; second articular face on arcus (fovea costalis caudalis)

The weakly-formed remainder of the transverse processes was visible at the fusion side of the body and vertebral arch of the 3rd and 4th cervical vertebrae which showed no spinous processes (Fig. 4). It was established that the arches of the 5th and 6th cervical vertebrae were fused (Fig. 4). While there is no spinous process on the 5th cervical vertebrea, the 6th does have one, though it is very small. The 7th cervical vertebrea has all the properties of a typical vertebrea except the fovea costalis caudalis that makes the joint with the ribs. Cranial and caudal articular faces were determined in all cervical vertebrae. The body shape of the thoracic vertebrae is like a pulley (Fig. 5 and 6). The caudally directed spinous processes, horizontally located transverse processes and the vertebral foramina were clearly visualized. The costal articular faces at the ends of the transverse processes were seen in all thoracic vertebrae. The first 4 vertebrae also carry a second costal articular face at the fusion point

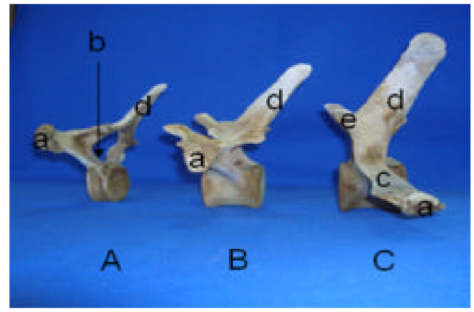

Fig. 6: Left side appearance of thoracal vertebras. A; 1st thoracic vertebra B; 6th. thoracic vertebra C; 12th thoracic vertebra a; fovea articularis processus transversi, b; fovea costalis caudalis, c; processus transversus, d; processus spinosus, e; processus articularis cranialis

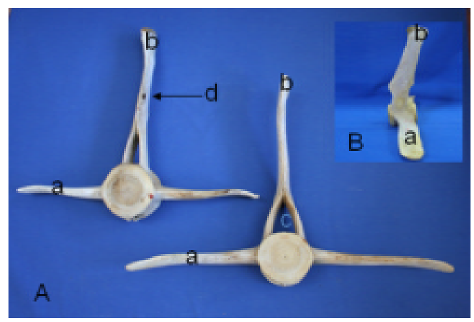

Fig. 7: Appearance of lumbal vertebras. A; cranial appearance, B; right side appearance, a; processus tansversus, b; processus spinosus, c; foramen vertebra, d; articular process on spinal process

of the vertebral body and arch. All thoracic vertebral bodies have completely flat articular faces. On the arches, the cranial and caudal articular faces make joints with each other. After the 6th thoracic vertebrea, cranial articular processes, carrying the cranial articular faces were determined and these processes appeared on all posterior thoracic vertebrae.

Lumbar vertebrae can be distinguished from thoracic vertebrae as they have no costal articular faces on the transverse processes (Fig. 7). Lumbar vertebrae have spinal processes that are initially caudally slanted, then vertical; they are long, laterally flat having sharp cranial and caudal borders (Fig. 7). Cranial and caudal articular processes were found on the cranial tip of vertebral arch. It was seen that the transverse processes became more spacious and shortened caudally and fused horizontally to the vertebral body. The vertebral foramen changed from a wide oval shape into a narrow isosceles triangle.

Total 27 caudal vertebrae having different anatomic properties and shapes were identified (Fig. 8-10). They were differentiated from the thoracic vertebrae by the double processes at the articular faces of the haemal bones at the caudal border of the vertebral body's ventral face (Fig. 10a). This difference was very plain to see until the last nine vertebrae where the processes disappeared even though the haemal bones were present. The first 17 overtebrae have transverse and spinous processes and a triangular vertebral foramen. The articular face of the body of the 18th caudal vertebrea was convex. Beginning from the 19th caudal vertebrea the vertebral foramen disappeared and the shapes changed into a craniocaudally flattened rectangle. Double, dorsoventrally situated foramina were determined from the 8th-27th caudal vertebrae (Fig. 9b and 10a). The haemal bones were seen at the basal surfaces of the caudal vertebrae (Fig. 10). Their shapes were initially Y (Fig. 11b, c) and reduced in size until by the last 9 vertebrae they were seen as 8 attached bones (Fig. 11a). A channel was observed whose dorsal border was the vertebral body dorsally with the haemal bones ventrally (Fig. 8-12). In all cited

