Standardizing Two-dimensional Echocardiographic Examination in Snakes

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Little is known about diseases affecting the ophidian heart. While echocardiography is the diagnostic test of choice for cardiac evaluation in mammals, this modality has rarely been used in snakes. The unique anatomic features of the ophidian heart have direct consequences on the approaches used and the structures viewed during an echocardiographic examination; these include the heart's mobility in the coelomic cavity, the presence of a single ventricle, opening of the tubular sinus venosus into the right atrium and the presence of three arterial trunks. Standardization of the ophidian echocardiographic examination (e.g., technique, transducer position and views) should add to the veterinarian's knowledge of heart disease in snakes and generally contribute to the development of cardiology for exotic animals.

The ophidian heart can be subject to various lesions: endocarditis, myocarditis, infarction, pericarditis, cardiomyopathy, parasitic infection and tumors.[1,5,6,8,11,13,16,18] The diagnosis in most cases is delivered post mortem. As in mammals, echocardiography should provide a noninvasive means of evaluating cardiac anatomy and function in snakes. The correlation between cardiac anatomy and two-dimensional echocardiographic cross sections has been reported in the Burmese python (*Python morulus bivittatus*).[20] Our goal in this study was to develop a standardized technique for performing echocardiographic examination in snakes and a means for evaluating the two-dimensional cross sections.

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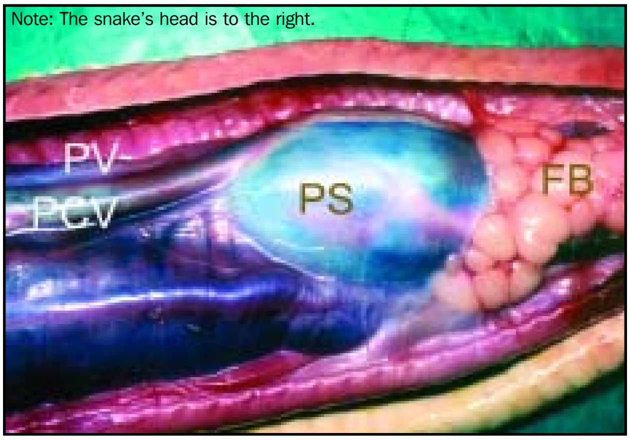
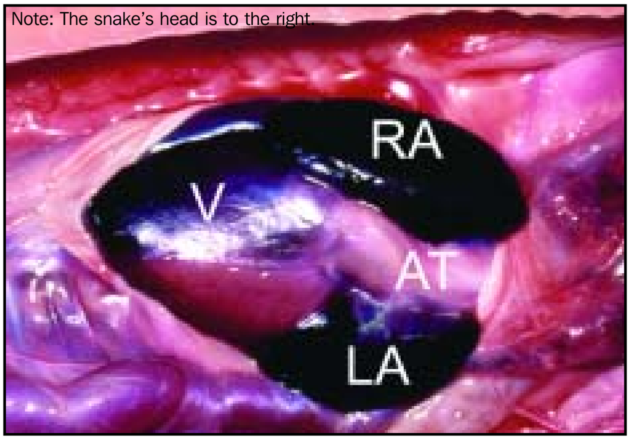
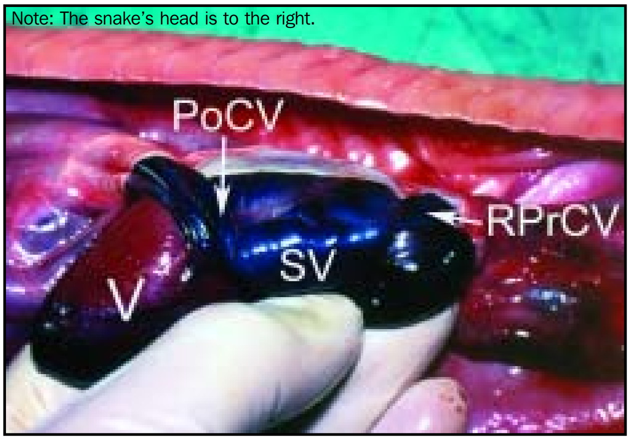
Distinctive Anatomic Characteristics

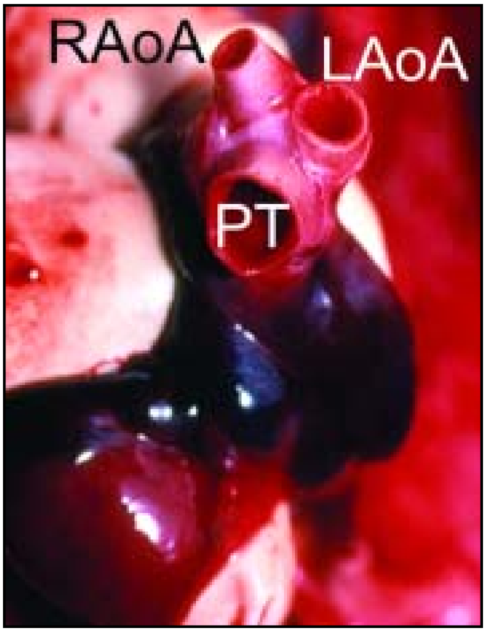


The ophidian heart is elongated, especially in colubrid snakes.[4,5,9,15,23,24] It is completely covered by a white, translucent, fibrous pericardial sac.[4] The location of the heart varies depending on the species, the animal's ecological niche and its behavior. In terrestrial species, the heart is positioned at about 0.15-0.25 the total body length (closer to the head in arborial species and more caudal in non-tree-dwellers); in marine and freshwater species, it is located near the middle of the body.[4,9,15,23] The snake does not have a diaphragm, and its heart is mobile within the coelomic cavity. This mobility probably facilitates the movement of large whole prey items along the esophagus.[4] The heart is caudal to the thyroid gland, lying at the cranial pole of the lung(s) and slightly ventral to the liver, facing the caudalmost tracheal rings.[9] Unlike other reptiles, in which the apex of the heart is attached to the pericardium by a ligament termed the *gubernaculum cordis*, the distal aspect of the snake's ventricle remains free within the pericardial space. It is offset slightly toward the left, leaving the caudal vena cava to travel close to the median plane.[4]





These photos show the ventral aspect of the heart in a Burmese python after resection of the pericardial sac. The heart is composed of four main cavities: 1) a single ventricle (V), which looks like an inverted cone with rounded edges, often taller than it is wide; 2) two atria, which can be seen from the ventral aspect of the heart, the right atrium (RA) being markedly more developed than the left atrium (LA); and 3) a tubular sinus venosus (SV), which rests on the dorsal aspect of the right atrium at the confluence of the three venae cava — the right precaval (RPrCV), left precaval (LPrCV) and postcaval (PoCV) veins.[4,16,20,24]



Three arterial trunks originate in the ventricle and rotate toward the right at a 180° angle: the left aortic arch (LAoA), right aortic arch (RAoA) and pulmonary trunk (PT).[4,5,9,18,20,23]

