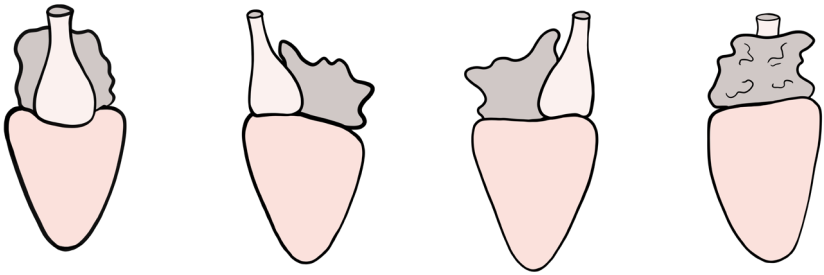
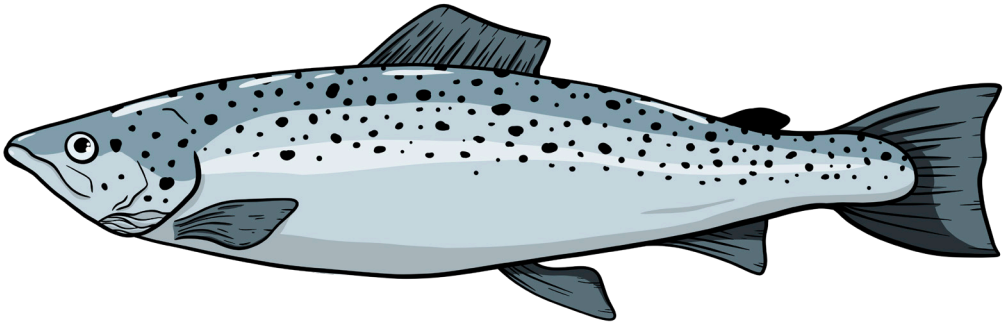
A Guide to Atlantic Salmon Heart Morphology

v 1.0





Vilde Arntzen Engdal
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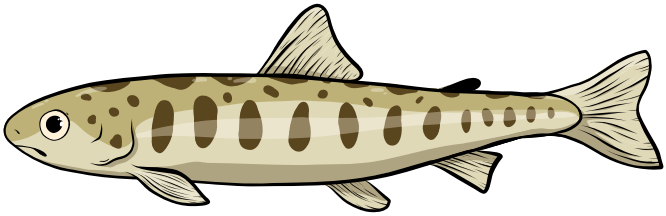

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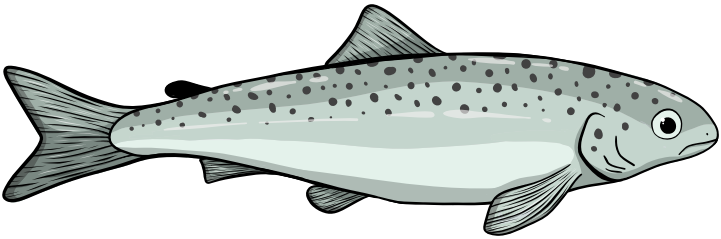

Introduction

This booklet is created to assist in determining heart morphology in Atlantic salmon. Farmed Atlantic salmon (*Salmo salar*) possess a considerable variation in morphometric traits and deviations not commonly found in wild salmon hearts. We provide a qualitative method for recording heart traits in Atlantic salmon.

Traits may be described by using the nomenclature provided in this booklet. Numbers inside brackets refer to the nomenclature on Figure 2. Each trait is supplied with six examples of salmon hearts possessing the trait.

We acknowledge that this work may be limited in heart traits and that updates may be necessary. If the method does not cover morphological heart traits you find essential, please contact us, and we will make updates accordingly.

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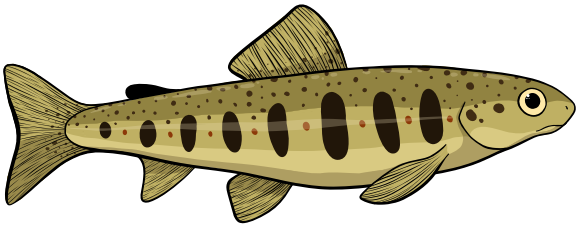
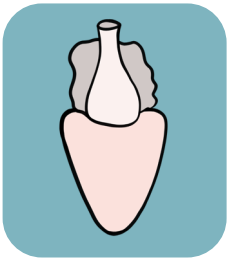
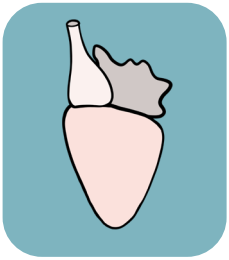


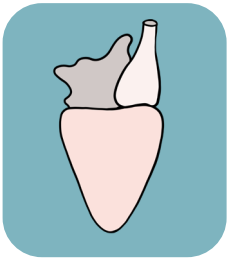
Projections



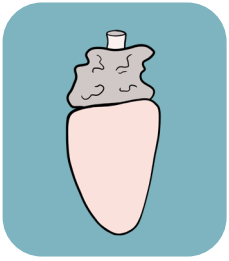
VD - Ventrodorsal projection



LL - Left lateral projection



RL - Right lateral projection

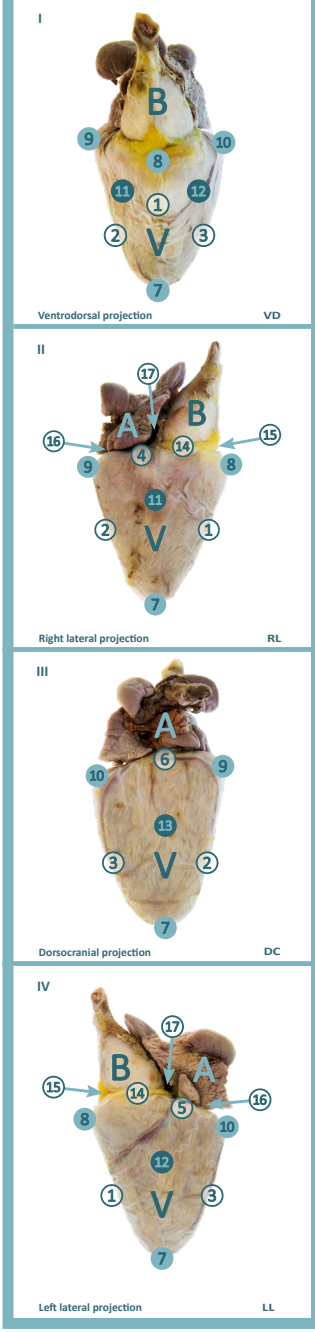


DC - Dorsocranial projection

AP - Any projection

Figure 1

Nomenclature



A	Atrium
V	Ventricle
B	Bulbus arteriosus
1	Ventroventricular ridge (*crista ventricularis ventralis*)
2	Right longitudinal ventricular ridge (*crista ventricularis sinister*)
3	Left longitudinal ventricular ridge (*crista ventricularis dexter*)
4	Right olique ventricular ridge (*crista ventricularis obliquus dexter*)
5	Left olique ventricular ridge (*crista ventricularis obliquus sinister*)
6	Transversal ridge (*crista ventricularis transversalis*)
7	Caudal ventricular apex (*apex ventricularis*)
8	Ventral ventricular apex (*apex ventricularis ventralis*)
9	Right dorsal ventricular apex (*apex ventricularis dorsalis sinister*)
10	Left dorsal ventricular apex (*apex ventricularis dorsalis dexter*)
11	Right ventricular surface (*facies ventricularis sinister*)
12	Left ventricular surface (*facies ventricularis dexter*)
13	Dorsoventricular surface (*facies ventricularis dorsalis*)
14	Ventriculobulbar junction (*sulcus ventriculobulbaris*)
15	Ventriculobulbar groove (*sulcus ventriculobulbaris*)
16	Atrioventricular groove (*sulcus atrioventricularis*)
17	Atriobulbar groove (*sulcus atriobulbaris*)

Figure 2

Quantitative measurments

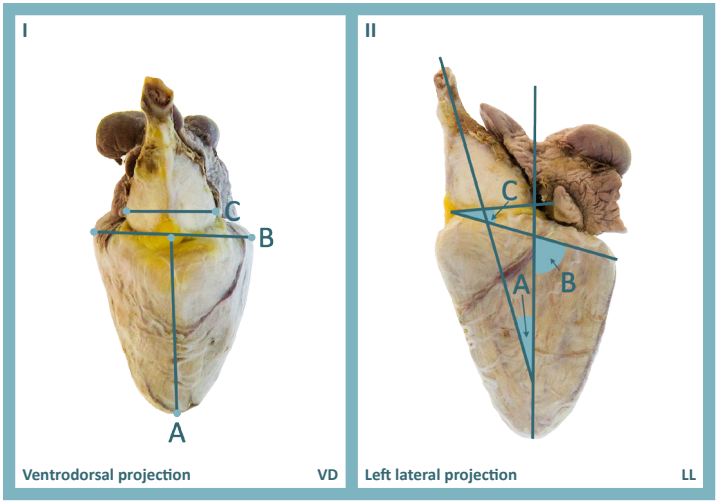


Figure 3

Ventricular height:width ratio (Figure 3, I, A : B)
On VD surface (Figure 3, I), ventricular height (Figure 3, I, A) was obtained by measuring a line from the caudal ventricle apex (Figure 2, I, 7) to the ventricubulbar groove (Figure 2, I, 15) according to Frisk et al. (2020). The ventricular width (Figure 3, I, B) was obtained by measuring a line from the right dorsal ventricle apex (Figure 2, I, 9) to the left dorsal ventricle apex (Figure 2, I, 10). The ratio was calculated by dividing ventricular height by ventricular width.

