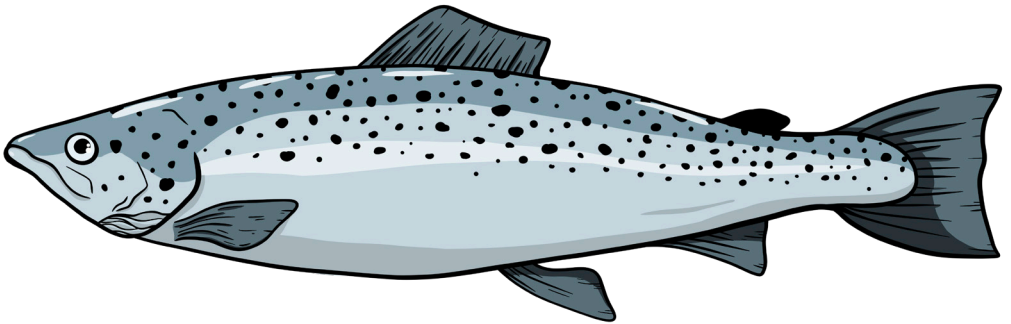
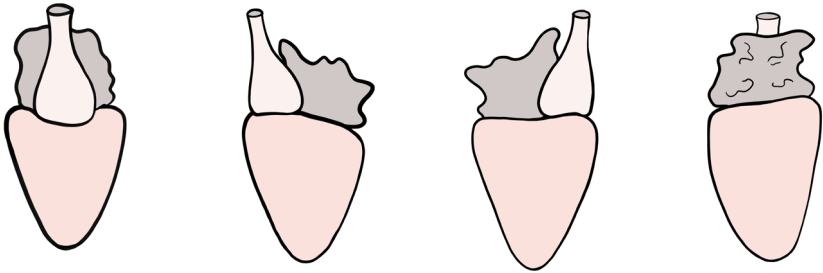


A Guide to Atlantic Salmon Heart Morphology

v 1.0



Vilde Arntzen Engdal

Alf Dalum

Michael Frisk

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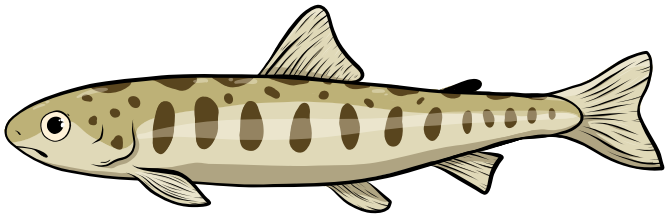
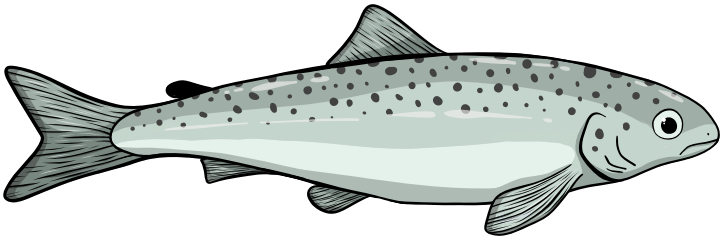


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Introduction

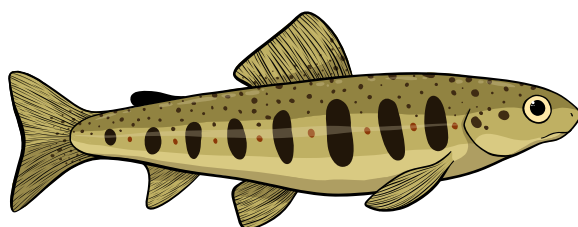
This booklet is created to assist in determining heart morphology in Atlantic salmon. Farmed Atlantic salmon (*Salmo salar*) possess a considerable variation in morphometric traits and deviations not commonly found in wild salmon hearts. We provide a qualitative method for recording heart traits in Atlantic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

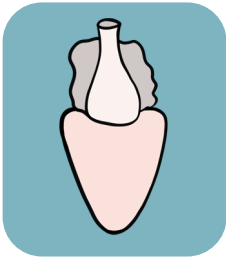
We acknowledge that this work may be limited in heart traits and that updates may be necessary. If the method does not cover morphological heart traits you find essential, please contact us, and we will make updates accordingly.

Contact information

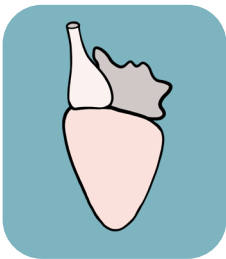
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| Harriet Romstad | harriet@aqua-kompetanse.no |
| Ida Beitnes Johansen | ida.johansen@nmbu.no |