The two aortic arches merge caudally to form the common abdominal aorta. The pulmonary trunk (the efferent arterial trunk with the largest diameter) divides into the left and right pulmonary arteries in ophidians with two lungs (e.g., boid snakes). In other species (e.g., colubrids, viperids and elapids), the pulmonary trunk develops into a single anterior pulmonary artery directed cranially and a posterior pulmonary artery directed caudally.[4]

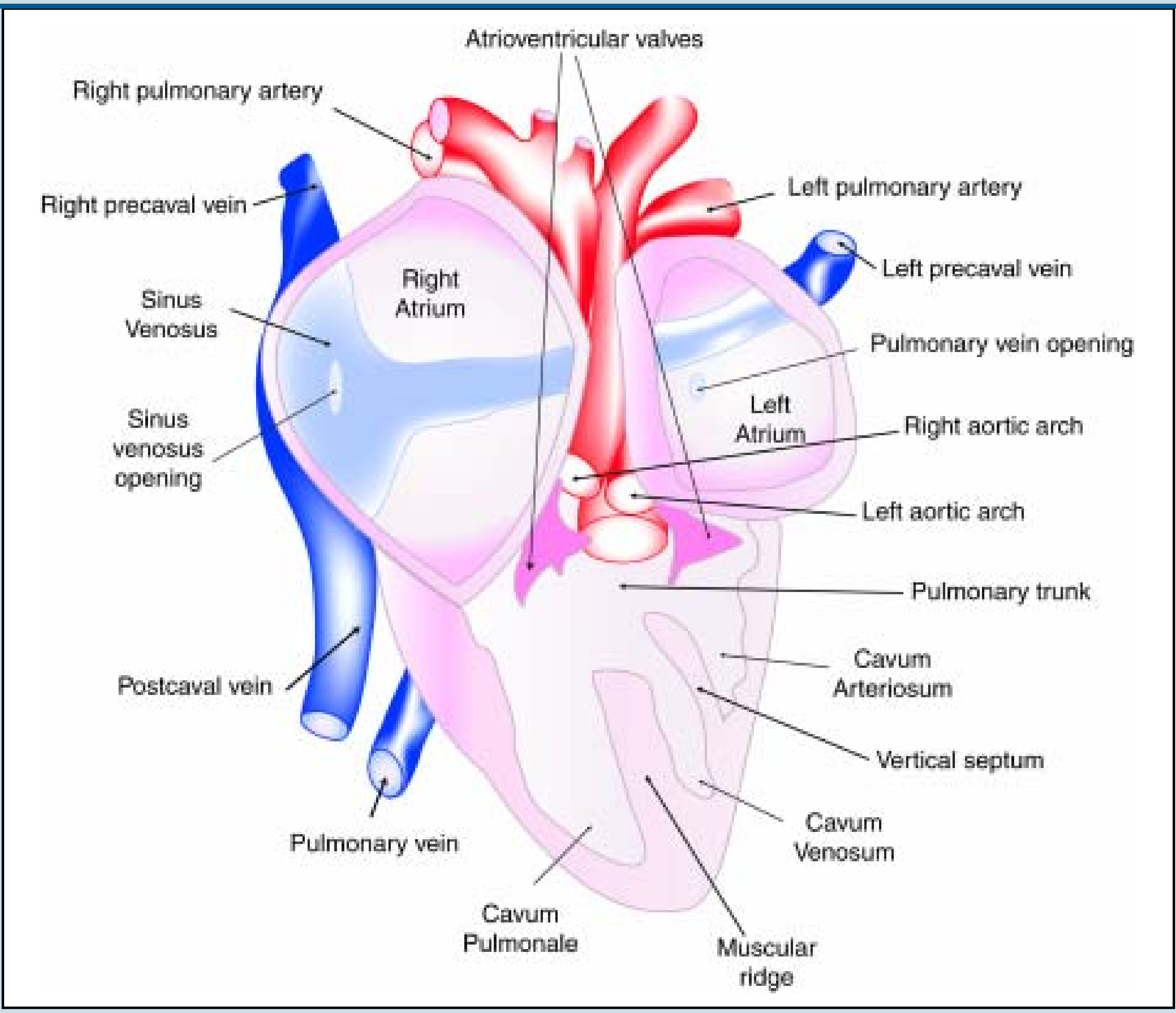
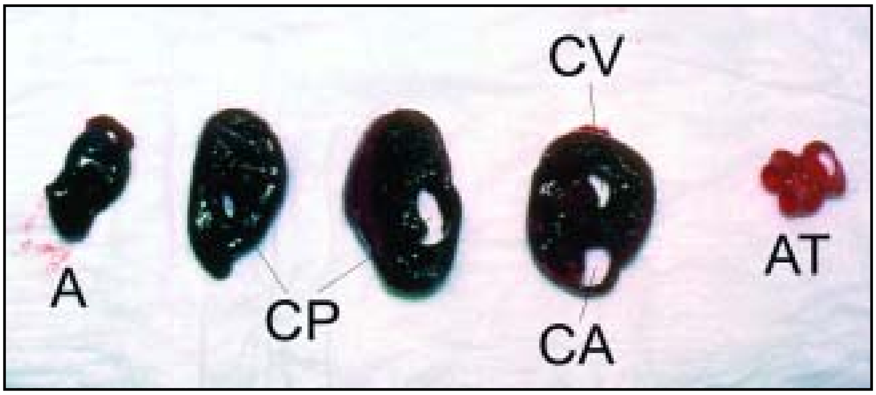


Fig 1. Four afferent veins drain into the sinus venosus: the pulmonary vein (which, in double-lunged snakes, proceeds from the point of confluence of the right and left pulmonary veins),[4] right and left precaval veins (RPrCV and LPrCV) and the postcaval vein (PoCV).



These cross sections of the ventricle of the heart in a Burmese python are taken from the apex (A) on the left to the arterial trunks (AT) of the heart's base on the right. Three communicating cavities are recessed within the ventricular cavity: the cavum venosum (CV) (right dorsal chamber), cavum arteriosum (CA) (left dorsal chamber) and cavum pulmonale (CP) ("ventral ventricle").[4,15,24]

The pulmonary vein drains into the dorsal wall of the left atrium close to the interatrial septum. The sinus venosus opens into the right atrium at the sinoatrial opening, which has a pair of flap valves (sinoatrial valves derived from the endocardium) that are membranous or muscular, depending upon the species.[4] The atria communicate with the single ventricle through the left and right atrioventricular (A-V) orifices, each of which is equipped with a single A-V valve (septal monocuspid atrioventricular valve).[4,5,9] The left and right aortic arches arise from the cavum venosum at two separate orifices, each equipped with bicuspid valves in contrast to the tricuspid valves seen in mammals. The pulmonary trunk is a continuation of the cavum pulmonale; its base contains two small semilunar valves.[4]

