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DOI: <https://doi.org/10.1177/1040638713495545>

Posted at the Zurich Open Repository and Archive, University of Zurich

ZORA URL: <https://doi.org/10.5167/uzh-85824>

Accepted Version

Originally published at:

de Brot, S; Grau-Roma, L; Vidal, E; Segales, J (2013). Occurrence of osteochondromatosis (multiple cartilaginous exostoses) in a domestic pig (*Sus scrofa domesticus*). *Journal of Veterinary Diagnostic Investigation*, 25(5):599-602.

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1 **Occurrence of osteochondromatosis (multiple cartilaginous exostoses) in a pig (*Sus***
2 ***scrofa domesticus*)**

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17 **Running title:** Osteochondromatosis in a pig.

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1 **Abstract**

2 Osteochondromatosis is a condition in which multiple benign, cartilage-capped tumors
3 arise from the surface of bones formed by endochondral ossification. The current report
4 describes the presence of 4 prominent exophytic masses, measuring between 4 and 13
5 cm in diameter, arising from the surface of ribs and located within the thoracic cavity, in
6 a 2-year-old female domestic pig. Histological studies revealed that masses were well-
7 differentiated cartilage-capped proliferations with an orderly pattern of endochondral
8 mineralization toward deeper areas. The observed gross and microscopical findings are
9 characteristic of osteochondromatosis, which has not been reported in pigs before.

10

11 **Keywords**

12 Multiple cartilage exostosis; osteochondroma; ribs; swine; tumor.

13

1 An osteochondroma is a benign, cartilage-capped tumor arising from the surface of
2 bones formed by endochondral ossification.^{9,12} Osteochondromas may occur in two
3 forms: solitary or multiple. Despite their identical histological appearance and
4 biological behavior, the multiple form of the condition is termed osteochondromatosis
5 or multiple cartilaginous exostoses.¹² This condition is usually recognized as an
6 incidental finding during routine controls, radiographic examination or at necropsy.
7 Occasionally, clinical signs might occur and are due to compression or distortion of
8 adjacent structures. Osteochondromatosis is infrequently reported. So far, it has been
9 described in humans,¹⁴ horses,⁶ dogs,¹ a macaque⁷ and cats,⁸ although feline
10 osteochondromatosis has significant differences in regards to etiology, biological
11 behavior and pathology compared to other species affected.^{11,12} The present report
12 describes a case of osteochondromatosis in swine.

13

14 A 2-year-old female pig, belonging to a batch of 133 pigs (mainly sows), was
15 slaughtered in an officially inspected abattoir in Catalonia (Spain). During the post-
16 mortem inspection, 4 prominent exophytic, cauliflower shaped masses, ranging between
17 4 and 13 cm in diameter were noticed in the thoracic cavity arising from the surface of
18 ribs (Figs. 1 and 2). The masses had a smooth surface and were attached with a broad
19 sessile base to the costal cartilage or the costal body of the ribs. Three and one nodules
20 were present in the left and right hemithorax, respectively. The masses were solid, had a
21 hard consistency and had bluish-white and reddish areas on its outer surface. During the
22 inspection, no other abnormalities were observed in the carcass or in the internal organs,
23 but the carcass was considered not adequate for consumption due to the observed
24 lesions. One of the masses was collected, fixed in 10% buffered formalin, and submitted
25 to the Slaughterhouse Support Network (Servei de Suport a Escorxadors, SESC-

1 CReSA) for diagnosis. Once in the laboratory, the sample was decalcified in 5% formic
2 acid over 7 days and routinely processed for histopathology. Four μm thick tissue
3 sections were processed for hematoxylin and eosin staining (HE).

4

5 Histological examination revealed that the studied tissue was a multilobulated mass
6 with multiple irregular islands of well-differentiated hyaline cartilage and bony
7 trabeculae, the latter originating from endochondral mineralization. Discontinuously,
8 hyaline cartilage covered the surface of the mass and had an orderly pattern of
9 mineralization and transition into mature trabecular bone towards the central and deeper
10 areas of the mass, mimicking the structure of a growth plate (Fig. 3). Above the
11 cartilage, a variably thick perichondrial membrane was also present. Chondrocytes were
12 enmeshed within an abundant hyalinized amphophilic extracellular cartilage matrix.
13 Between the cartilage and bone trabeculae there were large spaces containing loose
14 tissue with a moderate number of fusiform cells resembling fibroblasts, adipocytes and
15 thin-walled blood vessels. In the deeper sections, bone marrow was present amongst the
16 bony and cartilaginous trabeculae. Chondrocytes were well-differentiated and showed
17 hypertrophy in the areas close to endochondral ossification. No mitoses were seen.
18 Multifocally, some chondrocytes within irregular trabeculae had necrotic features. Bony
19 trabeculae often showed active remodelling, with abundant osteoclasts and rows of
20 plump osteoblasts lining their surface (Fig. 4).