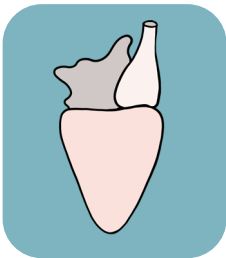
Projections



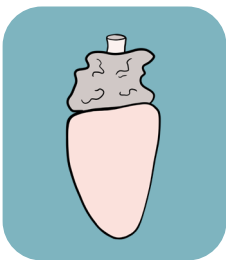
VD - Ventrodorsal projection



LL - Left lateral projection



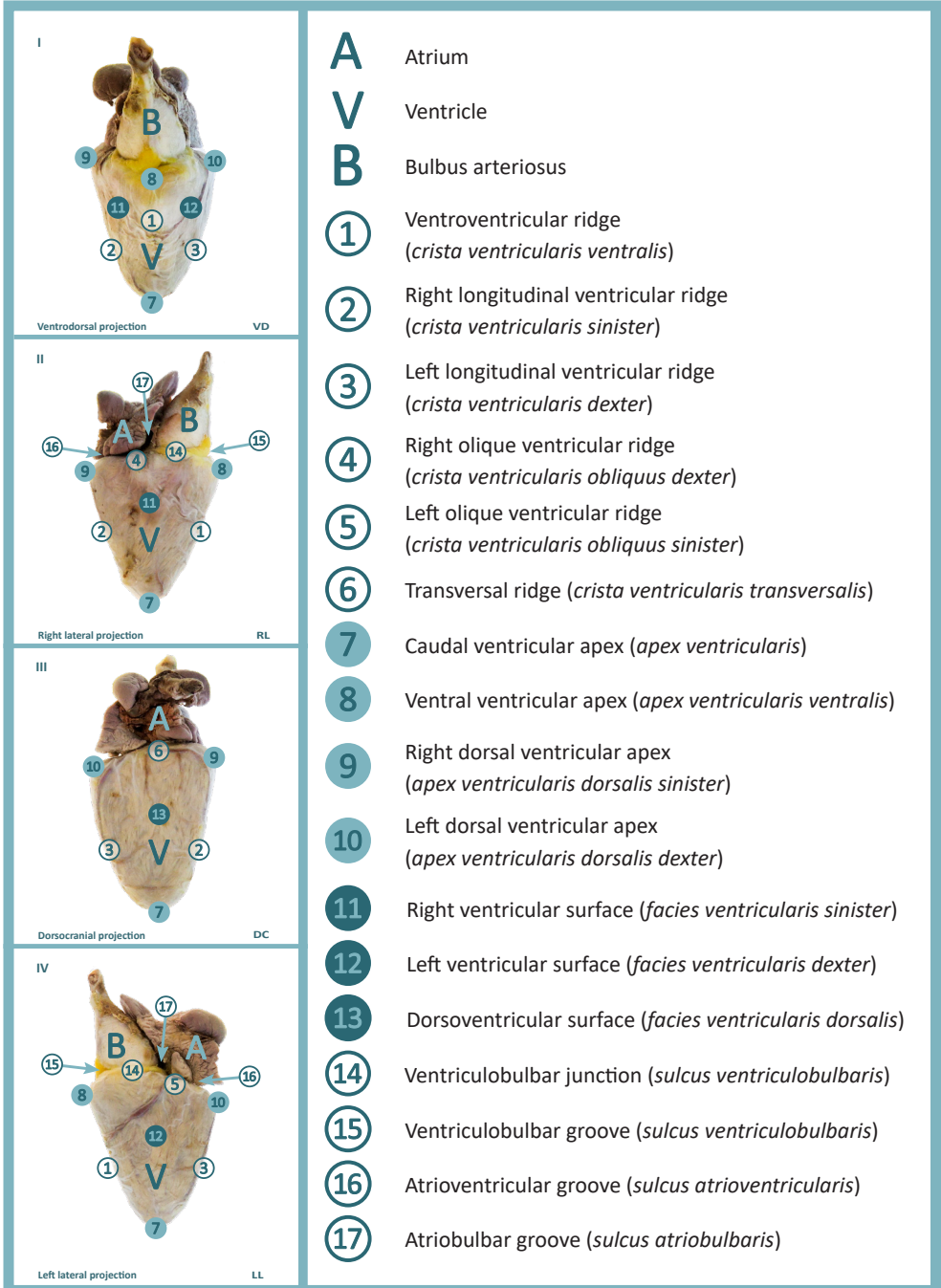
RL - Right lateral projection



DC - Dorsocranial projection

AP - Any projection

Nomenclature



4 Figure 2

Quantitative measurements

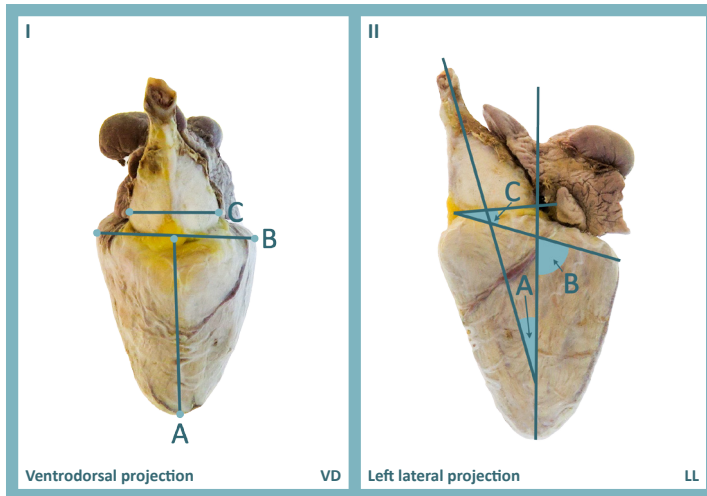


Figure 3

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 ventriculobulbar 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).







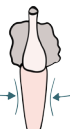



































Ventricular asymmetry (Figure 3, II, B)

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

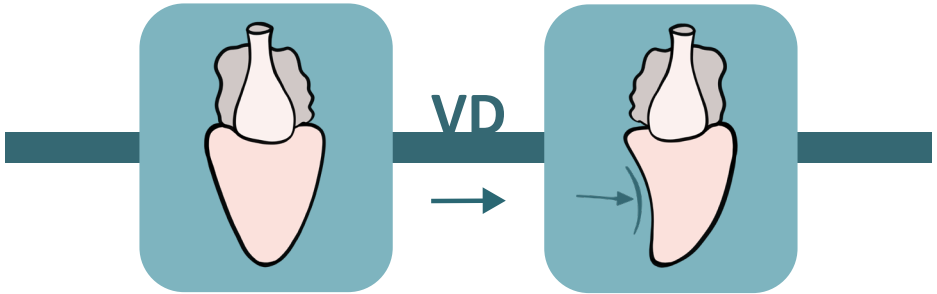
| | | | | | |
|--|---|---|---|---|--|
| 1 VD  Wild Atlantic salmon heart | 2 VD  Ventricle curved right | 3 VD  Ventricle curved left | 4 VD  Triangle ventricle | 5 VD  Short ventricle high axis | 6 VD  Ball shaped ventricle |
| 7 VD  Tube shaped ventricle | 8 VD  Bulboventricular junction shifted right | 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 ventriculobulbar 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 |

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 high 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 ventriculobulbar 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 |
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| 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

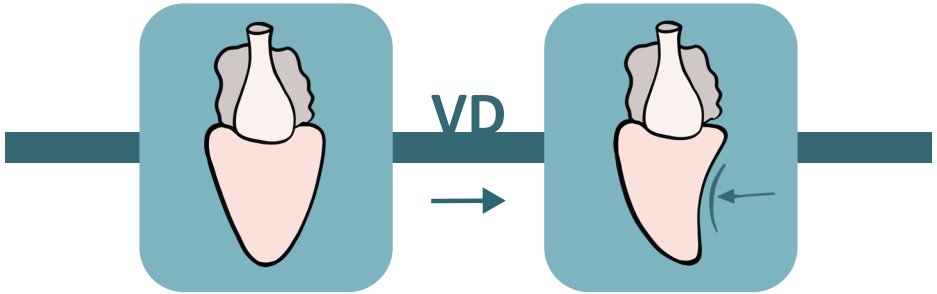


In VD projection; Inward curvature on ventricle in right ventricular surface (11). Caudal ventricular apex (7) shifted right may or may not occur.



Ventricle curved left

3

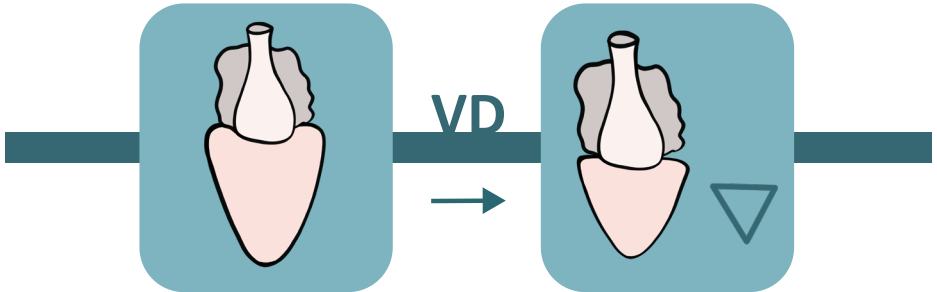


In VD projection; Inward curvature on ventricle in left ventricular surface (12). Caudal ventricular apex (7) shifted left may or may not occur.