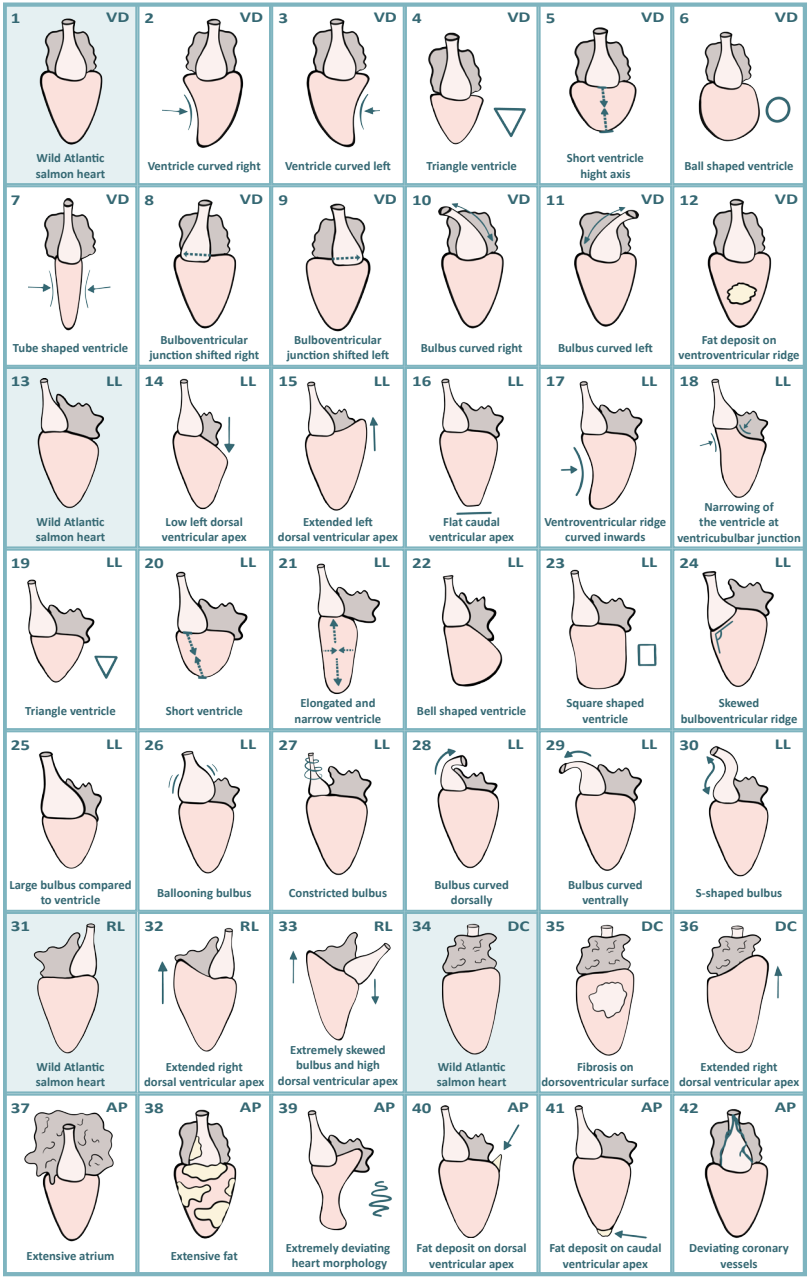
Bulbus width:ventricular width ratio (Figure 3, I, C : B)
On VD surface (Figure 3, I), bulbus width (Figure 3, I, C) was obtained by measuring the bulbus on its widest width. Ventricular width (Figure 3, I, B) was obtained by measuring a line from the right dorsal ventricular apex (Figure 2, I, 9) to the left dorsal ventricular apex (Figure 2, I, 10). The ratio was calculated by dividing bulbus width by ventricular width.

Alignment of bulbus arteriosus (Figure 3, II, A)
On LL surface (Figure 3, II), the angle "alignment of bulbus arteriosus" (Figure 3, II, A) was obtained by drawing a line from the caudal ventricular apex (Figure 2, IV, 7) to the atriobulbar groove (Figure 2, IV, 17). Then a line following the midsection of the bulbus to the lines cross. Angle A (Figure 3, II, A) was then measured according to Poppe et al. (2003).

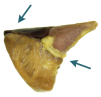
Ventricular asymmetry (Figure 3, II, B)
On LL surface (Figure 3, II), the angle is obtained by drawing a line from the caudal ventricular apex (Figure 2, IV, 7) to the atriobulbar groove (Figure 2, IV, 17). Then a line from the ventriculobulbar groove (Figure 2, IV, 15) to the left dorsal ventricular apex (Figure 2, IV, 10). Angle B (Figure 2, II, B) was then measured according to Frisk et al. (2020).

Bulbus misalignment (Figure 3, II, C)
On LL surface (Figure 3, II) the angle was obtained by drawing a line from the ventriculobulbar groove (Figure 2, IV, 15) to the left dorsal ventricular apex (Figure 2, IV, 10). Then a line from the ventriculobulbar groove (Figure 2, IV, 15) to the atriobulbar groove (Figure 2, IV, 17) following the junction between the ventricle and bulbus was drawn. Angle C (Figure 3, II, C) was then measured according to Frisk et al. (2020).

Qualitative measurments

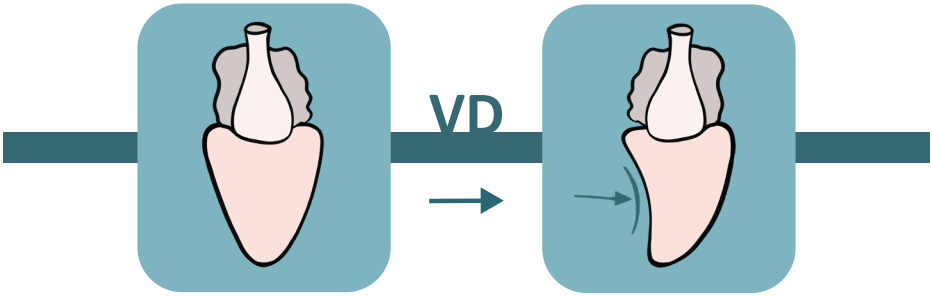


Qualitative measurments

1 VD  Wild Atlantic salmon heart	2 VD  Ventricle curved right	3 VD  Ventricle curved left	4 VD  Triangle ventricle	5 VD  Short ventricle hight axis	6 VD  Ball shaped ventricle
7 VD  Tube shaped ventricle	8 VD  Bulboventricular junction shifted right	9 VD  Bulboventricular junction shifted left	10 VD  Bulbus curved right	11 VD  Bulbus curved left	12 VD  Fat deposit on ventroventricular ridge
13 LL  Wild Atlantic salmon heart	14 LL  Low left dorsal ventricular apex	15 LL  Extended left dorsal ventricular apex	16 LL  Flat caudal ventricular apex	17 LL  Ventroventricular ridge curved inwards	18 LL  Narrowing of the ventricle at ventricubulbar junction
19 LL  Triangle ventricle	20 LL  Short ventricle	21 LL  Elongated and narrow ventricle	22 LL  Bell shaped ventricle	23 LL  Square shaped ventricle	24 LL  Skewed bulboventricular ridge
25 LL  Large bulbus compared to ventricle	26 LL  Ballooning bulbus	27 LL  Constricted bulbus	28 LL  Bulbus curved dorsally	29 LL  Bulbus curved ventrally	30 LL  S-shaped bulbus
31 RL  Wild Atlantic salmon heart	32 RL  Extended right dorsal ventricular apex	33 RL  Extremely skewed bulbus and high dorsal ventricular apex	34 DC  Wild Atlantic salmon heart	35 DC  Fibrosis on dorsoventricular surface	36 DC  Extended right dorsal ventricular apex
37 AP  Extensive atrium	38 AP  Extensive fat	39 AP  Extremely deviating heart morphology	40 AP  Fat deposit on dorsal ventricular apex	41 AP Fat deposit on caudal ventricular apex	42 AP Deviating coronary vessels

Ventricle curved right

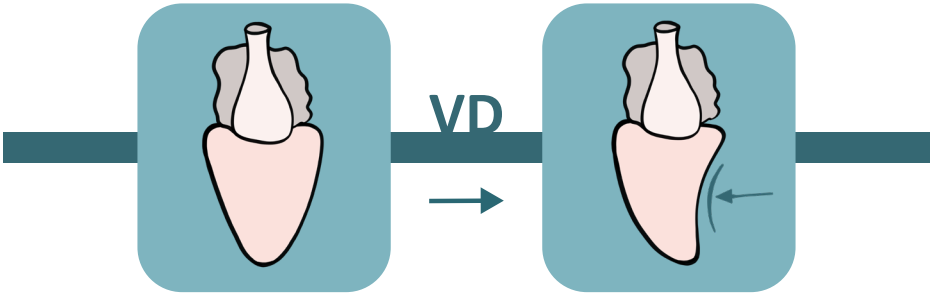
2



In VD projection; Inward curvature on ventricle in right ventricular surface (11). Caudal ventricular apex (7) shifted right may or may not occur.