21

22 Based on gross and histological features, a diagnosis of osteochondromatosis was made.

23

1 In humans, dogs and horses, osteochondromatosis typically occurs in young individuals,
2 and is known to be inherited in an autosomal dominant pattern.^{9,12} In dogs and horses,
3 the lesion most commonly arises from scapula, ribs, vertebrae and pelvis.¹² In those
4 species, it is not clear if this condition should be considered true neoplasia or not, since
5 its growth stops once bone growth ceases, and the cartilage cap is replaced by bone.
6 Similarly, in the present case, the masses were seen on ribs surface from a young adult
7 animal (in pigs, growth plate closure occurs around 3,5 years of age¹³). In contrast,
8 osteochondromatosis in cats has many differences and is not considered to be analogous
9 to the condition observed in horses and dogs. Thus, osteochondromatosis in cats may
10 occur in mature animals and can involve bones derived from intramembranous
11 ossification, which never happens in horses and dogs. Moreover, in cats, the lesions are
12 reported to enlarge progressively and without interruption, being therefore more
13 consistent with true neoplasia.^{11,12} In addition, several authors have associated this
14 lesion with infection by *Feline leukemia virus* and it is not considered to be
15 hereditary.^{3,8,12} Another differential feature of this condition in cats is the fact that the
16 mass is usually not connected with the marrow cavity of the adjacent bone. In the
17 present case, deep sections of the mass showed bone marrow amongst cartilaginous and
18 bony trabeculae, suggesting a communication between the mass and the bone marrow of
19 the rib. Finally, stromal cells are reported to have higher pleomorphism and atypical
20 features in cats.¹² In the present case, in all the studied sections, stromal cells had a low
21 degree of pleomorphism. Therefore, according to all these findings, the
22 osteochondromatosis presented here resembles the condition described in horses and
23 dogs rather than the one reported in cats.

24

1 The scientific literature contains a single description, written in German, of synovial
2 osteochondromatosis in swine.¹⁵ However, synovial osteochondromatosis is considered
3 to be a different condition than osteochondroma and osteochondromatosis, since it
4 arises from synovial membranes instead of bone surfaces, and is considered to be a
5 metaplasia of synovial cells.^{9,12}

6

7 In the present case, considered differential diagnoses included chondroma and
8 chondrosarcoma. Chondroma is a rare benign neoplasm of cartilage that is referred as
9 enchondroma if it originates within bone medullary cavity, or ecchondroma if arising
10 from cartilage elsewhere in the skeleton.¹² Few cases of chondromas are reported in
11 several veterinary species^{2,3,5}, and no descriptions were found in pigs at the time of this
12 writing. Histologically, chondromas consist of irregular lobules of hyaline cartilage
13 which may also show foci of endochondral ossification and mineralization.¹¹ However,
14 chondromas miss the growth plate-like organization of the cartilaginous matrix that
15 characterizes osteochondromas and that was observed in the present case.^{2,9}

16

17 Malignant transformation of osteochondroma to either chondrosarcoma or osteosarcoma
18 has occasionally been described in older dogs⁴ and humans.¹⁰ However, in the present
19 case, no features of malignancy such as binucleated chondrocytes, tumor cells with
20 plump nuclei and prominent nucleoli or mitotic figures were observed.^{9,11} Nevertheless,
21 it must be taken into account that, histologically, osteochondroma can be very difficult
22 to differentiate from low grade chondrosarcoma, which may show few indications of
23 malignancy and may closely resemble benign tumors of cartilage.^{11,12} Therefore, in the
24 present case, although malignant transformation to chondrosarcoma was not observed,

1 its occurrence cannot be totally excluded. In conclusion, gross and microscopic findings
2 in the present case support a final diagnosis of osteochondromatosis in swine.

3

4 **Acknowledgements**

5 The authors thank Paula Agunin and Gemma Garcia (ASPC slaughterhouse veterinary
6 inspectors) for macroscopic pictures and case description. The authors thank also the
7 Slaughterhouse Support Network (Servei de Suport a Escorxadors, SESC-CReSA),
8 which is funded by *Agència de Salut Pública de Catalunya (ASPC), Departament de*
9 *Salut, Generalitat de Catalunya.*

10

11 **Declaration of conflicting interests**

12 The authors declared no potential conflicts of interest with respect to the research,
13 authorship, and/or publication of this article.

14 **Funding**

15 The authors received no financial support for the research, authorship, and/or
16 publication of this article.

17

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43 **Figures**

44 Fig. 1. Pig carcass; Two prominent exophytic, multilobular masses arising from left ribs
45 are seen within thoracic cavity.

1 Fig. 2. A closer view of one of the masses showing smooth surface and white-bluish
2 areas, reflecting the presence of the cartilaginous component.

3 Fig. 3. Cartilage capped proliferation showing an orderly pattern of endochondral
4 mineralization toward the central areas of the mass. Hematoxylin and eosin. Bar
5 = 100 μm .

6 Fig. 4. Irregular cartilage trabeculae undergoing endochondral ossification. Abundant
7 active osteoclasts (black arrow) and plump osteoblasts (open arrow) indicate
8 active bone remodeling. Hematoxylin and eosin. Bar = 50 μm .