One muscular ridge, the vertical septum, is located in the ventricular cavity between the cavum arteriosum and the cavum venosum (Fig 1). Because of its position facing the interatrial septum, it contributes to the separation of flow from the pulmonary vein (oxygenated blood) and systemic venous return (deoxygenated blood) during ventricular diastole. A second relatively strong muscular ridge, the horizontal septum, originates between the pulmonary trunk and the left aortic arch and twists towards the dorsoapical region of the ventricle. This muscular ridge marks a separation between the cavum venosum and the cavum pulmonale.[4]

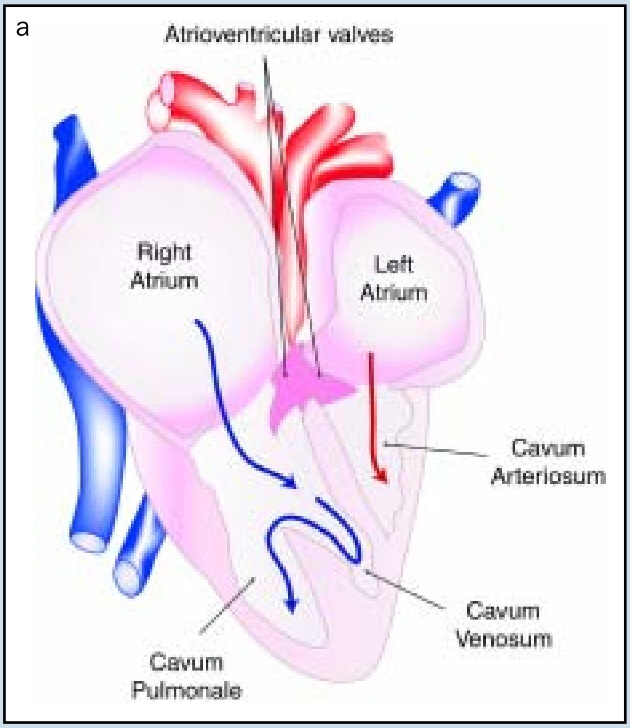


Fig 2a. During atrial systole, both A-V valves open, oxygenated blood in the left atrium flows into the cavum arteriosum, and deoxygenated blood in the right atrium flows into the cavum pulmonale via the cavum venosum.

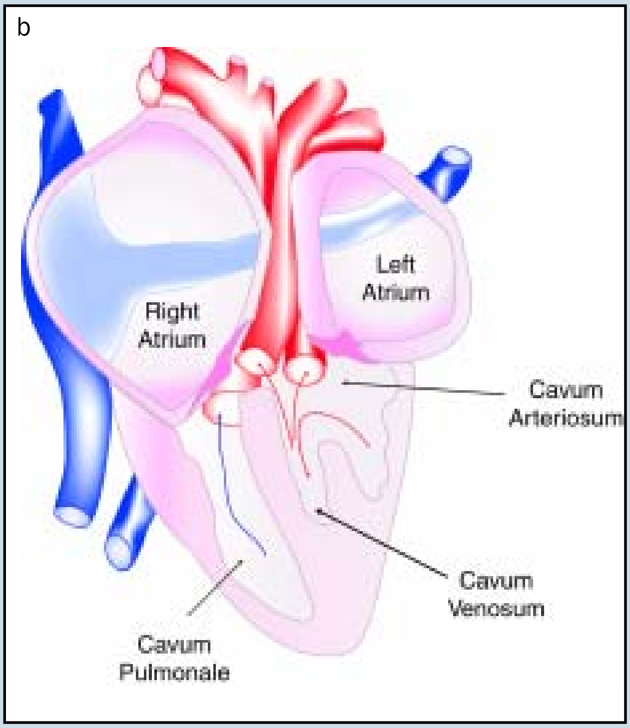


Fig 2b. During ventricular systole, both A-V valves close, and oxygenated blood is pumped out of the cavum arteriosum, towards the cavum venosum and on to the left and right aortic arches. Deoxygenated blood is pumped out of the cavum pulmonale into the pulmonary arterial trunk.[4,15,16,20,24] Blood flowing in the two aortic arches is mixed, because the cavum venosum contains both deoxygenated and oxygenated blood. However, this mixture is incomplete, because contraction of the vertical septum during diastole and the horizontal septum during systole ensures nearly complete separation of the pulmonary and systemic circulations.[4,5,16,20]

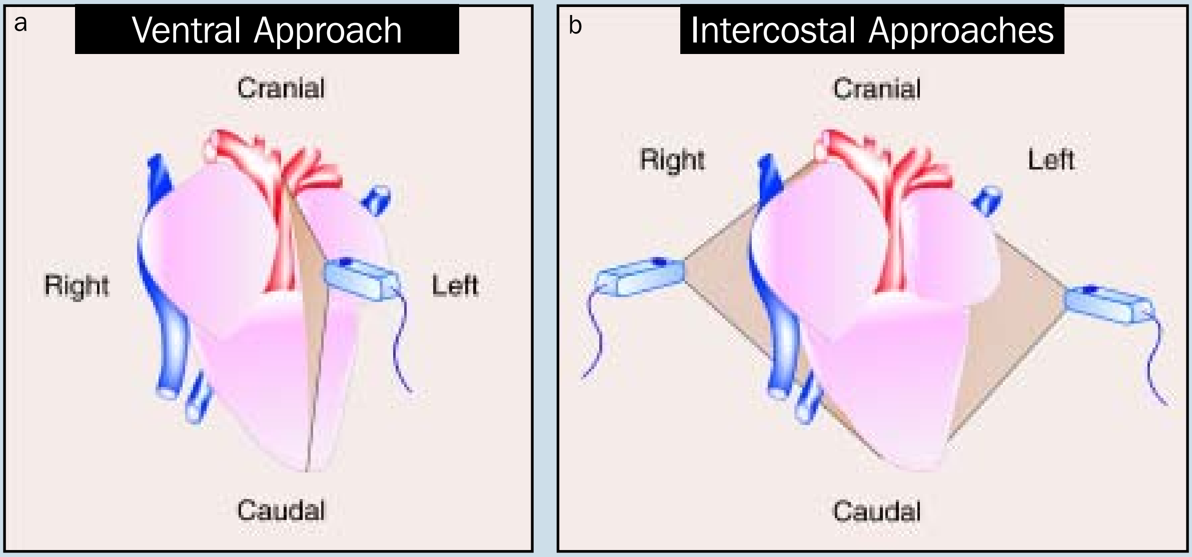
Two-Dimensional Echocardiographic Examination

Preparing and Positioning the Patient

The snake is held in dorsal recumbency by 2 assistants. Anesthesia is generally not necessary for the echocardiographic exam except with aggressive or particularly agitated animals. Tiletamine-zolazepam (15-30 mg/kg IM) produces sufficient muscular relaxation to diminish, if not completely abolish, the roll-over reflex.[2,12,18] The heart's position is indicated by visualizing the ventral precordial tap.