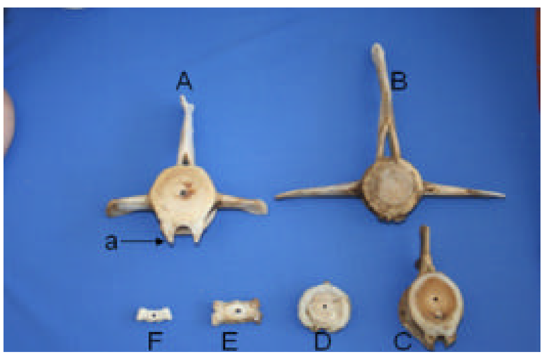

Fig. 8: Appearance of caudal vertebras. A; 10th caudal vertebrae, B; 7th caudal vertebrae, C; 15th caudal vertebrae, D; 19th caudal vertebrae, E; 24th caudal vertebrae F; 27th caudal vertebrae a; articular process for the haemal bone

Fig. 9 : Lateral appearance of caudal vertebras (left side). A; 10th caudal vertebrae, B; 1st caudal vertebraea; articular process on the spinal process, b; foramen on body, c; articular process for haemal bone

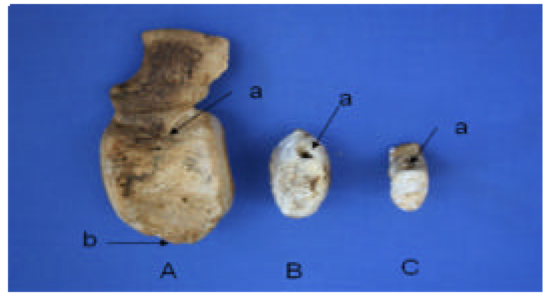

Fig. 10: Lateral appearance of caudal vertebras (right side). A; 15th caudal vertebrae, B; 19th caudal vertebrae, C; 24th caudal vertebrae, a; symetrical foramen on body, b; articular process for haemal bone

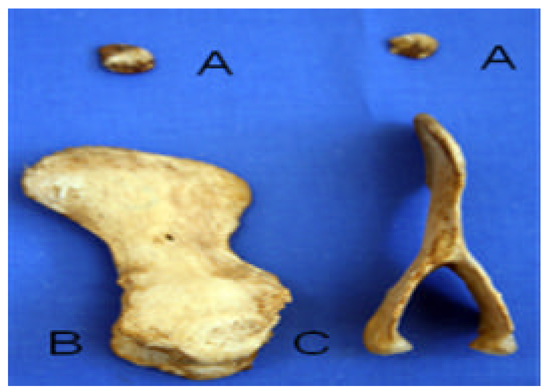

Fig. 11: Appearance of the haemal bone. A; 26th, hemal bones, B; 1st (lateral side) and C; 2nd (caudal side) haemal bone

Fig. 12: Joining of the between caudal vertebra and haemal bone, a; Haemal arcus

Fig. 13: The columna vertebralis of *Globicephalus meleanae*

literatures it is pointed out that all species have 7 cervical vertebrae (Boszczyk *et al*., 2001; Fettucia and Lopes, 2004; Buchholtz *et al*., 2005) and 7 were duly found in this dolphin. A partial or total fusion in different dolphin species has been documented (Buchholtz and Schur, 2004; Buchholtz *et al*., 2005). In this study, fusion was determined between the atlas and axis and between the 5 and 6th cervical vertebrae by their vertebral arches. The study also found that the body of the cervical vertebrae very short, a finding consistent with the results of other researchers (Fettucia and Lopes, 2004; Buchholtz *et al*., 2005). Fettucia and Lopes (2004) described a vertebral foramen on the lateral sides of the body of the cervical vertebrae in *Sotalia guianensis*. In *Globicephala melaena*, the vertebral foramen was similar to that described in land mammals (Dursun, 2001). No craniocaudally directed foramen on the lateral sides of the vertebral body was detected in *Globicephala melaena* as Fettucia and Lopez (2004) stated in which they did not detect in *Sotalia guianensis*.