Triangle ventricle

4

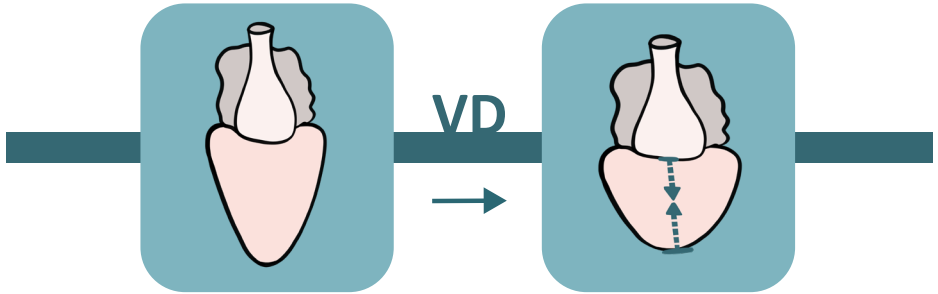


In VD projection ; A triangle shape to the ventricle where the caudal ventricular apex appears in a clear corner. The length between caudal ventricular apex (7), right dorsal ventricular apex (9) and left dorsal ventricular apex (10) are approximately uniform.



Short ventricle height axis

5

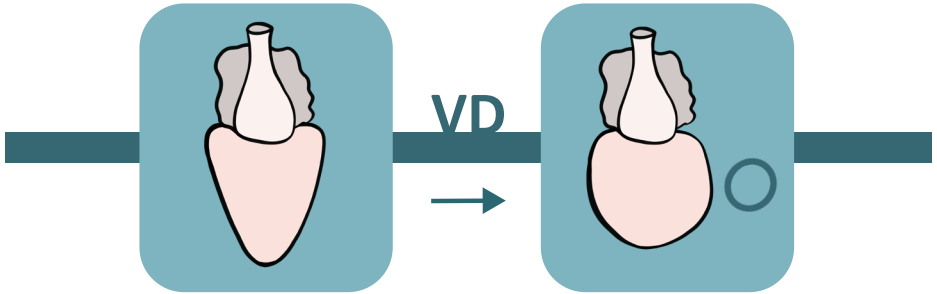


In VD projection; The length from the ventriculobulbar groove (15) to the caudal ventricular apex (7) is distinctly shortened.



Ball-shaped ventricle

6

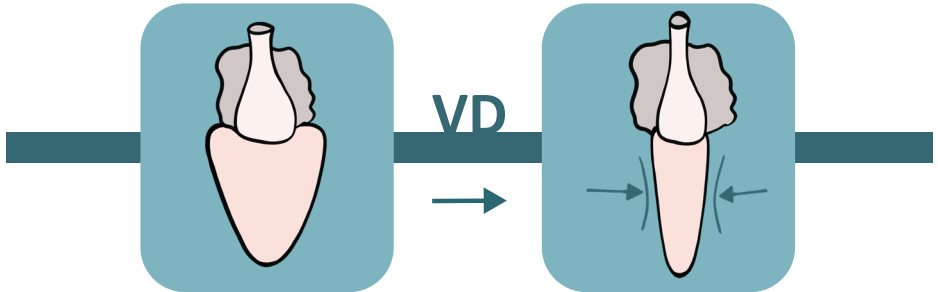


In VD projection; Ventricle appears round, caudal ventricular apex (7), right dorsal ventricular apex (9), and left dorsal ventricular apex (10) have less clear corners.



Tube-shaped ventricle

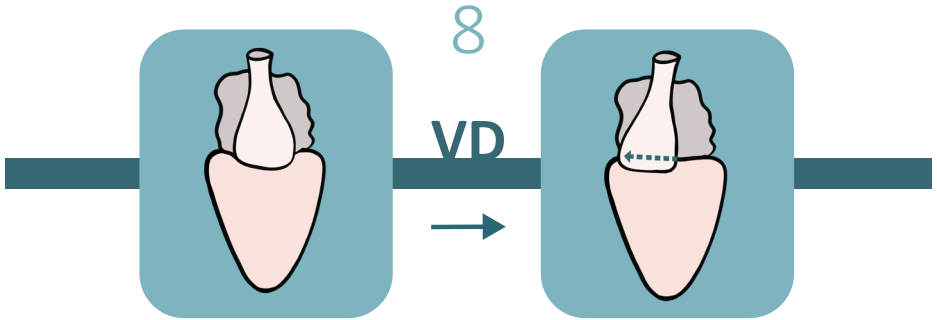
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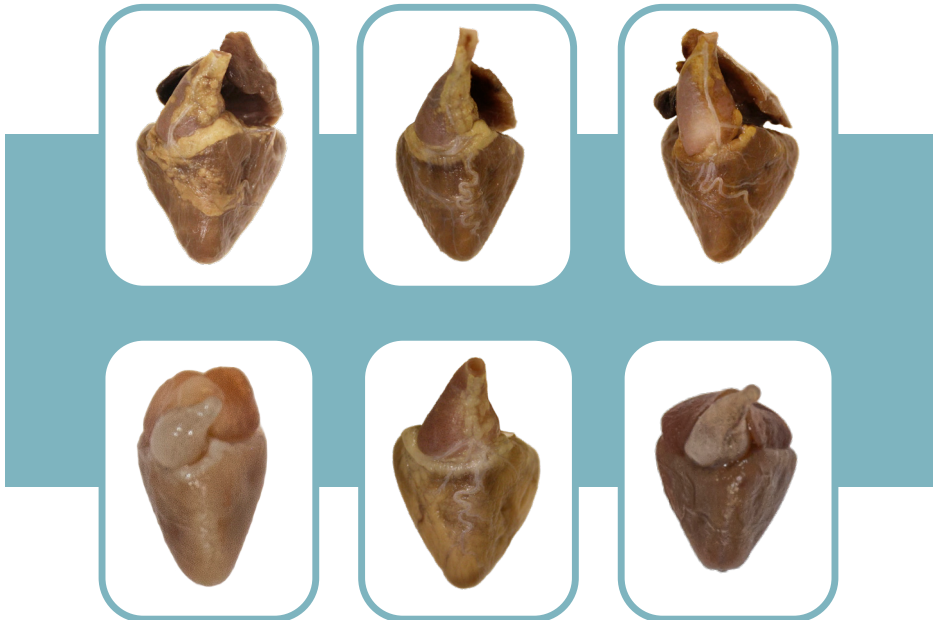
In VD projection; The ventricle appears elongated and narrow. Narrowing of left and right ventricular surface creating a tube-like shape.