Ventricle curved left

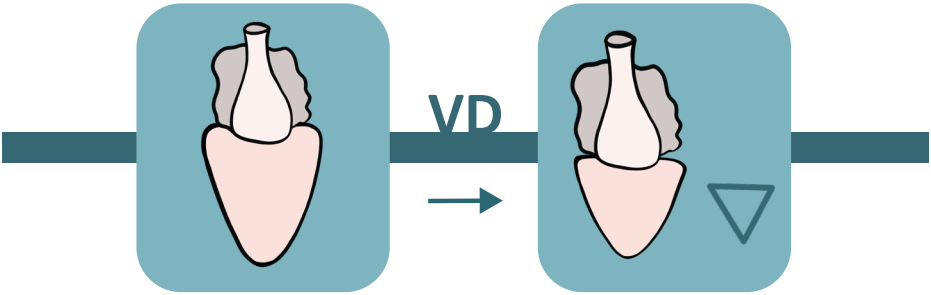
3



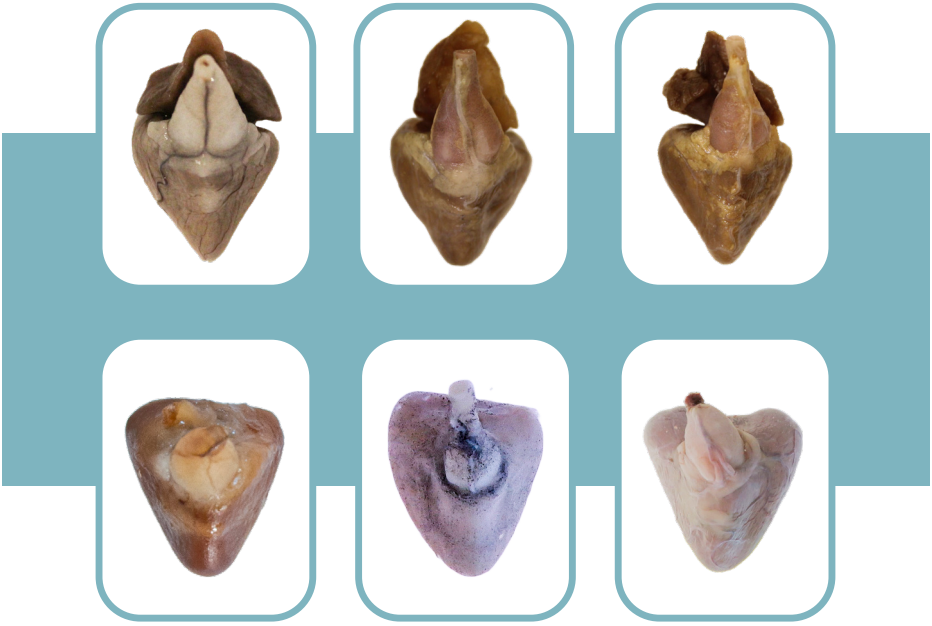
In VD projection; Inward curvature on ventricle in left ventricular surface (12). Caudal ventricular apex (7) shifted left may or may not occur.

Triangle ventricle

4

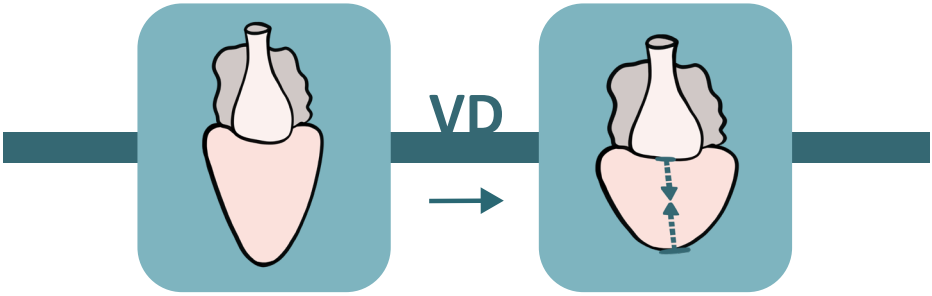


In VD projection ; A triangle shape to the ventricle where the caudal ventricular apex appears in a clear corner. The length between caudal ventricular apex (7), right dorsal ventricular apex (9) and left dorsal ventricular apex (10) are approximately uniform.



Short ventricle height axis

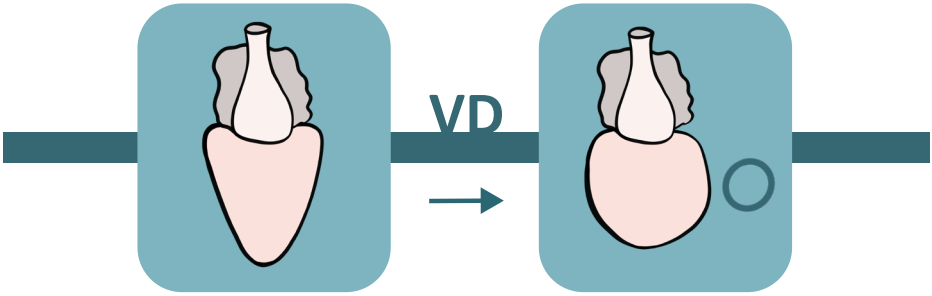
5



In VD projection; The length from the ventricubulbar groove (15) to the caudal ventricular apex (7) is distinctly shortened.

Ball-shaped ventricle

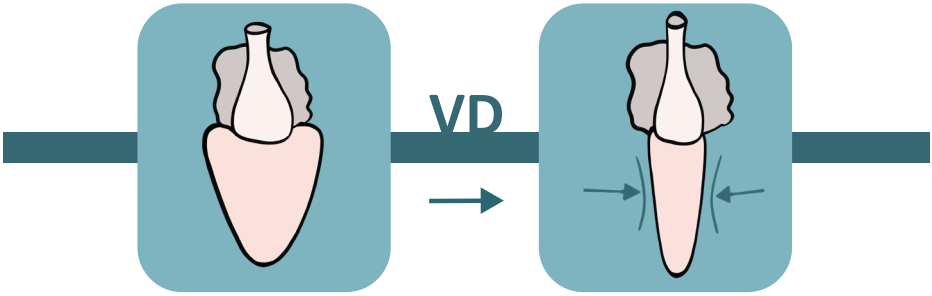
6



In VD projection; Ventricle appears round, caudal ventricular apex (7), right dorsal ventricular apex (9), and left dorsal ventricular apex (10) have less clear corners.

Tube-shaped ventricle

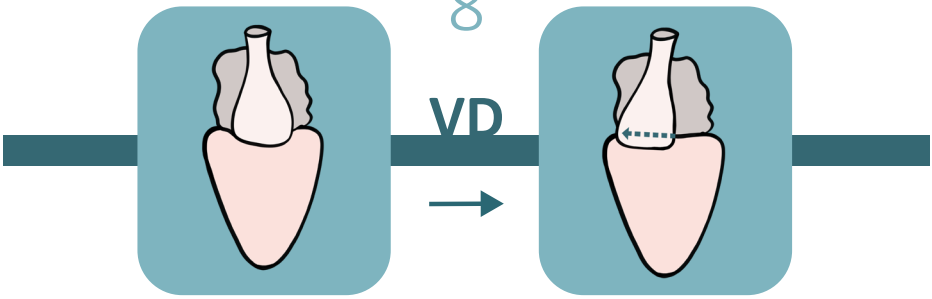
7



In VD projection; The ventricle appears elongated and narrow. Narrowing of left and right ventricular surface creating a tube-like shape.

Bulboventricular junction shifted right

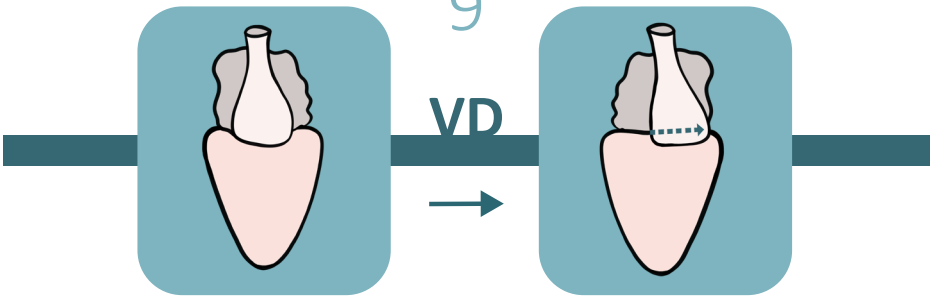
8



In VD projection; Bulbus position on the ventricle shifted to the right side of the ventricle. The entire bulbus may be shifted or a ballooning only towards the right side of the ventricle may occur.