Echocardiography in this report was performed using an ultrasound unit equipped with a 5.0- to 7.5-MHz phased-array transducer. A thick layer of contact gel is applied ventrally to ensure optimal contact between the probe and the snake's scales. Because of the mobility of the snake's heart inside the coelomic cavity, the operator may need to move the transducer several centimeters, either cranially or caudally relative to its initial position, during the echocardio-graphic examination.

Examination Windows



Figs 3a,b. a) Three windows are used in succession for a complete echocardiographic examination. The majority of the study is done using the ventral window, via which it is possible to view the heart from the apex of the ventricles to the atria; in specific, the sinus venosus, A-V junctions and three arterial trunks can be seen. **b)** The other two approaches, the right and left intercostal windows, are accessed by laterally positioning the probe. These windows may be used to complete the ventral cranial examination and laterally view the three arterial trunks and both atria that communicate with the single ventricle.

Designation of Cross Sections

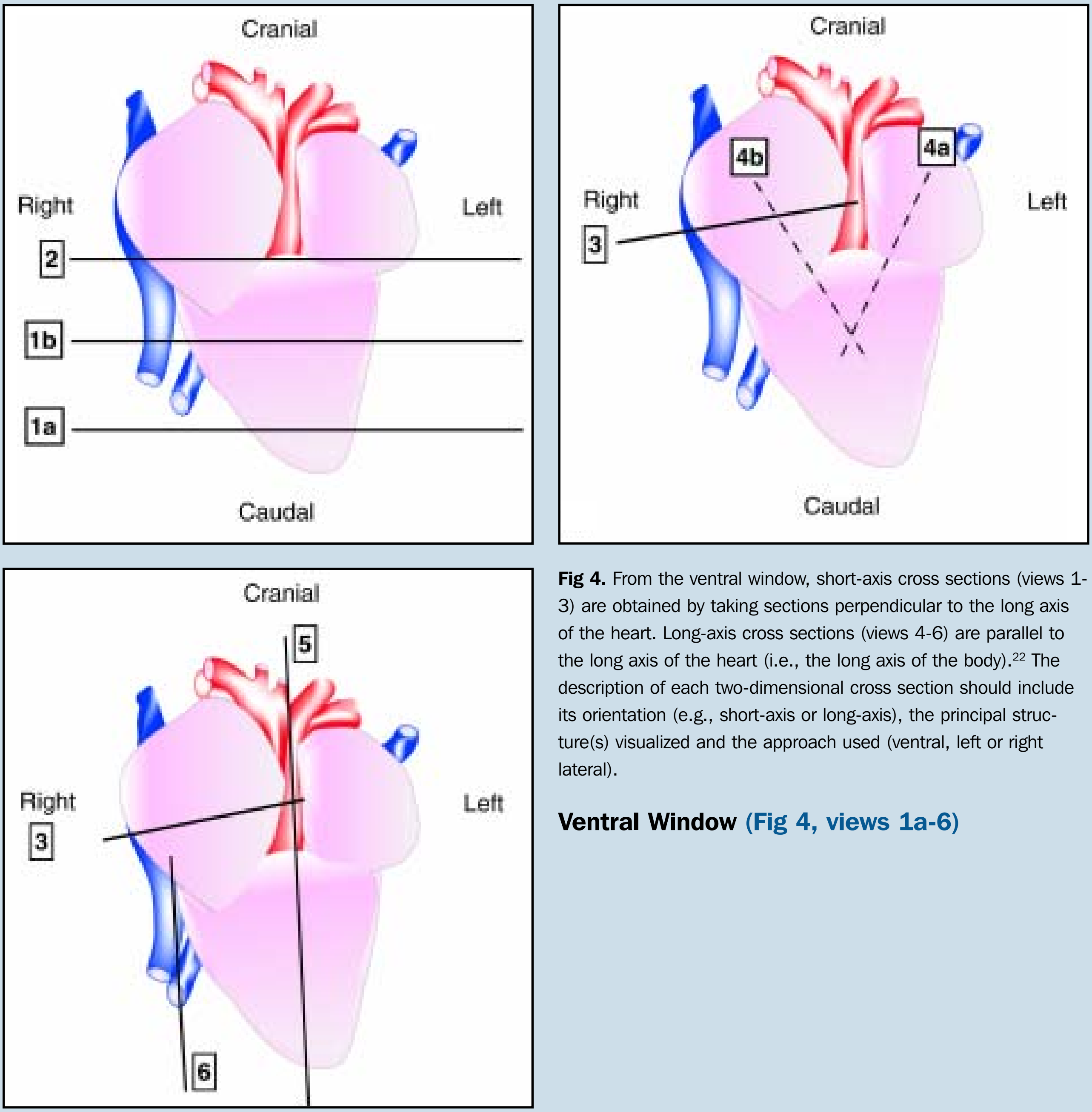


Fig 4. From the ventral window, short-axis cross sections (views 1-3) are obtained by taking sections perpendicular to the long axis of the heart. Long-axis cross sections (views 4-6) are parallel to the long axis of the heart (i.e., the long axis of the body).[22] The description of each two-dimensional cross section should include its orientation (e.g., short-axis or long-axis), the principal structure(s) visualized and the approach used (ventral, left or right lateral).

Ventral Window (Fig 4, views 1a-6)

Short-axis Views (Fig 4, views 1a to 3)

See Figs 5a,b; Figs 6a,b

By placing the probe ventral to the heart, the operator can scan or "sweep" the organ from its apex to the arterial trunks along its short axis.