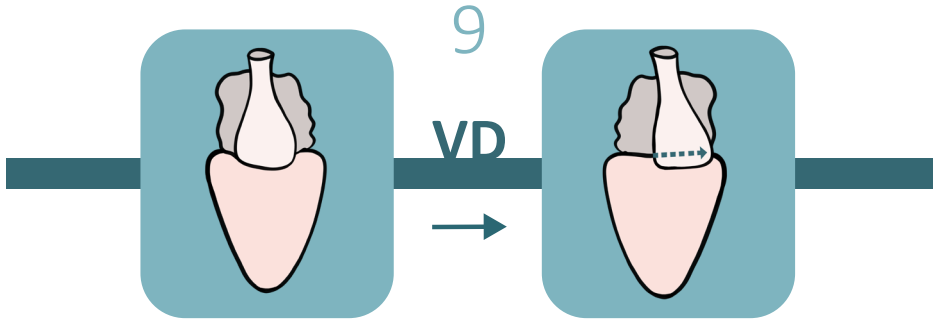
Bulboventricular junction shifted right



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

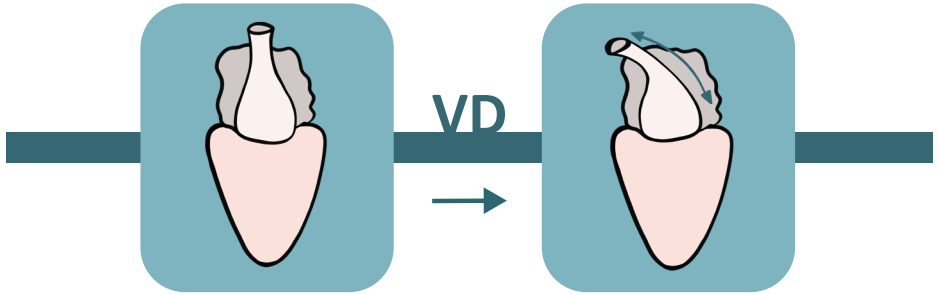


In VD projection; Bulbus position on the ventricle shifted to the left side of the ventricle. The entire bulbus may be shifted or a ballooning only towards the left side of the ventricle may occur.



Bulbus curved right

10

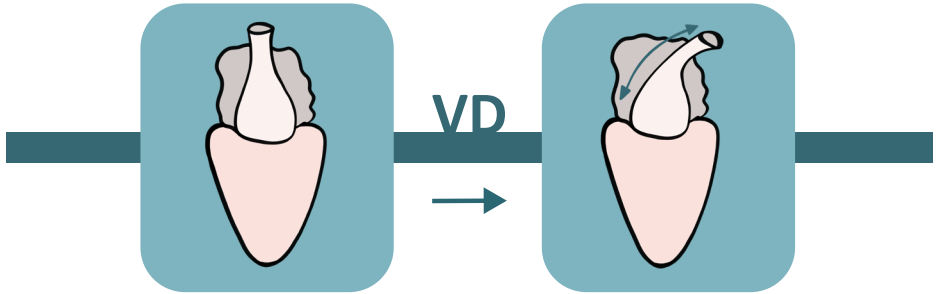


In VD projection; Bulbus curved right.



Bulbus curved left

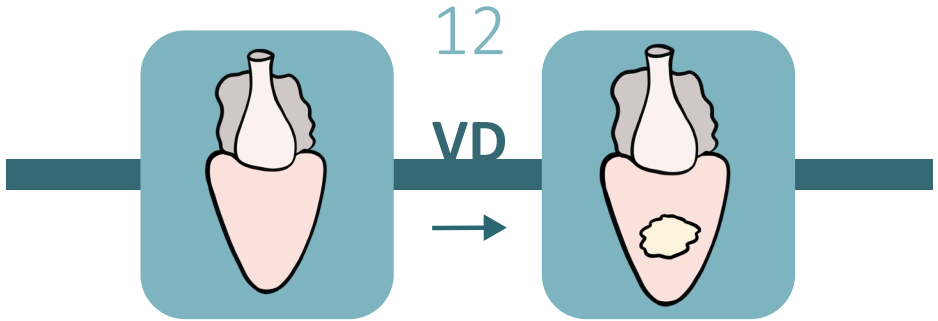
11



In VD projection; Bulbus curved left.



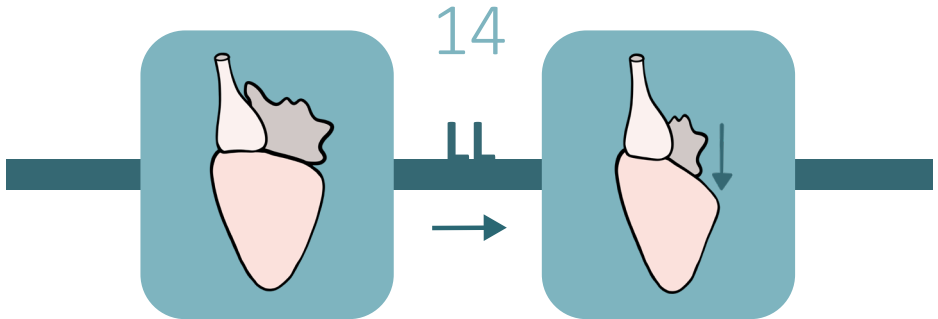
Fat deposit on ventroventricular ridge



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



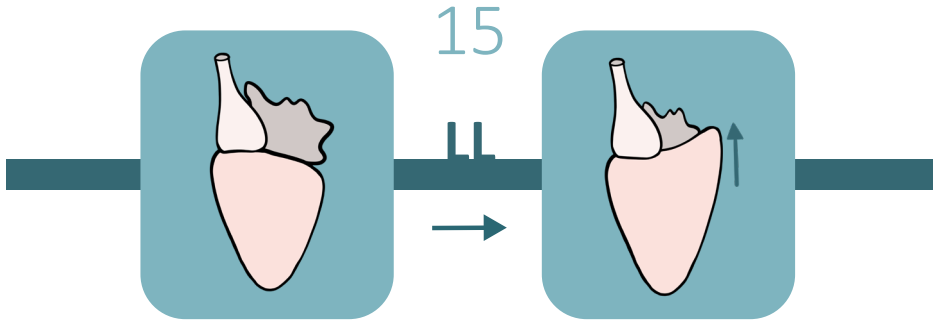
Low left dorsal ventricular apex



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



Extended left dorsal ventricular apex

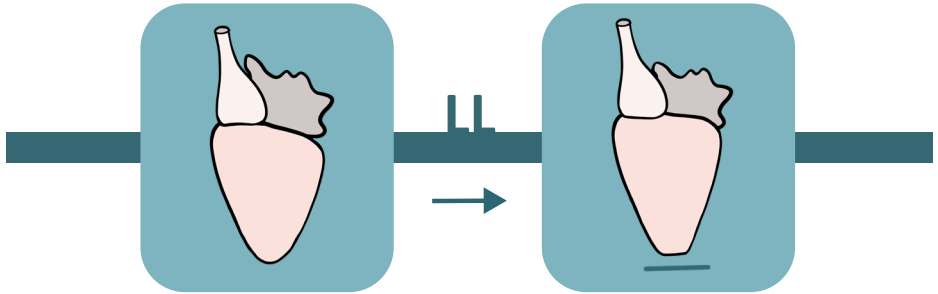


In LL projection; Left lateral ventricular apex (10) extended upwards, extended beyond the ventral ventricular apex (8)



