

Distribution and morphology of ventricular bands in the hearts of ringed seals

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Abstract

In contrast to studies on domestic animals, few reports describe ventricular bands in wildlife, and none in aquatic mammals. Ventricular bands in the endangered Saimaa ringed seal (*Pusa hispida saimensis*) and the Baltic ringed seal (*Pusa hispida botnica*) were examined as part of an ongoing research on the comparative anatomy of ringed seal subspecies. The dissections illustrated that a varying number of thin or thick ventricular bands from the papillary muscles to the ventricular walls were visible in the ventricles of all ringed seal specimens examined. The histological appearance of the ventricular bands was characterized by a fibromuscular pattern.

KEYWORDS

anatomy, histology

1 | INTRODUCTION

Ventricular bands, also known as false tendons, are thin fibrous or fibromuscular bands that traverse the ventricular lumen between the papillary muscles, ventricular wall and interventricular septum (Gerlis et al., 1984; Kervancioğlu et al., 2003). There is no proper name for ventricular bands determined in the Veterinary Gross Anatomical Nomenclature (ICVGAN, 2017). Unlike the chordae tendineae, ventricular bands have no association with atrioventricular cusps (Gerlis et al., 1984; Kervancioğlu et al., 2003). Ventricular bands have been reported from humans and several animal species (Cope, 2019; Kareinen et al., 2020; Kervancioğlu et al., 2003; Kimura et al., 2016; Kosiński et al., 2012, 2013; Luetmer et al., 1986; Turner, 1893). The bands in the left ventricle have been studied more extensively, apparently because they are more common, larger and more visible than the ones found in the right ventricle (Kosiński et al., 2012). In domestic dogs, several band types and multiple ventricular band combinations have been described (Cope, 2017). Because of the gross similarity of ventricular bands and trabeculae septomarginalis in animals (Cope, 2019), histological studies are needed to differentiate these anatomical structures.

In contrast to studies on domestic animals, few reports describe ventricular bands in wildlife (Ateş et al., 2017; Kareinen et al., 2020), and none in aquatic mammals. The aim of this study was to examine ventricular bands in the endangered Saimaa ringed seal (*Pusa hispida saimensis*) and the Baltic ringed seal (*Pusa hispida botnica*) as part of an ongoing research on the comparative anatomy of ringed seal subspecies.

2 | MATERIALS AND METHODS

All Saimaa ringed seals that are found dead are collected by the Parks and Wildlife staff of the state enterprise Metsähallitus and stored at -20°C until necropsy to collect various samples for research and conservation purposes. Specimens are usually in various stages of decomposition, but in 2017 and 2019, one and two individuals, respectively, were in relatively good condition, enabling histological examination (Table 1). The seals examined were by-catch found in gill nets. The frozen carcasses were shipped to the Veterinary Faculty of the University of Helsinki for dissections and tissue sampling for histology in 2018 and 2020. In

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addition, two Baltic ringed seals (Table 1) legally shot by a hunter in the Bothnian Bay (the northernmost part of the brackish water Baltic Sea) were shipped frozen via the University of Oulu to the Veterinary Faculty of the University of Helsinki for dissections and histological sampling carried out in summer 2020. Permit for the use of animal material in research was available through research agreement between Metsähallitus and the University of Helsinki. The types (thin, thick, single or web-like) and points of attachments of ventricular bands were determined by opening the ventricles via a vertical section through the free walls from the ventricular base to the apex (Figure 1). Standard histological samples were prepared from all bands and stained using haematoxylin and eosin and Masson's trichrome stains for light microscope examination.

Representative slides of thin and thick bands were scanned (BI Histoscanner, Institute of Biotechnology, Histoscanner, University of Helsinki) for illustrative purposes (Figures 2 and 3). The scanner utilizes a 4MP CMOS camera with 130 fps speed and has 0.24 $\mu\text{m}/\text{pixel}$ resolution with the combined 20 \times /0.8 NA objective (equivalent to 40 \times magnification).