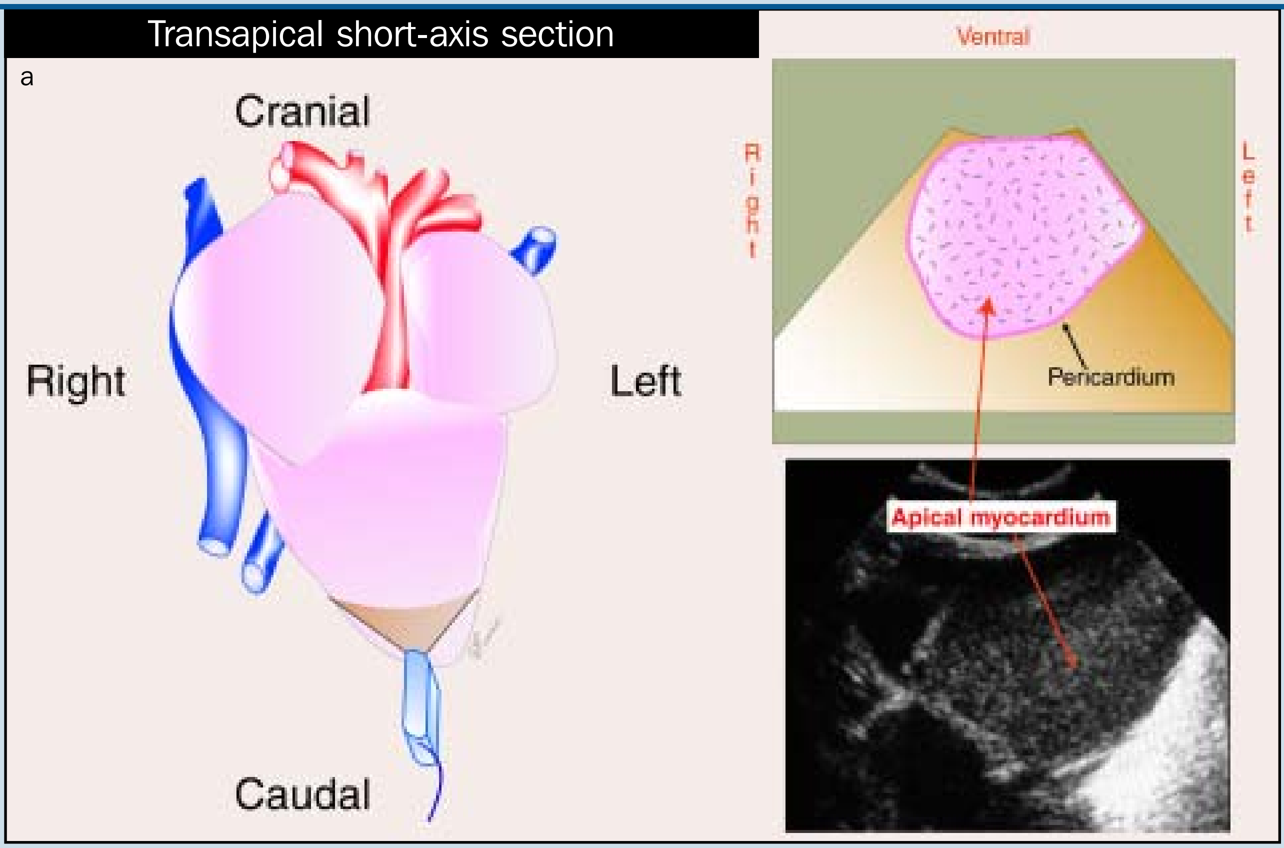
Two transventricular sections (Fig 4, views 1a and 1b) can be obtained using the ventral approach and moving the probe from the apex toward the base of the heart.

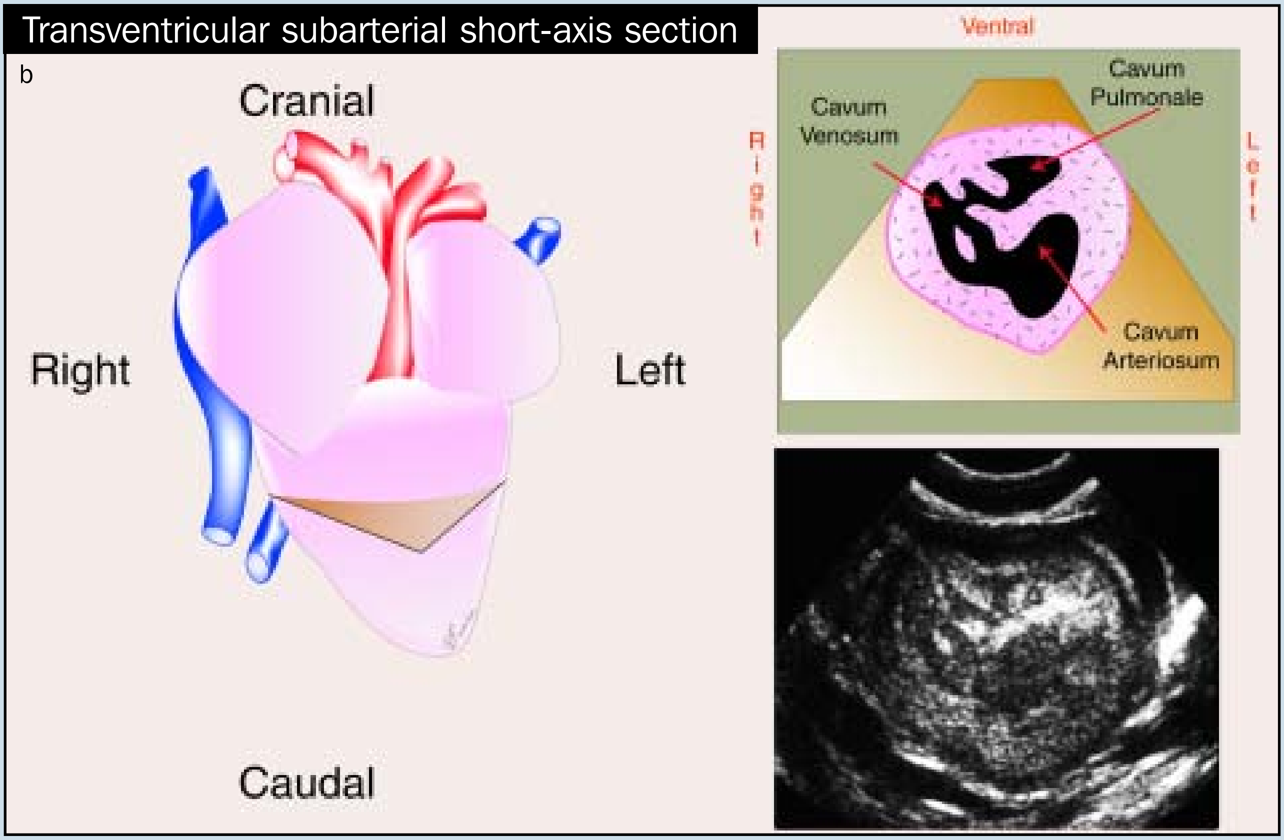
Long-axis views (Fig 4, views 4 to 6)