Bulboventricular junction shifted left

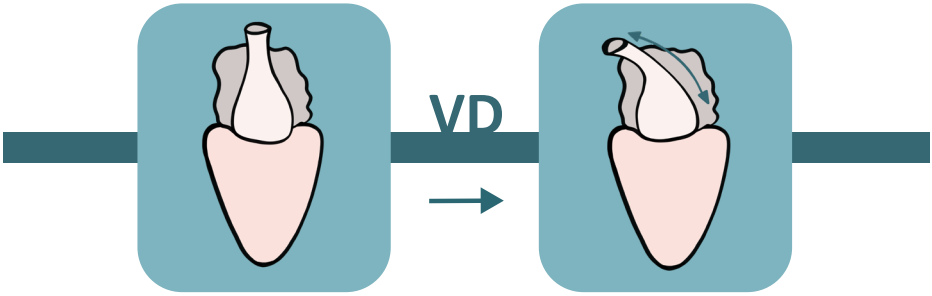
9



In VD projection; Bulbus position on the ventricle shifted to the left side of the ventricle. The entire bulbus may be shifted or a ballooning only towards the left side of the ventricle may occur.

Bulbus curved right

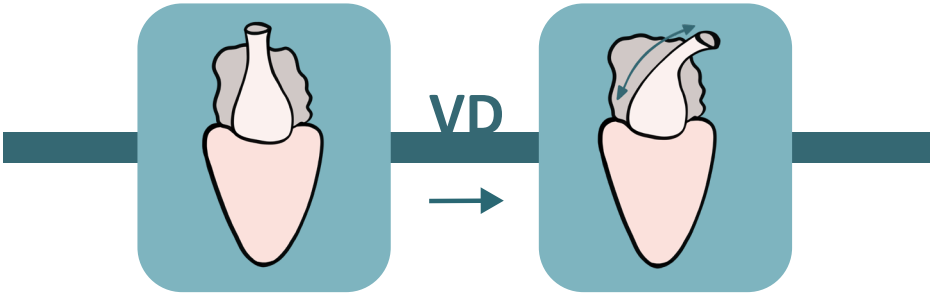
10



In VD projection; Bulbus curved right.

Bulbus curved left

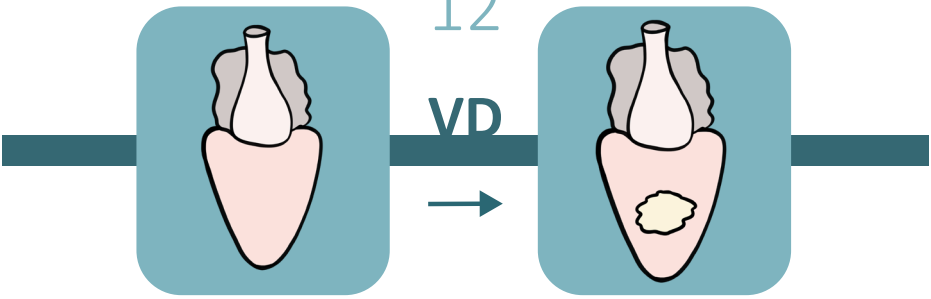
11



In VD projection; Bulbus curved left.

Fat deposit on ventroventricular ridge

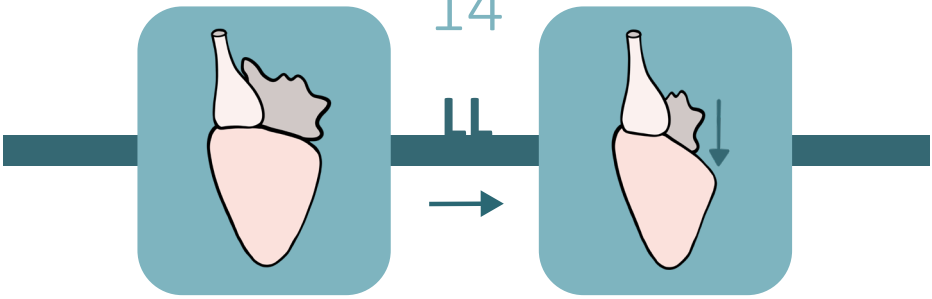
12



In VD projection; Fat deposit on ventroventricular ridge (1). Fat beyond the ventroventricular ridge - see trait 38.

Low left dorsal ventricular apex

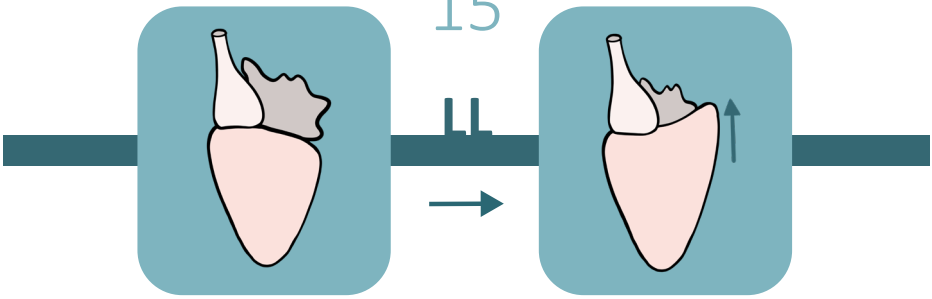
14



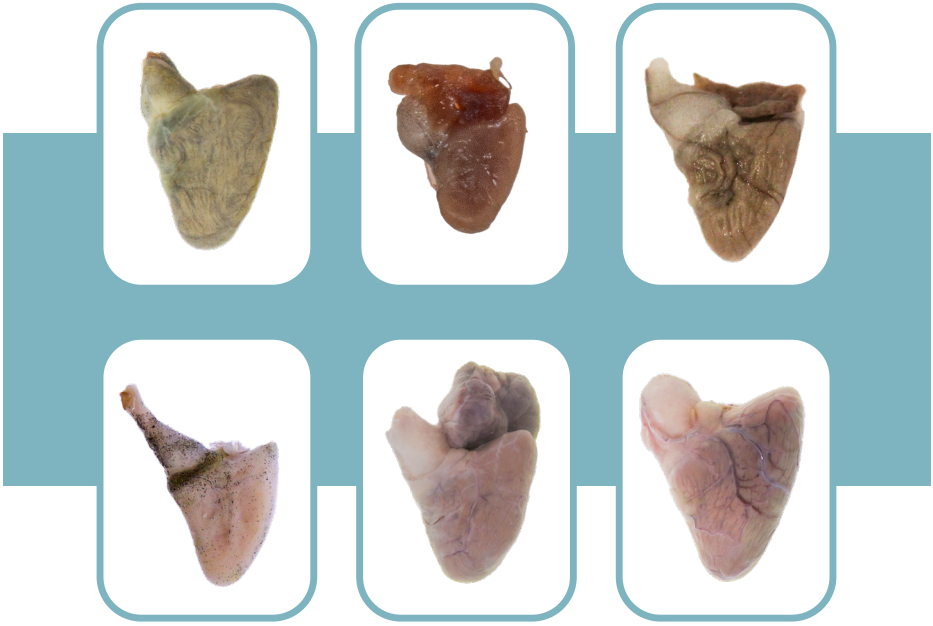
In LL projection; Left lateral ventricular apex (10) lowered beyond the ventral ventricular apex (8).

Extended left dorsal ventricular apex

15

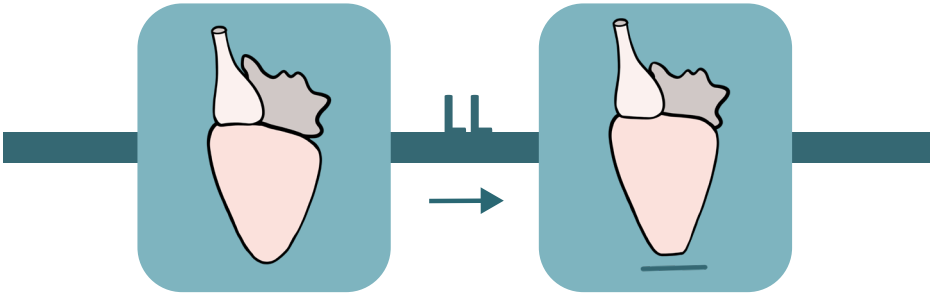


In LL projection; Left lateral ventricular apex (10) extended upwards, extended beyond the ventral ventricular apex (8)



Flat caudal ventricular apex

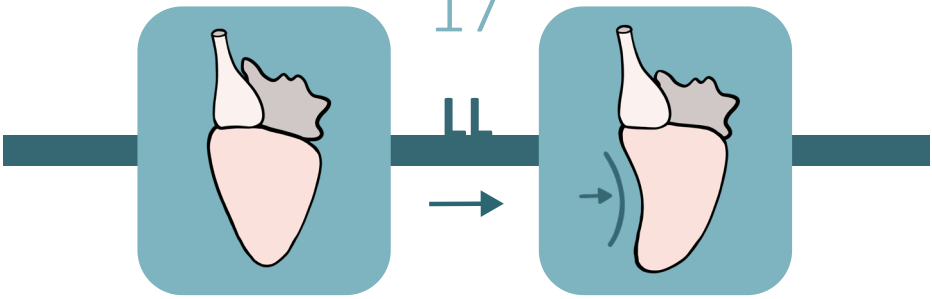
16



In LL projection; Caudal ventricular apex (7) appear flat.