3 | RESULTS

The general heart anatomy of the two subspecies was similar. The dissections illustrated that a varying number of thin, or wide but still thin, ventricular bands from the papillary muscles to the

Specimen	Subspecies	Sex	Age	Body weight (kg)	Heart weight (g)
2670	Saimaa	Female	Subadult	42	Not recorded due to other analysis
2744	Saimaa	Female	Pup	18.5	120
2747	Saimaa	Female	Pup	16.9	133
845	Baltic	Female	Adult	49.5	260
846	Baltic	Female	Adult	54.5	320

TABLE 1 Saimaa and Baltic ringed seal individuals examined for ventricular bands

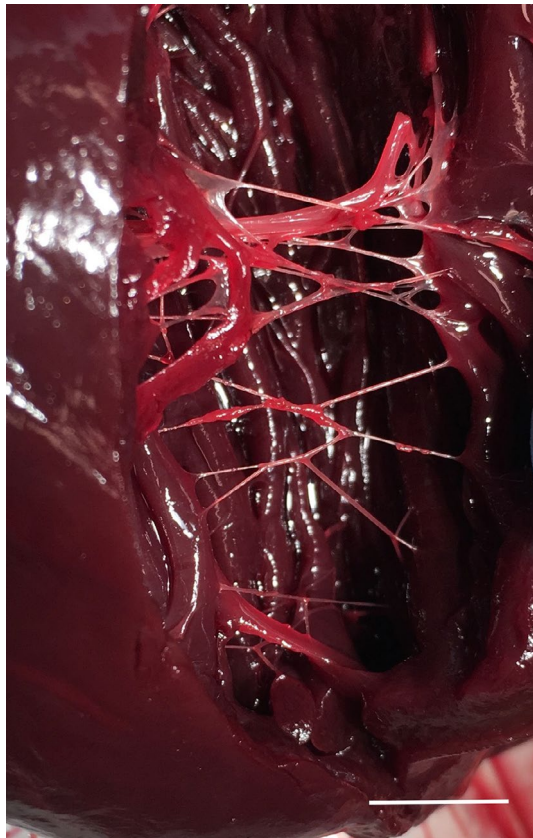


FIGURE 1 Saimaa ringed seal heart with the left ventricle partly opened to display the thick and thin ventricular bands. Scale bar = 1 cm

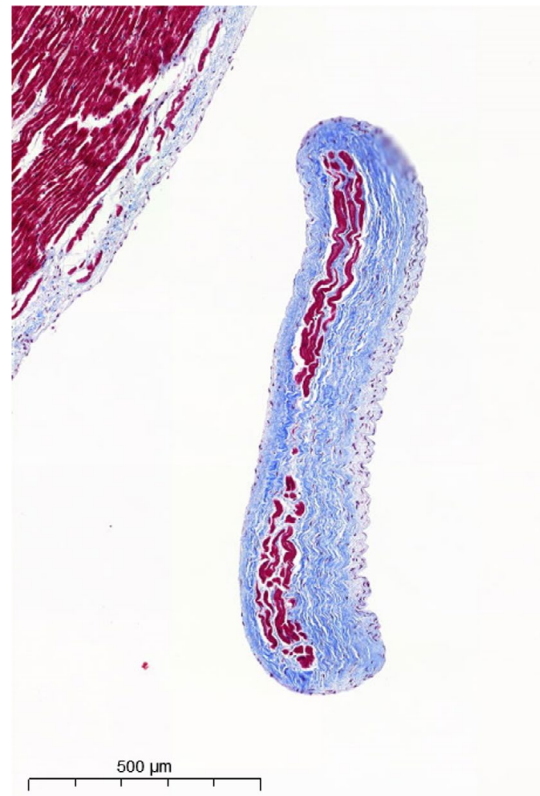


FIGURE 2 Single, thin ventricular band from the middle part of the left ventricle (ventricular wall on the left). Myocytes (purple) are surrounded by thick crisscrossing bands of connective tissue (blue). Saimaa ringed seal, Masson's trichrome stain