See Figs 7a,b; Figs 8a,b; Fig 9

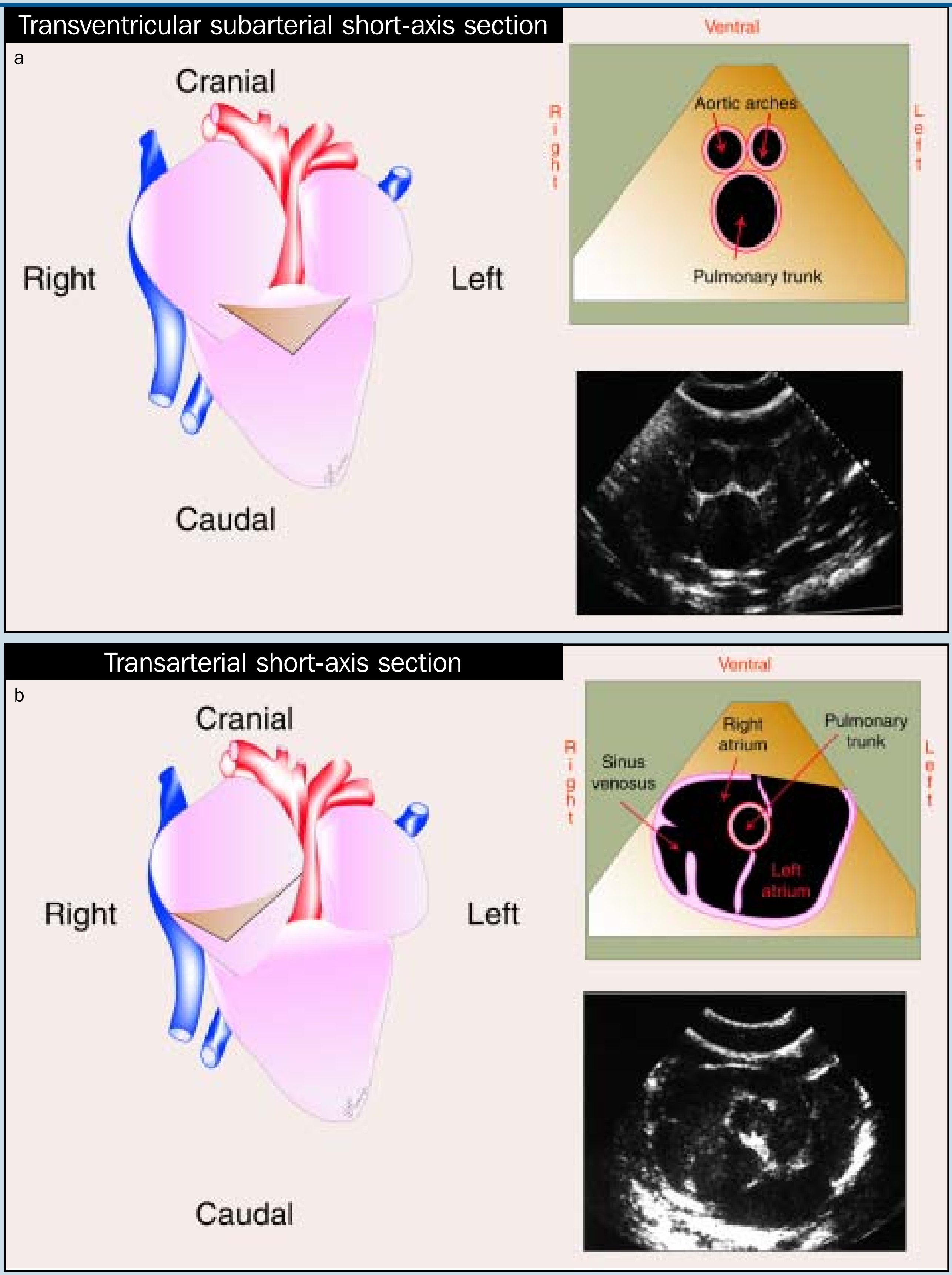
Long-axis views are obtained by turning the probe 90° in relation to the previously described short-axis projections.

Starting from the transventricular or subarterial section (Fig 4, view 1b), rotation of the probe provides two long-axis views called the atrioventricular sections (Fig 4, views 4a and b), which show both atrial cavities opening into the single ventricle via the A-V (septal monocuspid) valves.