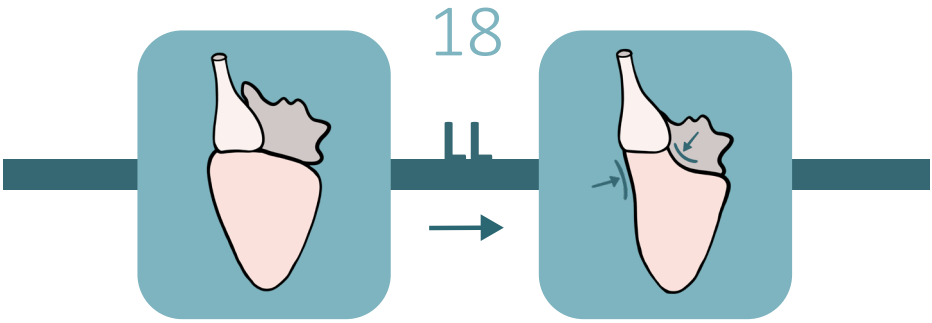
Ventroventricular ridge curved inwards

17



In LL projection; Inward curvature of the ventroventricular ridge (1).

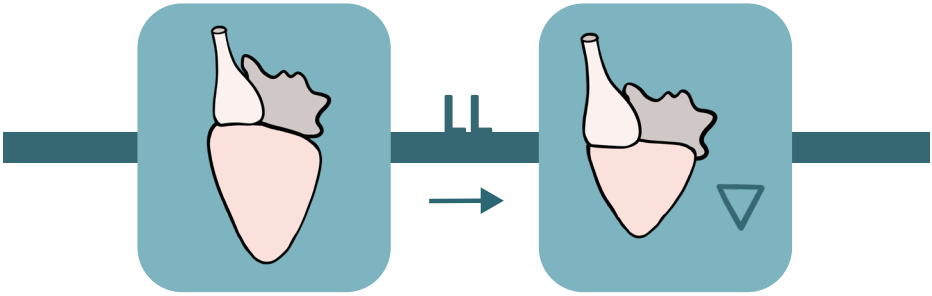
Narrowing of the ventricle at ventricubulbar junction



In LL projection; The ventricle appears pinched at atriobulbar groove (17) and between ventroventricular ridge (1) and ventral ventricular apex (8), resulting in a narrowing of the ventricle at ventricubulbar junction (14). Bulbus appears to sit as an extension of the ventricle.

Triangle ventricle

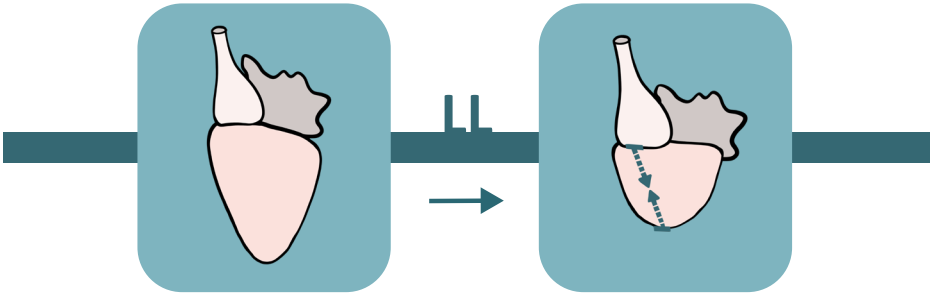
19



In LL projection; A triangle shape to the ventricle where the caudal ventricular apex appear in a clear corner. The length between caudal ventricular apex (7), right dorsal ventricular apex (9) and left dorsal ventricular apex (10) are approximately uniform.

Short ventricle

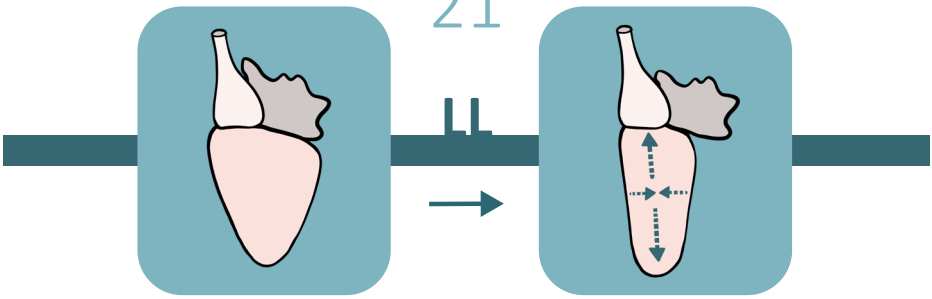
20



In LL projection; The length from the ventricubulbar groove (15) to the caudal ventricular apex (7) is distinctly shortened.

Elongated and narrow ventricle

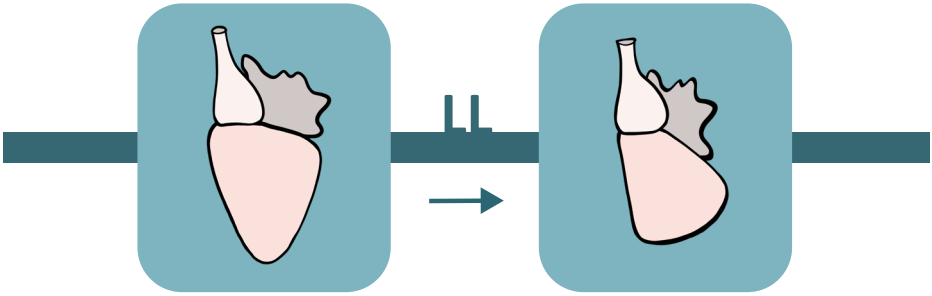
21



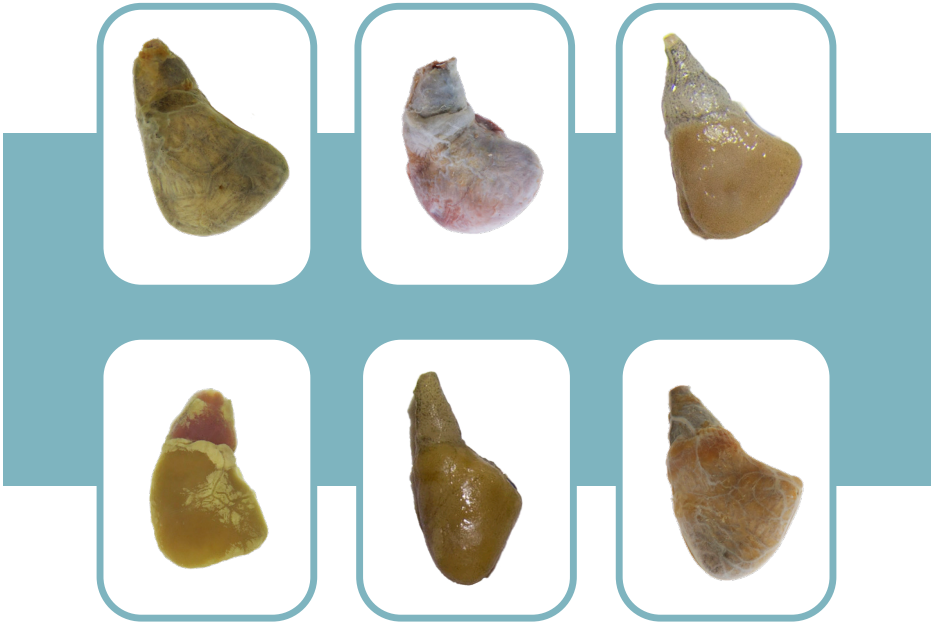
In LL projection; ventricle is elongated and narrow. Shortened length between left dorsal ventricular apex (10) and atriobulbar groove (17).