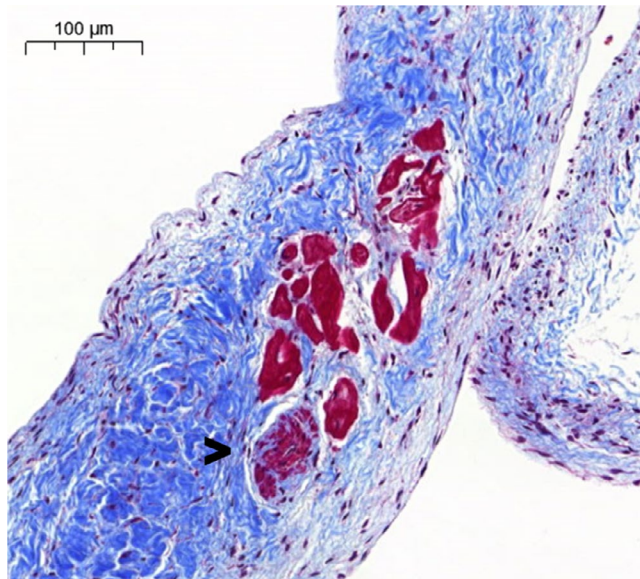


FIGURE 3 Single, thin ventricular band from the apex part of the right ventricle. Myocytes (purple) and Purkinje fibres (arrow) are surrounded by connective tissue (blue). Saimaa ringed seal, Masson's trichrome stain

ventricular walls were visible in the ventricles of all ringed seal specimens examined. No distinct band patterns could be discerned in the small sample set, but in three of the ringed seal specimen, a few longer, thin bands traversed the middle part of both ventricular lumens, and a few short bands branched to form a web-like structure near the narrow, apical part of the ventricular lumen (Figure 1). These were more numerous in the left ventricle. In four of the specimens, a thick band was visible in the middle part of the lumen on the left side. In one Saimaa ringed seal specimen, a thick band was visible near the apex of the left ventricle (Figure 1). The diameter of the thin bands varied only minimally and was less than one millimetre. The thick bands were 2 to 3 millimetres in diameter. The bands displayed variable branching patterns, ranging from single bands to web-like structures with two or three sites of attachment (Figure 1). All bands examined histologically consisted of myocytes surrounded by crisscrossing bands of connective tissue with a superficial endothelial lining (Figures 2 and 3). Purkinje fibres were visible in some tissue sections (Figure 3). Arteries and veins were visible especially near the edges of the bands. The cellularity of the connective tissue was low and consisted of elongated fibroblasts. There were some autolytic changes with bleeding in the thick bands.

4 | DISCUSSION

The macroscopic anatomy of the hearts of the Saimaa ringed seal and the Baltic ringed seal closely resembled that of the arctic *Pusa hispida* from Alaska (Pfeiffer & Viers, 1995; Smoldaka et al., 2008), but the conductive components or the ventricular bands have not

been studied previously in ringed seals (Pfeiffer & Viers, 1995). Similar to the results reported previously from other mammals (Kosiński et al., 2012) including wild lynx (Kareinen et al., 2020), ventricular bands of the ringed seals were more numerous in the left ventricle, and their histological appearance was characterized by a fibromuscular pattern (Figures 2 and 3). Purkinje fibres were visible in some but not all tissue sections. Many previous studies of various mammal species report that ventricular bands consisted of a mixture of fibrous connective and conductive tissue and of myocardial fibres (Ateş et al., 2017; Deniz et al., 2004; Kervancıoğlu et al., 2003; Kimura et al., 2016). The reported qualitative and quantitative differences in the various tissue types indicate that variations in the internal configurations of suspected ventricular bands may exist among different species of animals. Serial sections of the entire bands, both thin and thick, would be useful to determine whether Purkinje fibres are missing from some bands because of differences in examination effort or techniques. This study was limited by the small sample size available from the endangered Saimaa ringed seal subspecies excluding any quantitative analysis of anatomical variation within subspecies. The fact that histological samples were not available from fresh animals caused some autolytic changes with bleeding preventing detailed analyses of especially the thick bands in some tissue sections. As diving mammals, ringed seals store great quantities of blood in their muscle tissues.

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CONFLICT OF INTEREST

The author has no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are available on request from the author.

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