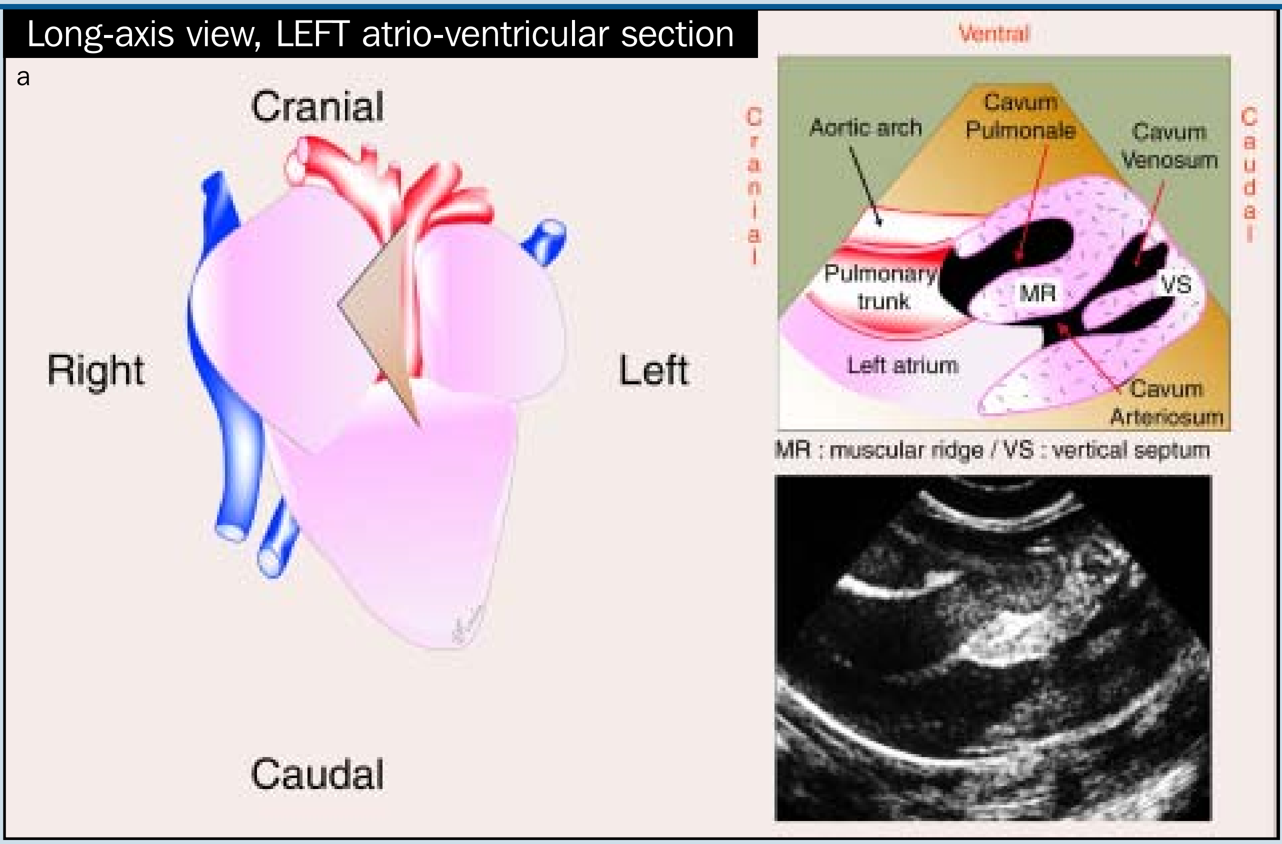


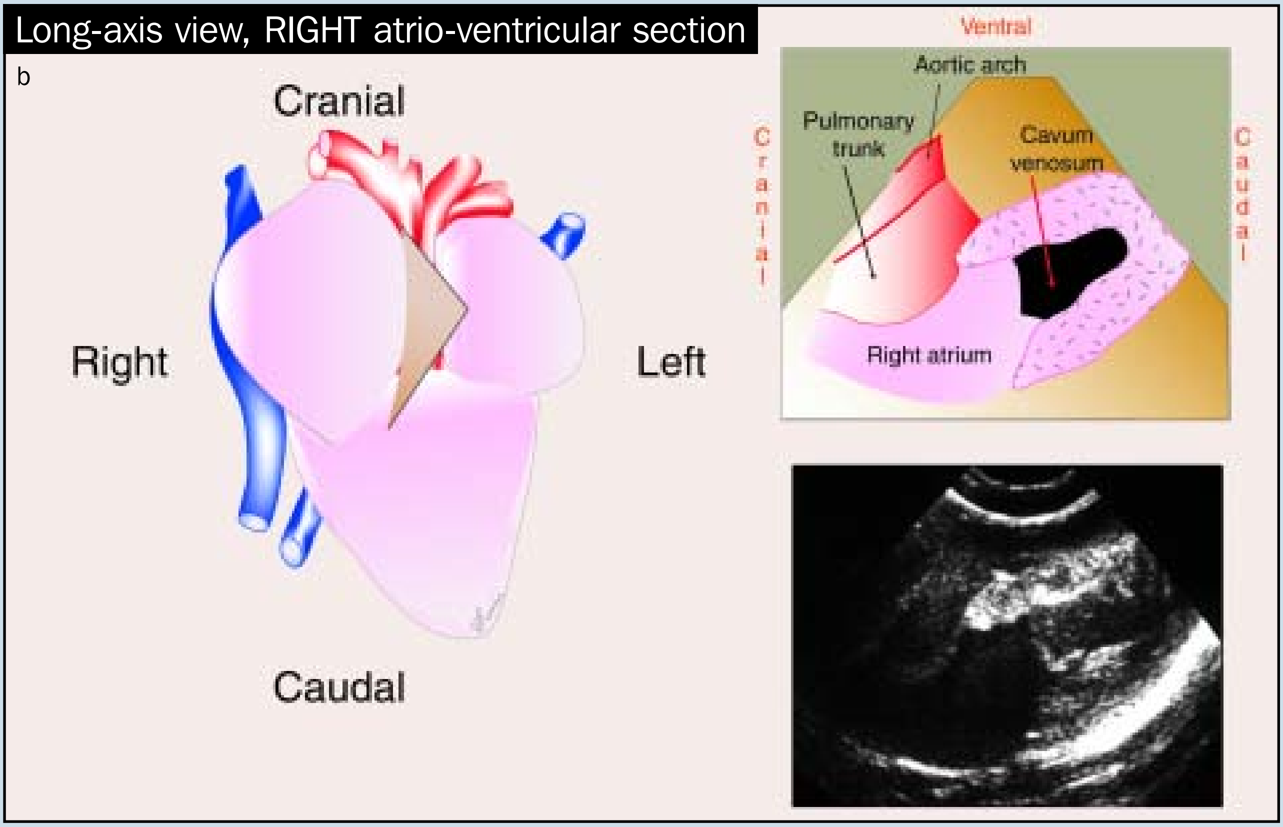


Figs 5a,b. a) The apical, or transapical, short-axis section shows a transverse section of the apical myocardium and pericardium, the latter visualized as an echogenic line. **b)** The transventricular subarterial short-axis section provides a transverse section of the ventral cavum pulmonale, right dorsal cavum venosum and left dorsal cavum arteriosum surrounded by the peripheral myocardium. The vertical septum, located in the ventricular cavity between the cavum arteriosum and cavum venosum, can be partially visualized as can the horizontal septum marking the separation between the cavum venosum and cavum pulmonale.