Bell-shaped ventricle

22

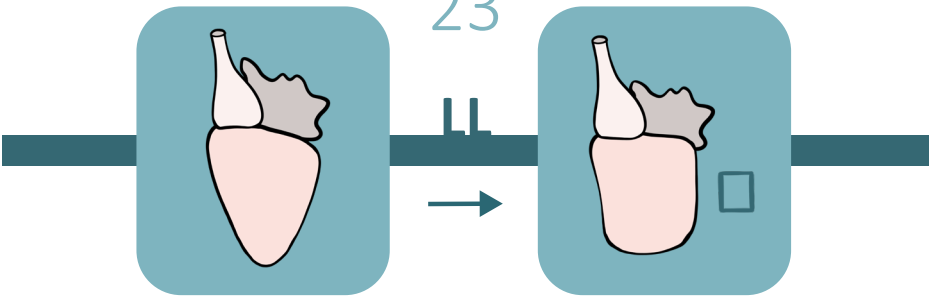


In LL projection; The shape of the ventricle resembles a bell.
Length from ventral ventricular apex to caudal ventricular apex (7) is shortened or/and the left dorsal ventricular (10) apex lowered.
caudal ventricular apex (7) appears rounded.



Square-shaped ventricle

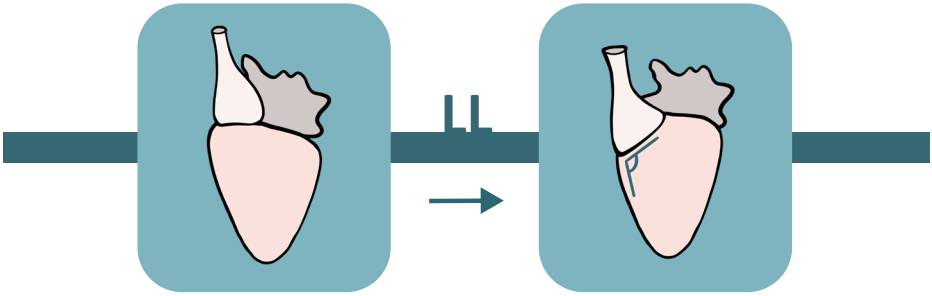
23



In LL projection; The ventricle appears more square like, with four corners.

Skewed bulboventricular ridge

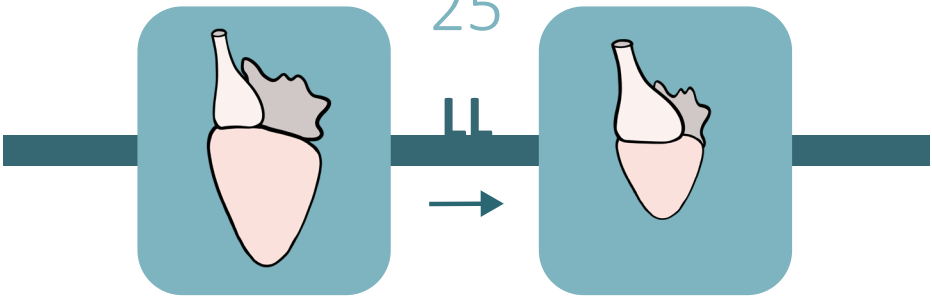
24



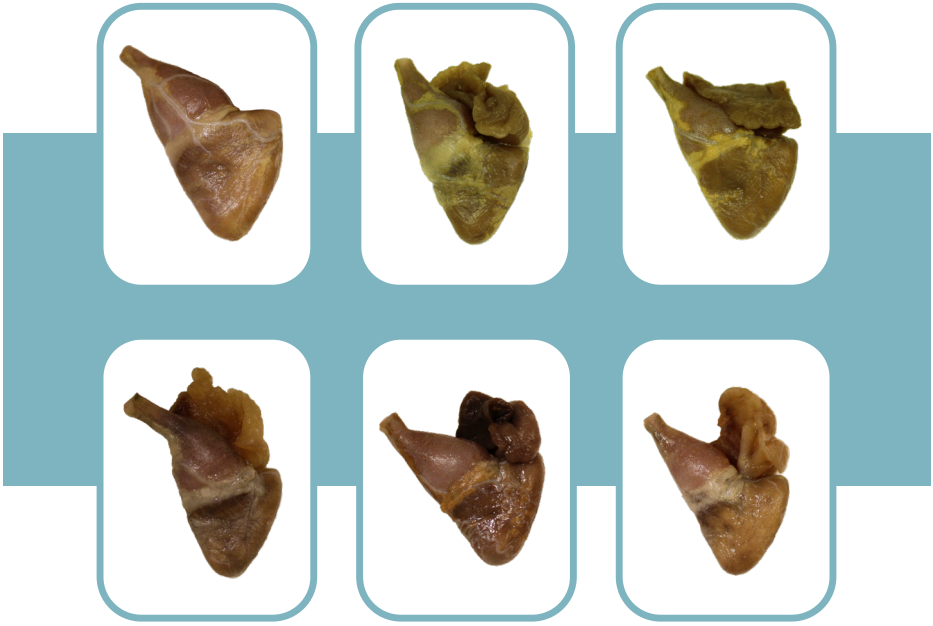
In LL projection; Bulbus sits in a obvious skewed position on the ventricle at the ventricubulbar junction (14).

Large bulbus compared to ventricle

25

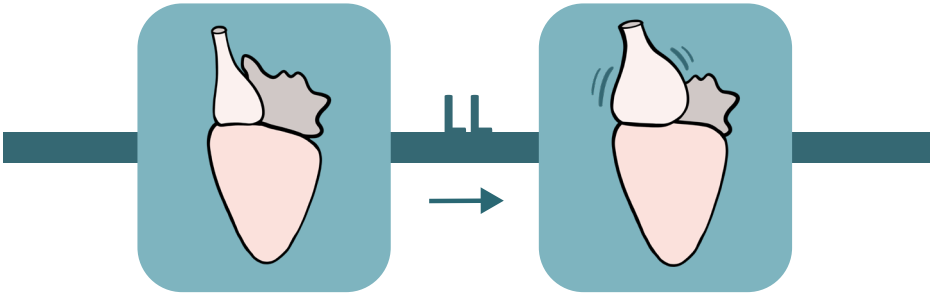


In LL projection; Bulbus appears large compared to the ventricle that appears small.



Ballooning bulbus

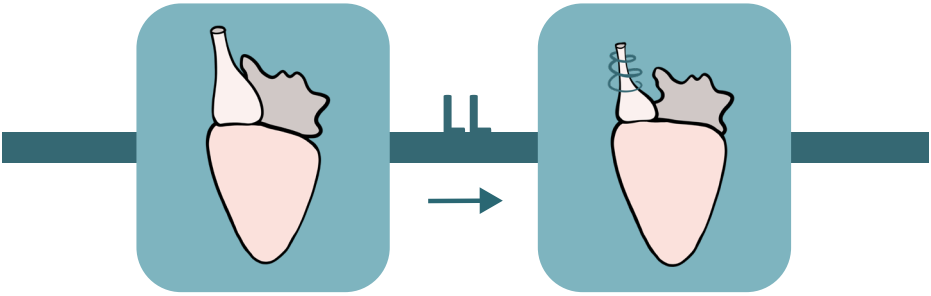
26



In LL projection; Bulbus is ballooning, meaning that bulbus or parts of bulbus appear large.

Constricted bulbus

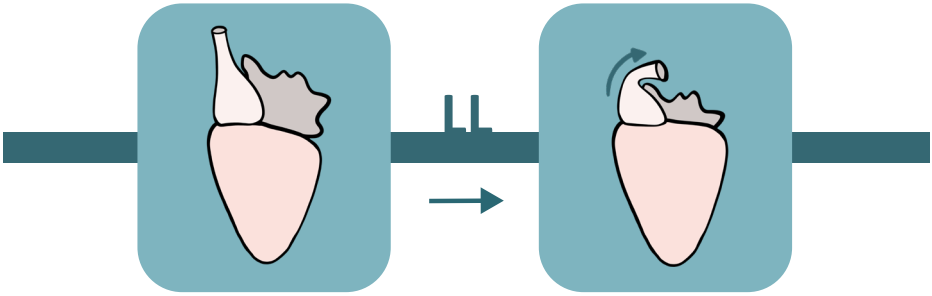
27



In LL projection; Bulbus is clearly constricted, either by size, positioning or curvature.