Flat caudal ventricular apex

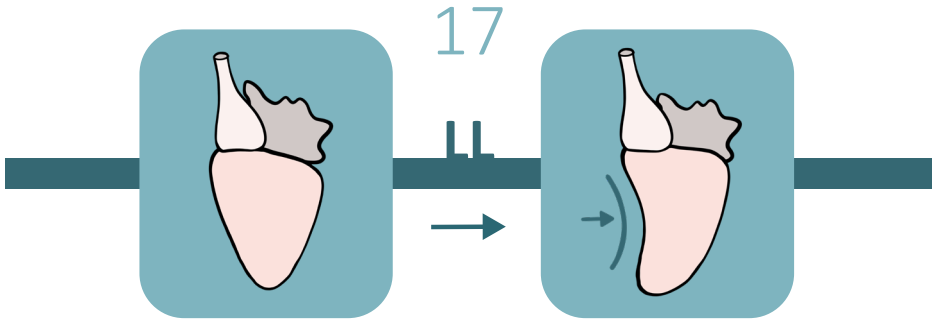
16



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



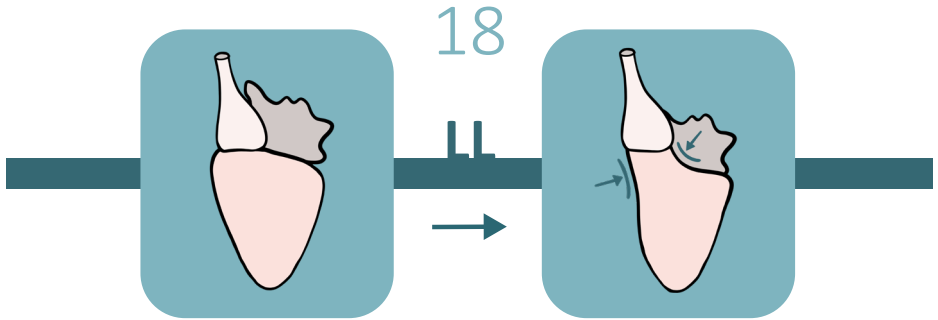
Ventroventricular ridge curved inwards



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



Narrowing of the ventricle at ventricubulbar junction

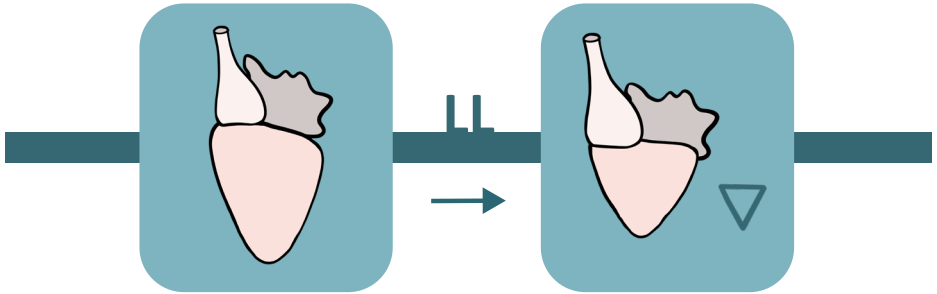


In LL projection; The ventricle appears pinched at atriobulbar groove (17) and between ventroventricular ridge (1) and ventral ventricular apex (8), resulting in a narrowing of the ventricle at ventricubulbar junction (14). Bulbus appears to sit as an extension of the ventricle.



Triangle ventricle

19

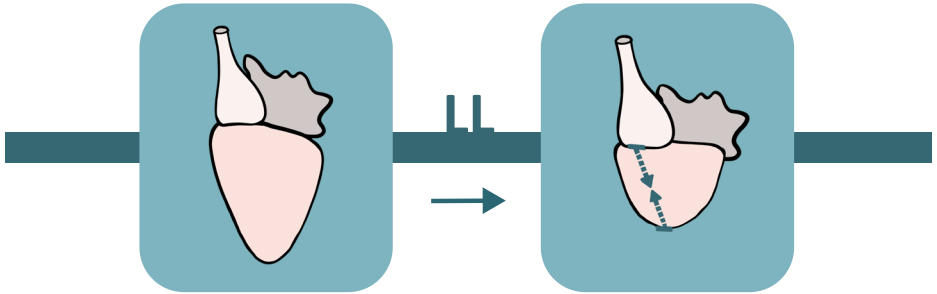


In LL projection; A triangle shape to the ventricle where the caudal ventricular apex appear in a clear corner. The length between caudal ventricular apex (7), right dorsal ventricular apex (9) and left dorsal ventricular apex (10) are approximately uniform.



Short ventricle

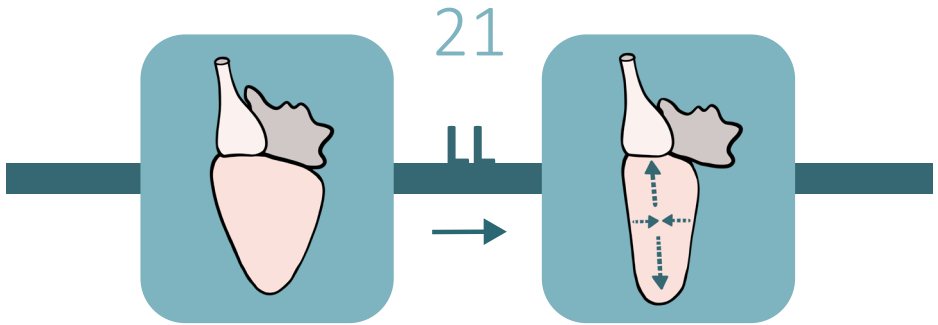
20



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



Elongated and narrow ventricle

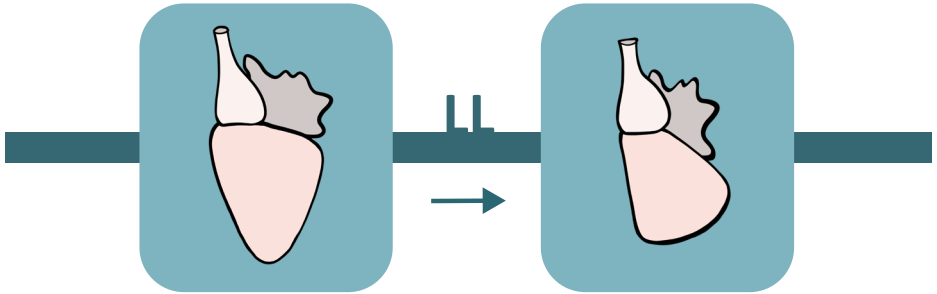


In LL projection; ventricle is elongated and narrow. Shortened length between left dorsal ventricular apex (10) and atriobulbar groove (17).



Bell-shaped ventricle

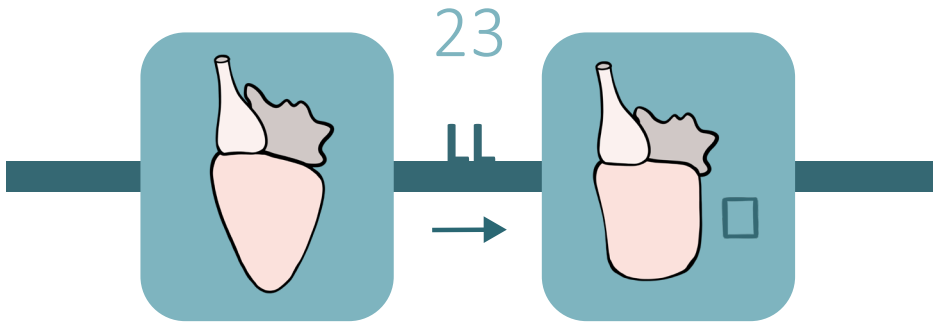
22



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

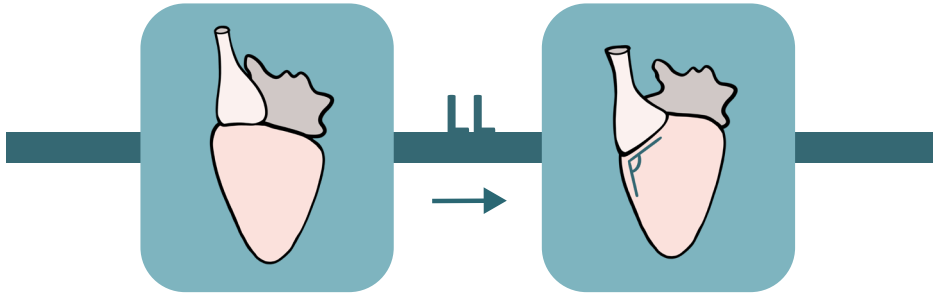


In LL projection; The ventricle appears more square like, with four corners.