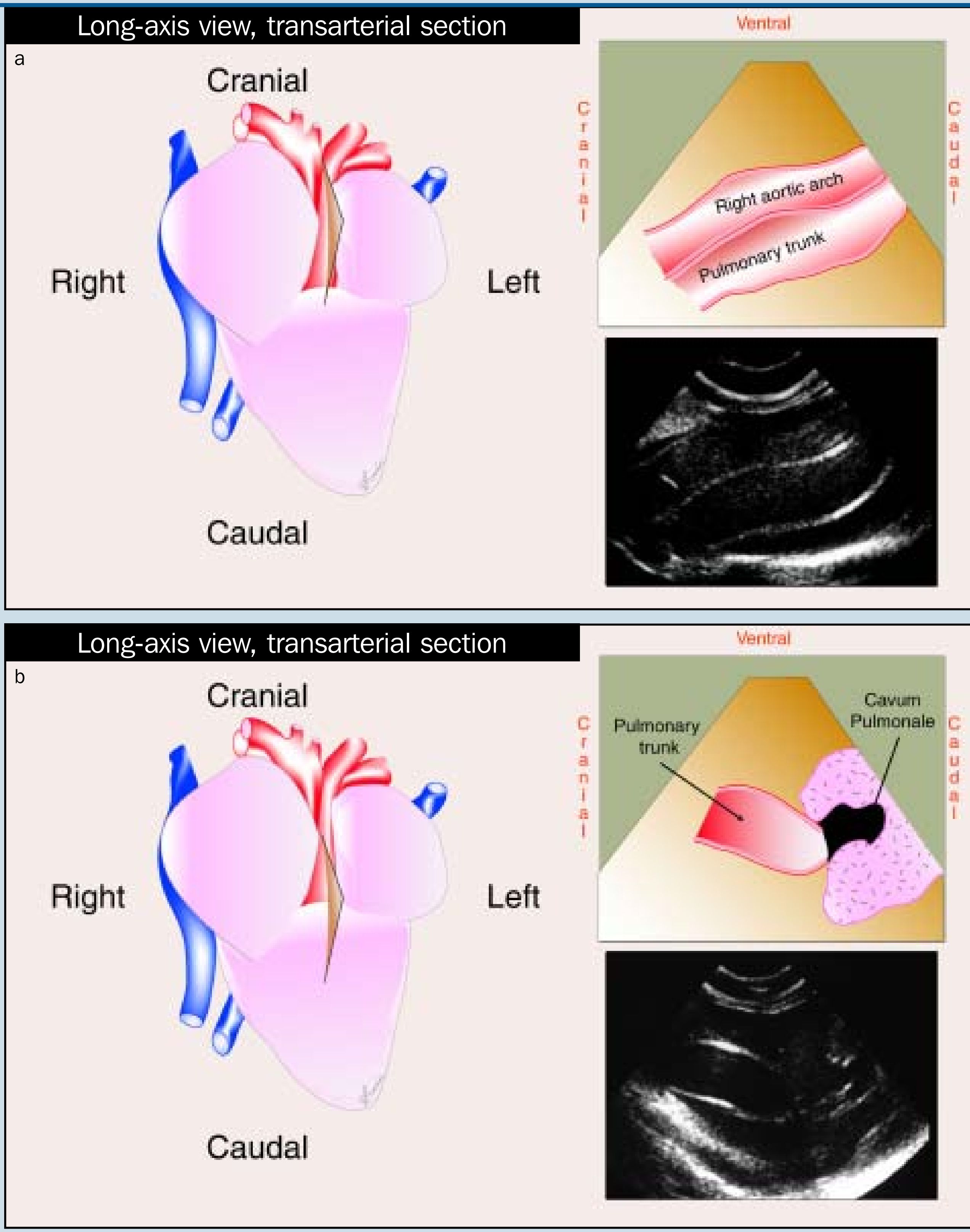


Figs 6a,b. a) By continuing to move the probe cranially, a transarterial short-axis section is obtained (Fig 4, view 2), which provides a transverse view of the three large arterial trunks: the two aortic arches of equal diameter and the larger pulmonary trunk. The image has a "Mickey-Mouse head" appearance. **b)** Leaving the probe in a ventral position but moving it slightly towards the right, the right trans-atrial short-axis section will show the opening of the sinus venosus into the right atrium and enable assessment of both sinoatrial valves.





Figs 7a,b. The left A-V junction can be observed by orienting the ultrasound plane ventro-dorsally from right to left. Similarly, the right A-V junction can be visualized by orienting the ultrasound plane ventro-dorsally from left to right. In each of the views in these photos, one of the two aortic arches and the pulmonary trunk are observed.



Figs 8a,b. Two-dimensional proximal (7a) and distal (7b) transarterial long-axis sections obtained by the ventral approach. The proximal view shows the path of the dorsal pulmonary trunk parallel to the ventral right aortic arch. The junction between the cranial pulmonary trunk and the caudal cavum pulmonale can be seen on the distal view. **a)** Starting from the short-axis orientation (Fig 4, view 2), the probe is rotated 90° to obtain a long-axis transarterial section (Fig. 4, view 5), which reveals the right aortic arch and pulmonary trunk running parallel. **b)** By moving the probe caudally, the path of the pulmonary artery comes closer to the probe ventrally then opens out on the right into the cavum pulmonale.

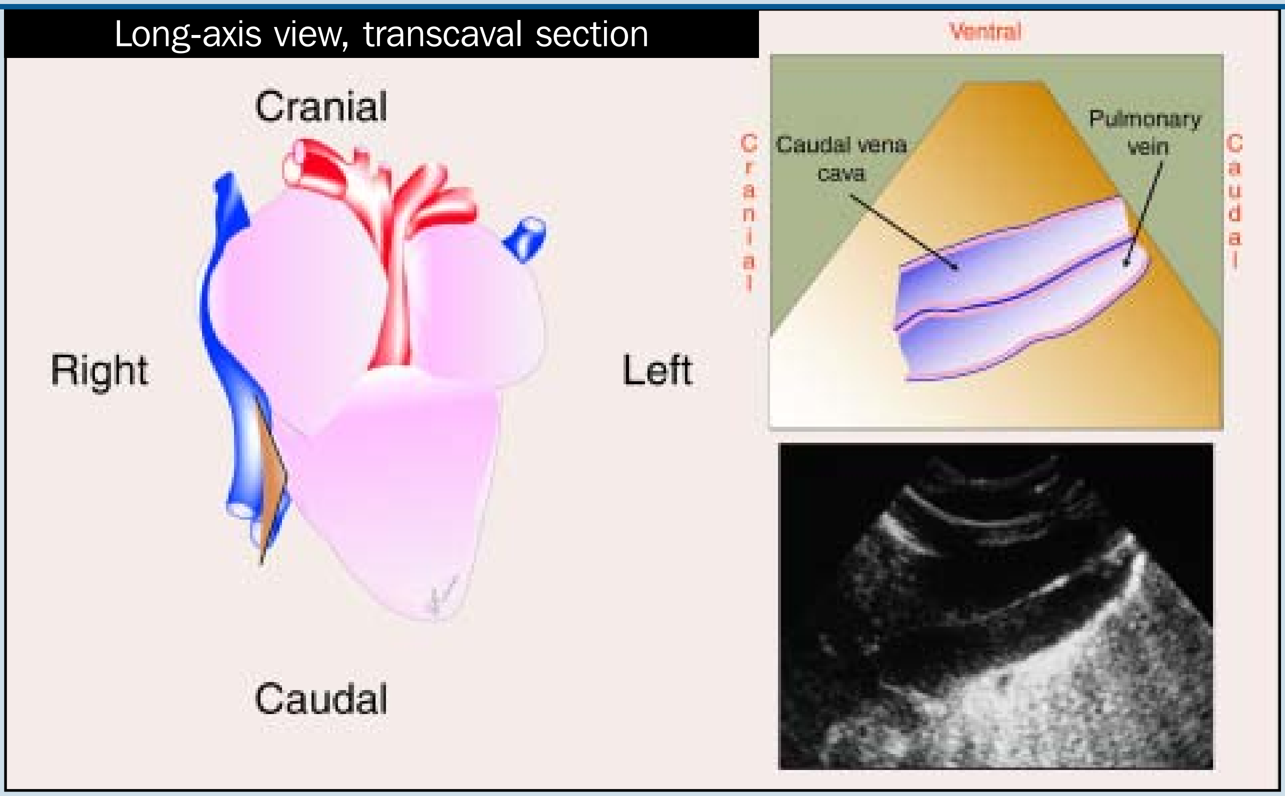


Fig 9. Finally, starting from the right transatrial short-axis section (Fig 4, view 3), the probe is rotated 90° and moved caudally to display the path of the ventral caudal vena cava running parallel to the more dorsal pulmonary vein. This long-axis lateral view (transcaval section) will also show the sinus venosus (Fig 4, view 6).

Intercostal Windows

If necessary, for example when dealing with small snakes, the examination may be completed by using two intercostal windows. The transarterial long-axis section, obtained via the right intercostal approach, provides clear visualization of the left atrium. The probe is placed laterally on the right so the cross section is parallel to the long axis of the body, and the left atrium is removed from the proximal field occupied by the large arterial trunks. Similarly, the left intercostal window provides a good approach for viewing the right atrium.

Conclusion

In general then, the ventral window provides a nearly complete echocardiographic evaluation of the ophidian heart. Both atria as well as the single ventricle, three cava, pericardium, sinus venosus, arterial efference and venous afference can thus be observed along short-axis or long-axis projections. The two intercostal approaches complete the study, especially providing views of the atria.

References and Further Reading

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Resources at a Glance

- Tiletamine-zolazepam - Zoletil, Laboratoire VIRBAC, Cedex, France, www.virbac.com
- Ultrasound unit equipped with a 5.0- to 7.5-MHz phased-array transducer - Vingmed Vivid 5, General Electric Medical System, Waukesha, WI, www.nationalultrasound.com/systems/index_GE_Vingmed_vivid_5.htm