Bulbus curved dorsally

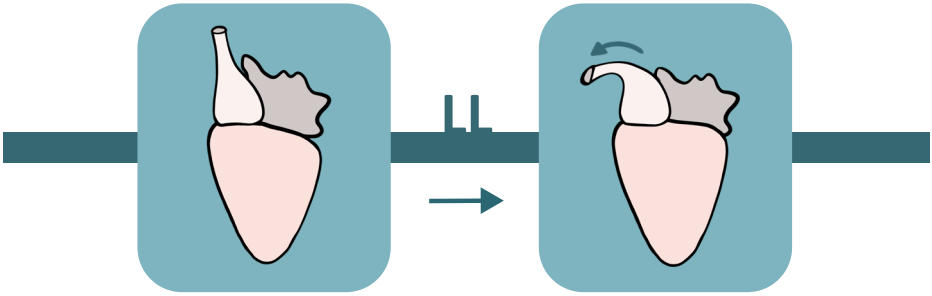
28



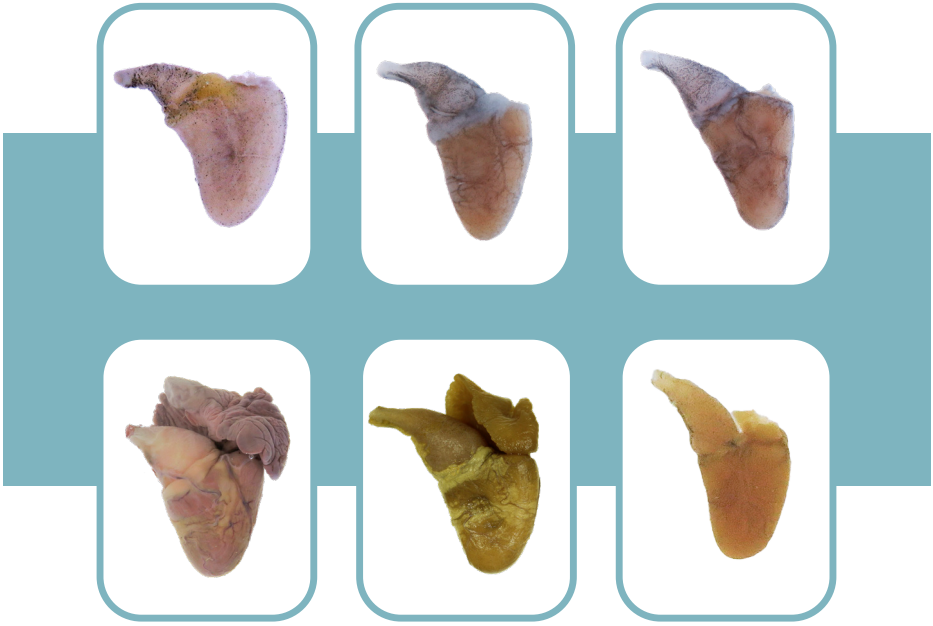
In LL projection; Bulbus curved dorsally.

Bulbus curved ventrally

29

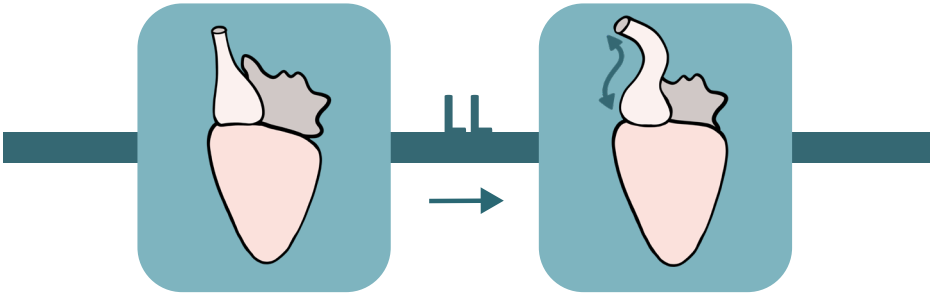


In LL projection; Bulbus curved ventrally.



S-shaped bulbus

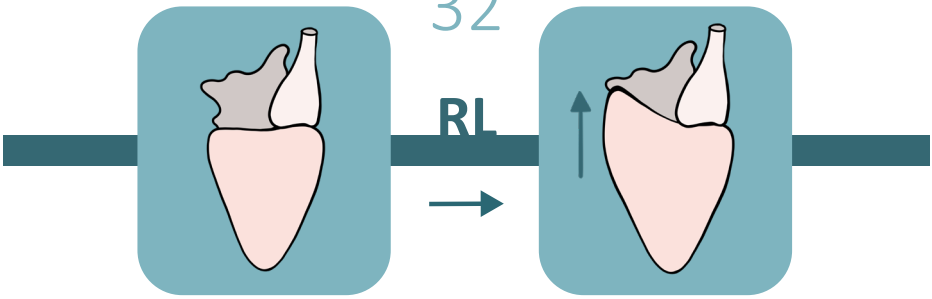
30



In LL projection; Bulbus curved in a S-shaped formation.

Extended right dorsal ventricular apex

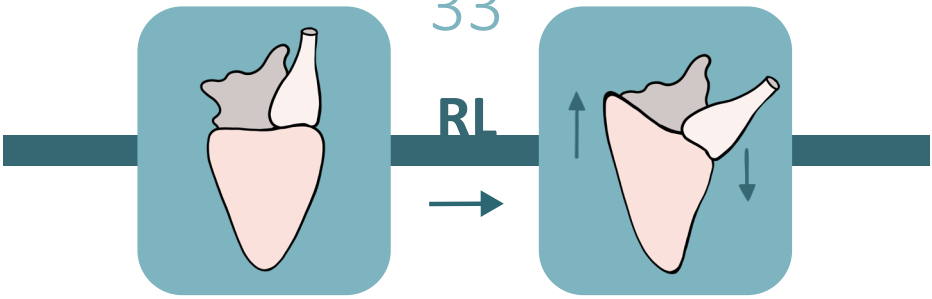
32



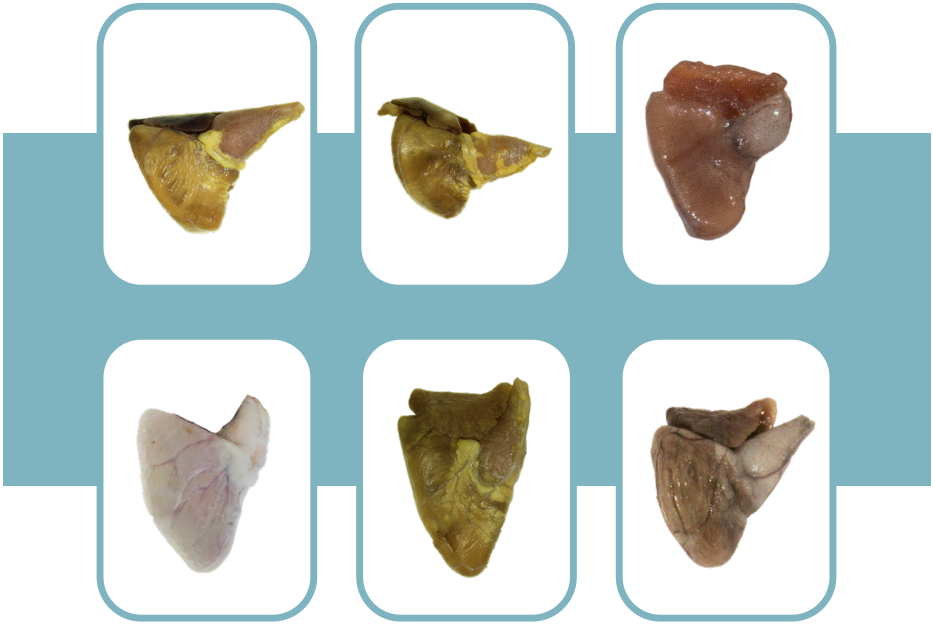
In RL projection; Right lateral ventricular apex (9) extended upwards beyond ventral ventricular apex (8).

Extremely skewed bulbus and high dorsal ventricular apex

33

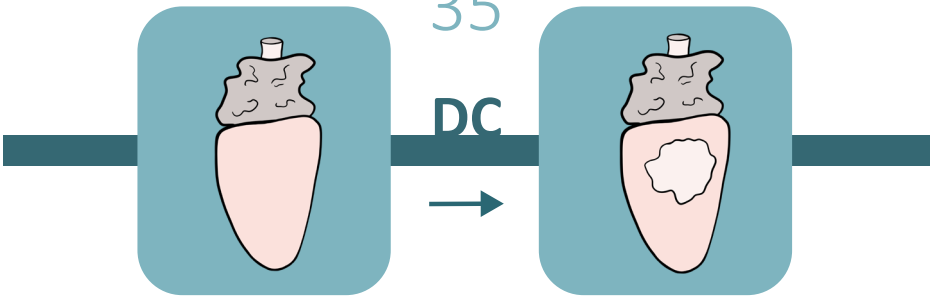


In RL projection; Right lateral ventricular apex (9) extended upwards, and bulbus positioned extremely skewed on ventricle.



Fibrosis on dorsoventricular surface

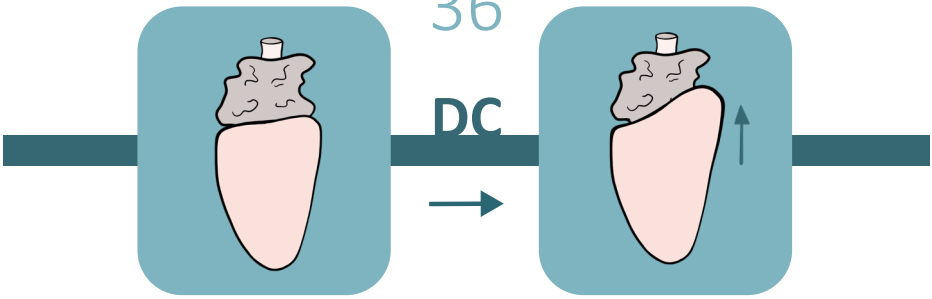
35



In DC projection; fibrosis on dorsoventricual surface.