Skewed bulboventricular ridge

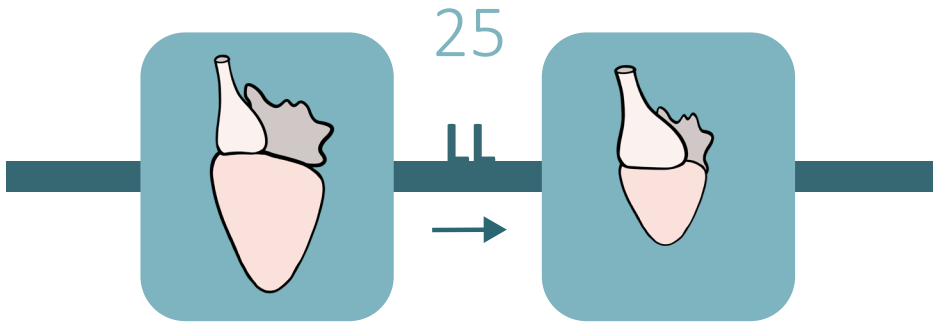
24



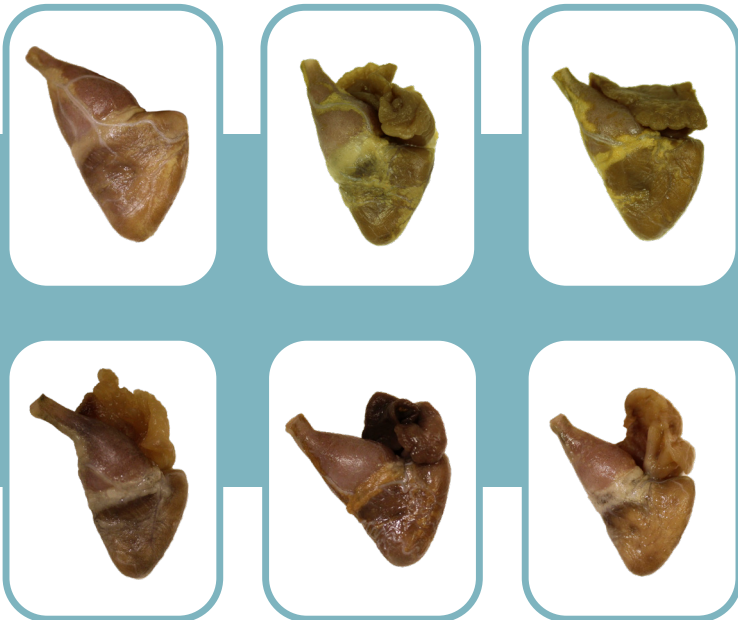
In LL projection; Bulbus sits in a obvious skewed position on the ventricle at the ventriculobulbar junction (14).



Large bulbus compared to ventricle

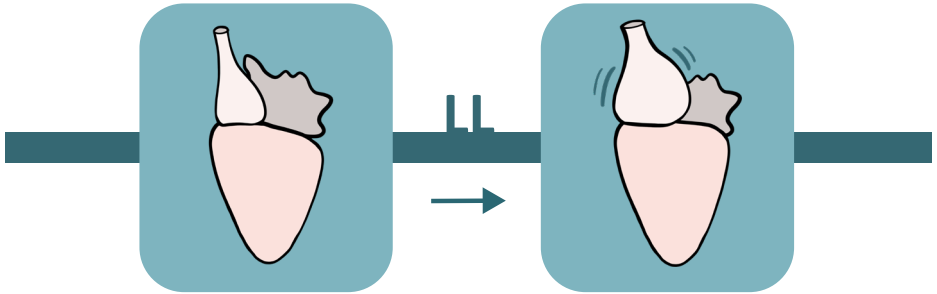


In LL projection; Bulbus appears large compared to the ventricle that appears small.



Ballooning bulbus

26

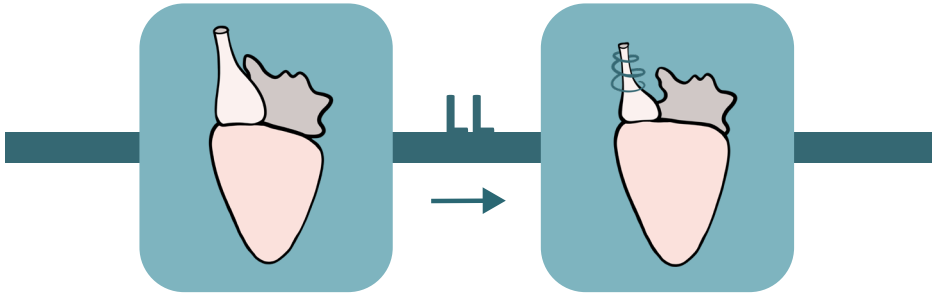


In LL projection; Bulbus is ballooning, meaning that bulbus or parts of bulbus appear large.



Constricted bulbus

27

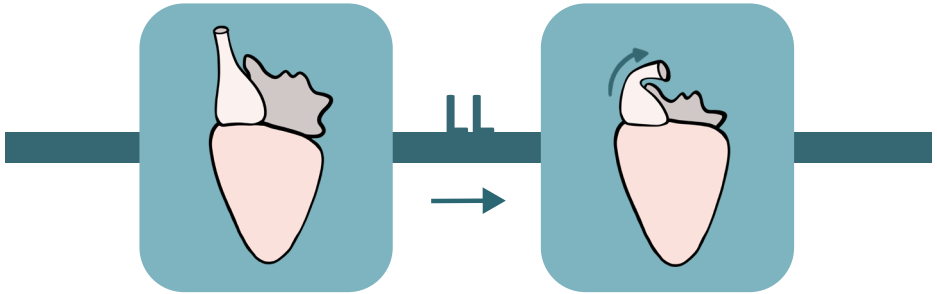


In LL projection; Bulbus is clearly constricted, either by size, positioning or curvature.