Buchholtz *et al*. (2005) found that *Lagenorhynchus acutus* usually has 14 thoracic vertebrae, though sometimes 13-16 while the normal 20 thoracic vertebrae may vary between 8 and 17 in other species. Fettucia and Lopes (2004) found 12 in 26 dolphins, 11 in the 27th. This study observed 12 thoracic vertebrae in *Globicephala melaena*. Buchholtz *et al*. (2005) claim that the first six vertebrae of *Lagenorhynchus acutus* have 2 articular faces for the ribs while the rest have just one while this study found for *Globicephala melaena* that only the first 4 have 2 faces and the other 8 have 1.

In the current study, it was observed that the transverse processes of thoracic vertebrae arose caudally but no literature has been found to enable comparison. Boszczyk *et al*. (2001) indicated that there were zygopophyseal articular faces back as far as the 7th thoracic vertebrea.

This study observed cranialis and caudalis articular processes in all thoracic vertebrae. The cranial articular processes on the 6th thoracic vertebrea were observed as very large notches. Globicephala melaena has 16 lumbar vertebrae. Buchholtz *et al*. (2005) (Fig. 13) reported 20-25 in *Lagenorhynchus acutus* and that those in other species numbered from 7-33. Fettucia and Lopes (2004) reported 10-12 lumbar vertebrae in *Sotalia guianensis*, and observed that the metapophyseal articular faces were on the spinous process.

The current study found articular processes on the processus spinosus, covering the front of the lumbar vertebrea. Some researchers (DeSmet, 1977; Fettucia and Lopes, 2004) have reported haemal bones and articular faces belonging to them on the caudal vertebrae, just below the corpus (body).

The present study's findings agree with them. Buchholtz *et al*. (2005) reported that the processus spinosus and the processus transversus (transverse process) of caudal vertebrae situated perpendicularly while the current study found both to be cranially inclined. Fettucia and Lopes (2004) defined the holes observed in the bodies of 6th caudal vertebrae in *Sotalia guianensis* as canalis vertebralis.

Buchholtz *et al*. (2005) recorded holes in the 19th and 24th caudal vertebrae of *Lagenorhynchus acutus* while Buchholtz and Schur (2004) recorded holes in the last vertebrae. In agreement with these findings, the present study observed 2 holes in the 19th caudal vertebrea; they had dorsoventral direction and passed through the corpus. Fettucia and Lopes (2004) and DeSmet (1977) reported that there were transverse processes until the 9th-13th caudal vertebrae and spinous processes until the 13th-15th in *Sotalia guianensis*.

CONCLUSION

In the current study, transverse processes were observed until the 17th caudal vertebrea, spinous processes to the 19th. Some researchers described haemal bones joined to the caudal vertebrae in the form of the letter Y. The present study also observed these but in the last 9 vertebrae saw the haemal bones as 2 small rectangular bones acting as accessories to the main structure of the skeleton of tail.

REFERENCES

Boszczyk, B.M., A.A. Boszczyk and R. Putz, 2001. Comparative and functional anatomy of the mammalian lumbar spine. Anatomical Record, 264: 157-168.

Buchholtz, E.A. and S.A. Schur, 2004. Vertebral osteology in delphinidea (Catacea). Zool. J. Linn Soc., 140: 383-401.

Buchholtz, E.A., E.M. Wolkovich and R.J. Clearly, 2005. Vertebral osteology and complexity in <ı>lagenorhynchus acutus</ı (delphinidae) with comparison to the other delphinoid genera. Marine Mammal Sci., 21: 411-428.

DeSmet, W.M.A., 1977. The Regions of Catacean Vertebral Column. In: Functional Anatomy of Marine Mammals, Harrison, J. (Ed.). Academic Press, New York, ISBN: 978-0123280022, pp: 58-60.

Dursun, N., 2001. Veteriner Anatomi I. Medisan Yayinevi, Ankara, pp: 110-132.

Fettucia, D.C. and S.C.P. Lopes, 2004. Morfologia da coluna vertebral do botocima, *Sotalia guinensis* (Cetacea, Delphinidae). Biotemas, 17: 125-148.

Long, Jr. J.H., D.A. Pabst, W.R. Shepherd and W.A. McLellan, 1997. Locomotor design of dolphin vertebral columns: Bending mechanics and morphology of *Delphinus delphis*. J. Exp. Biol., 200: 65-81.

Perin, W.F., 2002. Mammalian Species: Stenalla Frontalis. American Society of Mammologists, USA., pp: 1-6.