Extended right dorsal ventricular apex

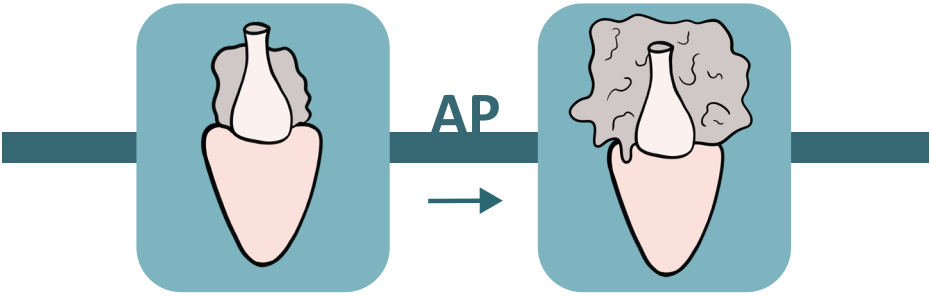
36



In DC projection; Right lateral ventricular apex (9) extended upwards beyond left lateral ventricular apex (10).

Extensive atrium

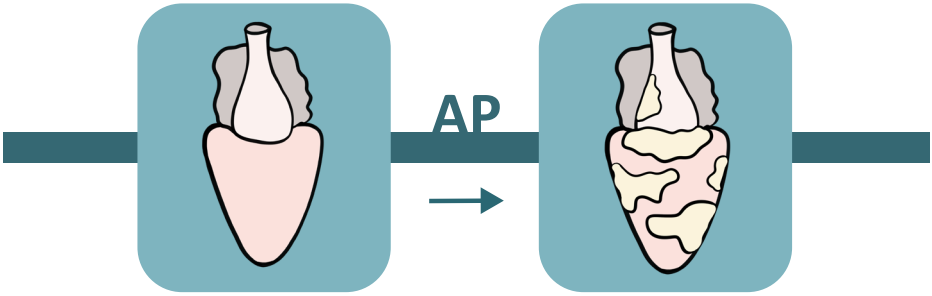
37



In AP projection; Atrium appears extensive

Extensive fat

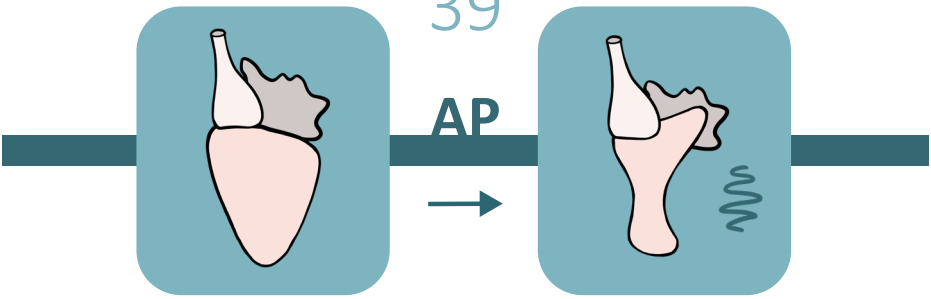
38



In AP projection; Extensive fat deposits in the epicardium. Multifocal or diffuse fat extending beyond the bulboventricular junction and ventroventricular ridge.

Extremly deviating heart morphology

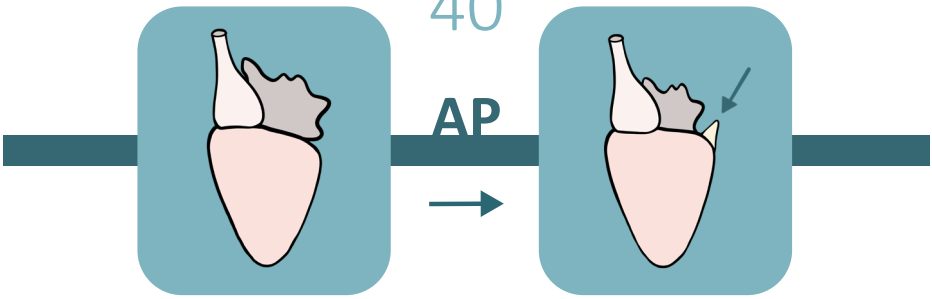
39



In AP projection; Heart morphology that appears extremely deviating and does not fall into the other categories.

Fat deposit on dorsal ventricular apex

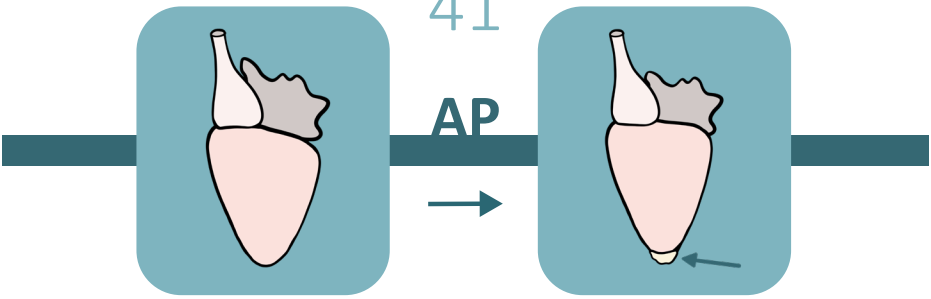
40



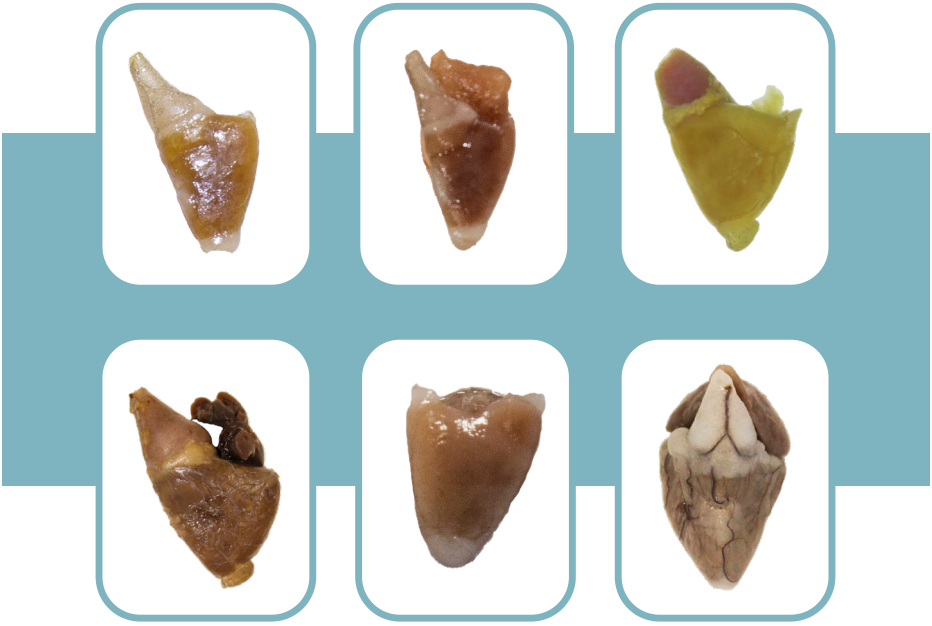
In AP projection; Fat deposit on left dorsal ventricular apex (10) or right dorsal ventricular apex (9).

Fat deposit on caudal ventricular apex

41

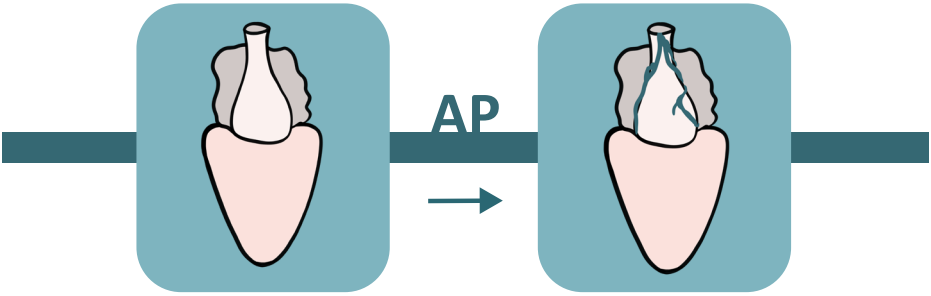


In AP projection; Fat deposit on caudal ventricular apex (7).



Deviating coronary vessels

42



In AP projection; Coronary vessels that clearly deviate from normal structure.

Refrences

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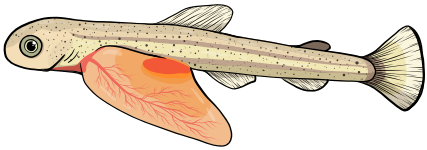
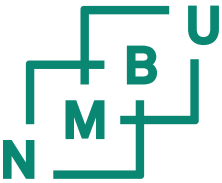
Poppe, T. T., Johansen, R., Gunnes, G., & Tørud, B. (2003). Heart morphology in wild and farmed Atlantic salmon Salmo salar and rainbow trout Oncorhynchus mykiss. Diseases of Aquatic Organisms, 57(1–2), 103–108.





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