Bulbus curved dorsally

28

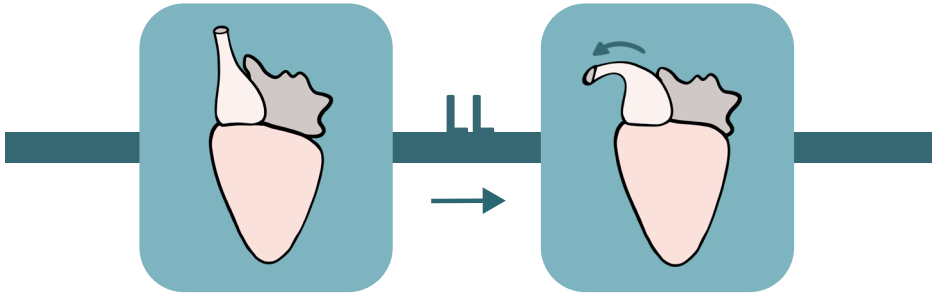


In LL projection; Bulbus curved dorsally.

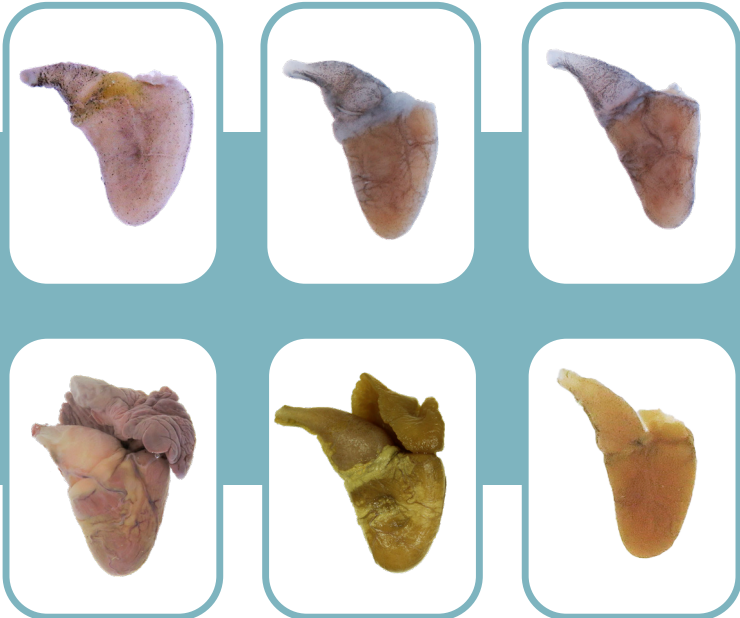


Bulbus curved ventrally

29

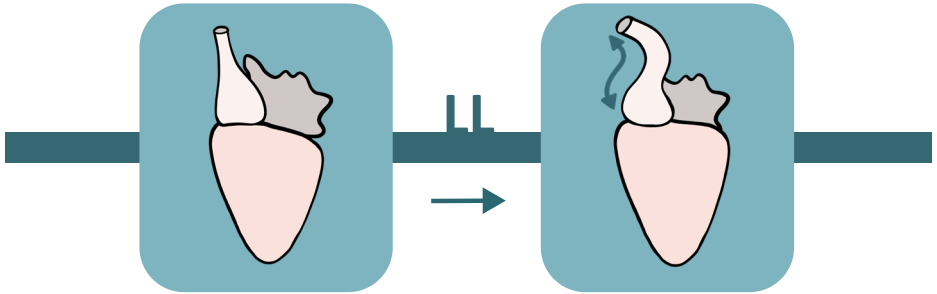


In LL projection; Bulbus curved ventrally.



S-shaped bulbus

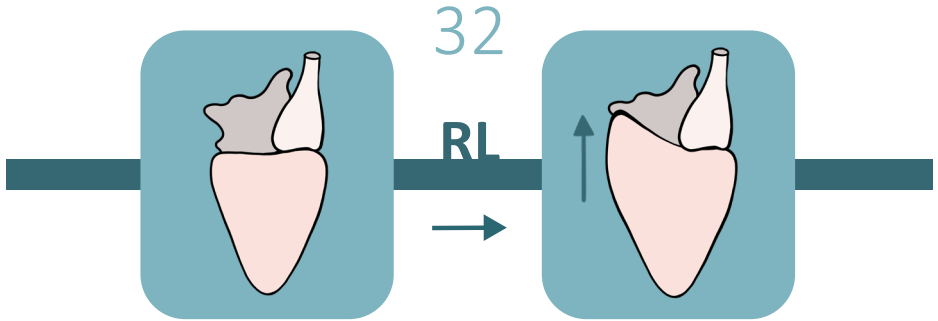
30



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



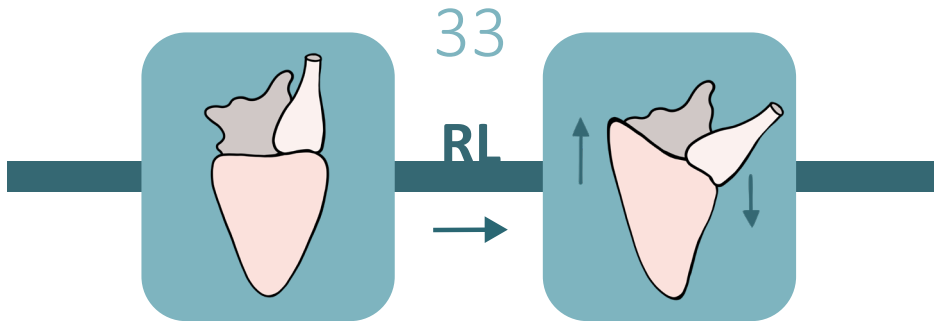
Extended right dorsal ventricular apex



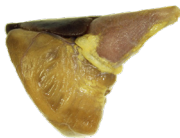
In RL projection; Right lateral ventricular apex (9) extended upwards beyond ventral ventricular apex (8).



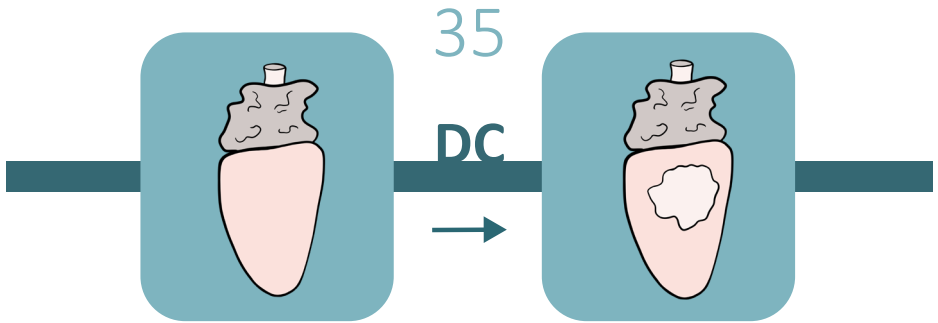
Extremely skewed bulbus and high dorsal ventricular apex



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



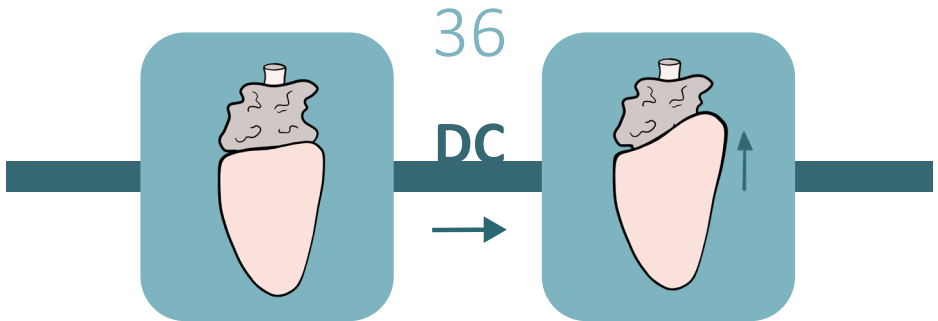
Fibrosis on dorsoventricular surface



In DC projection; fibrosis on dorsoventricular surface.



Extended right dorsal ventricular apex

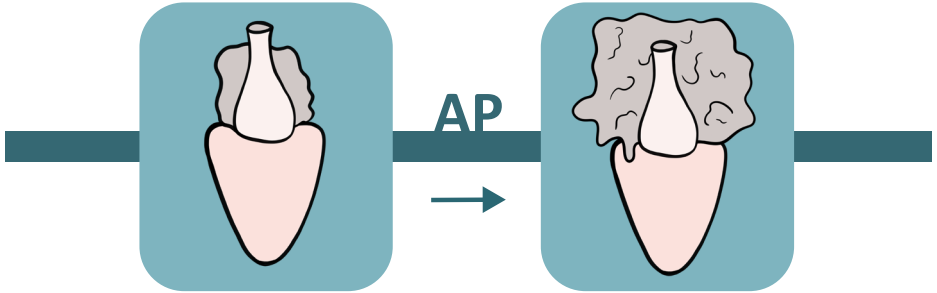


In DC projection; Right lateral ventricular apex (9) extended upwards beyond left lateral ventricular apex (10).



Extensive atrium

37

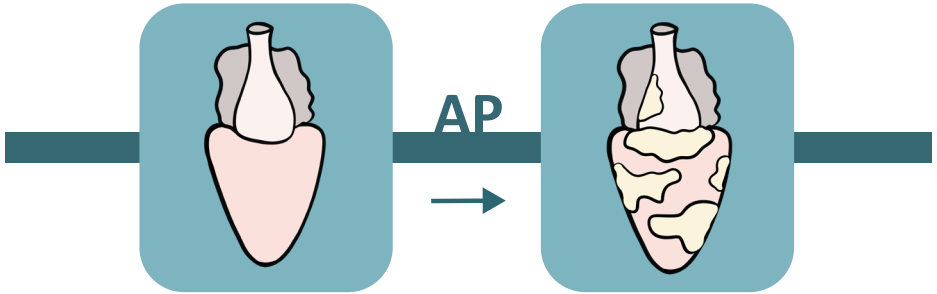


In AP projection; Atrium appears extensive



Extensive fat

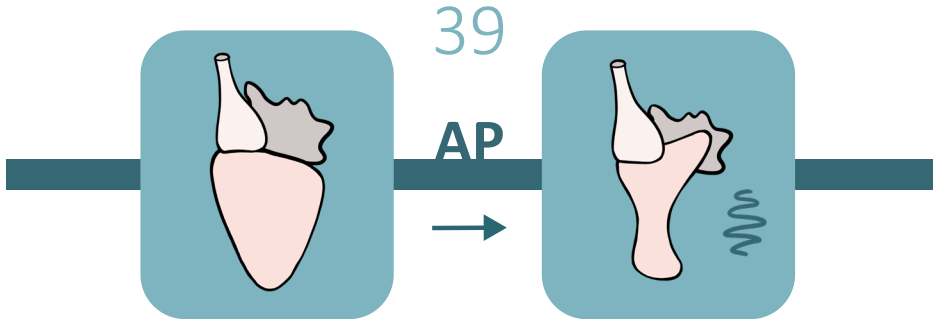
38



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



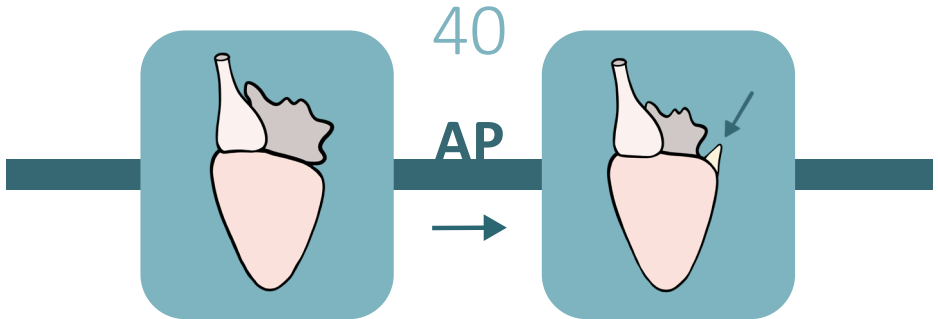
Extremely deviating heart morphology



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



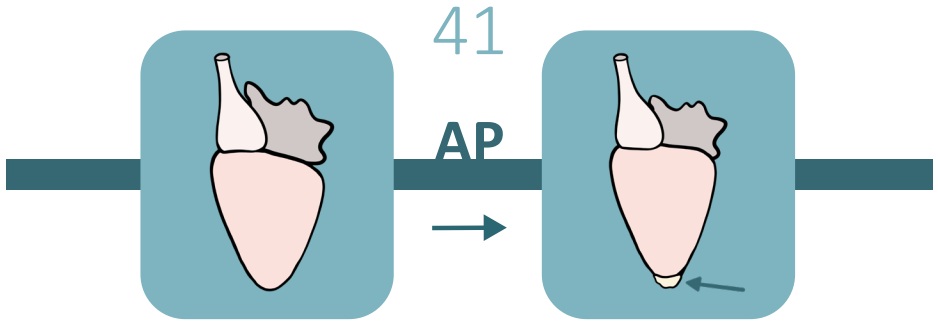
Fat deposit on dorsal ventricular apex



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



Fat deposit on caudal ventricular apex

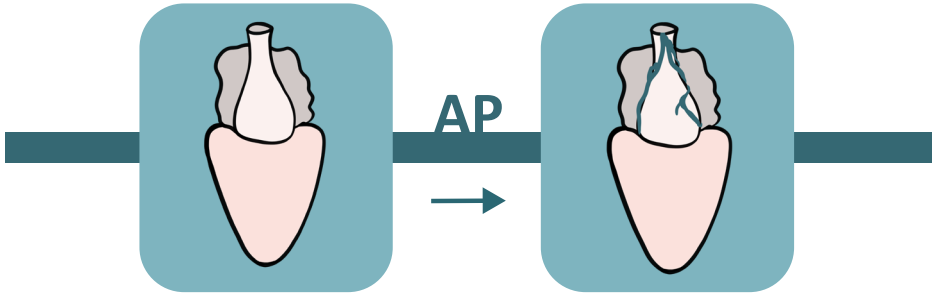


In AP projection; Fat deposit on caudal ventricular apex (7).



Deviating coronary vessels

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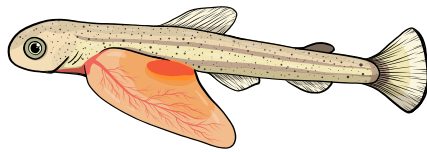


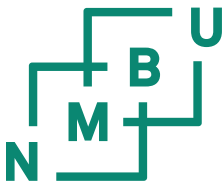
In AP projection; Coronary vessels that clearly deviate from normal structure.



References

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