Clinical ECG-gated MRI investigation of intracardiac shunting physiology in the red footed tortoise (*Chelonoidis carbonarius*).

Catherine J.A. Williams[1], Eva M. Greunz[2], Steffen Ringgaard[3], Kasper Hansen[4] Mads F. Bertelsen[2], Tobias Wang[1],
[1] Section of Zoophysiology - Aarhus University, [2] Centre for Zoo and Wild Animal Health, Copenhagen Zoo. [3] Institute for Clinical Medicine - The MR Research Centre, [4]Department of Forensic Medicine, Aarhus University Hospital,

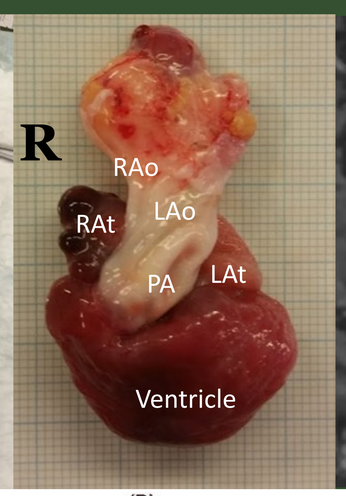
Chelonians have a complex cardiovascular system where changes in resistance in the systemic and pulmonary circulation under autonomic control, lead to shunting of blood in the undivided cardiac ventricle.[1,2]

Aim 1: Visualise blood flow in the cardiovascular system of intact chelonians.

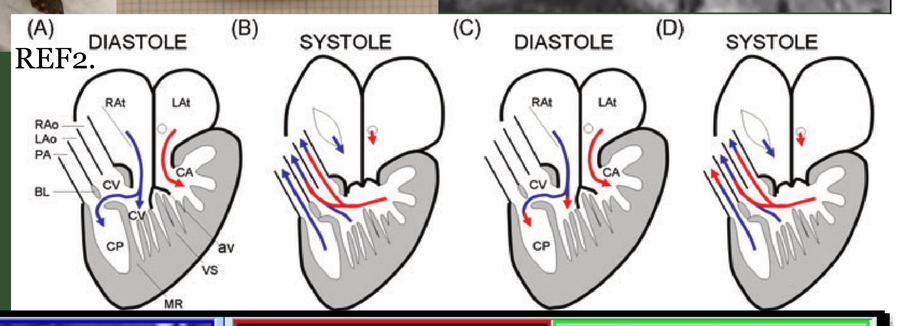
Method: Electrocardiogram (ECG) to mark phase of the cardiac cycle on magnetic resonance images (MRI). Retrospective gating to average across consecutive heart cycles.

Results: 1 mm³ resolution full heart-cycle video loops of the whole heart (see QR codes for video)

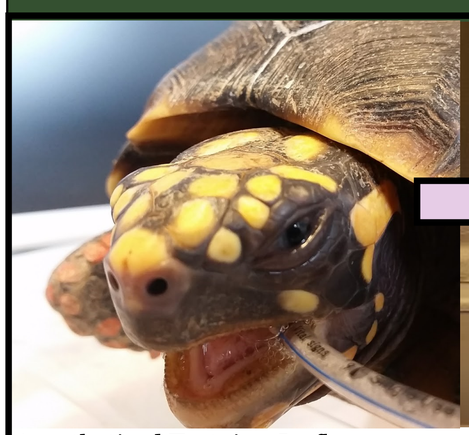
Future perspectives: Use ventricular mass, images and stroke volume to estimate ejection fraction.



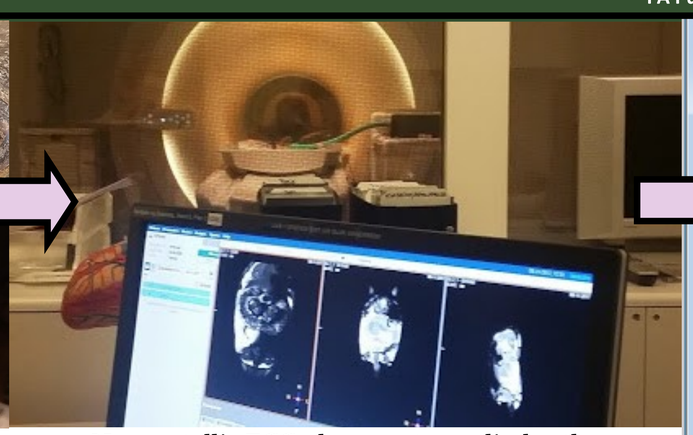
R Ao Right Aorta
L Ao Left Aorta
PA Pulmonary artery
R At Right Atrium
L At Left Atrium
Ventricle = CA, CV + CP



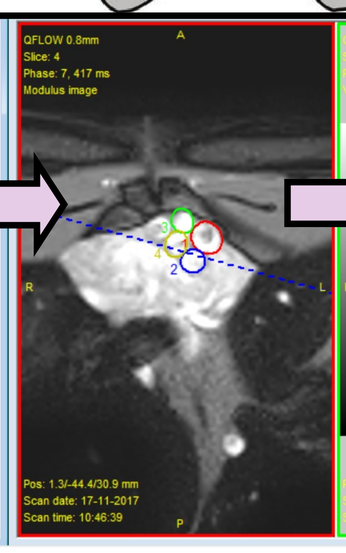
REF2.

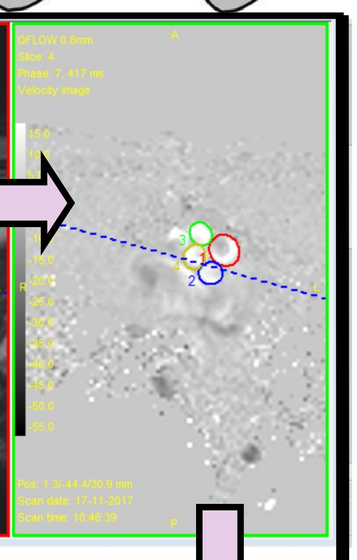


Anesthetised Tortoise: Isoflurane induction, intubation + lidocaine on glottis, mechanical ventilation Isoflurane 5% in oxygen)



Non metallic ECG placement on 4 limbs, thermostatic control 1.5T clinical MRI scanner. Balanced Steady-State-Free-Precession sequence

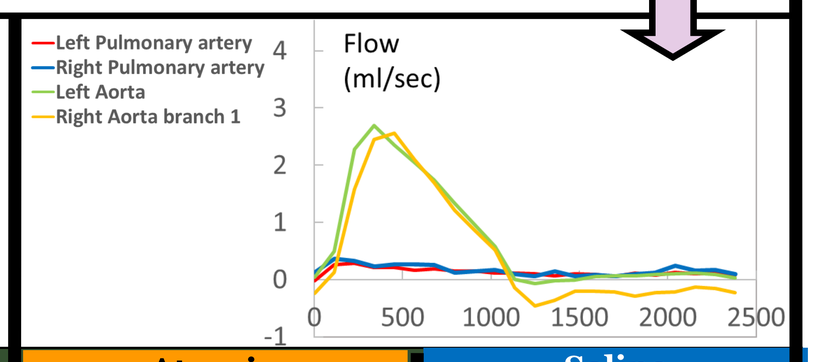




Blood flow quantification in reptiles currently uses surgical placement of probes.[1,3]

Aim 2: Quantify flow in outflow tract to demonstrate shunting without surgery.

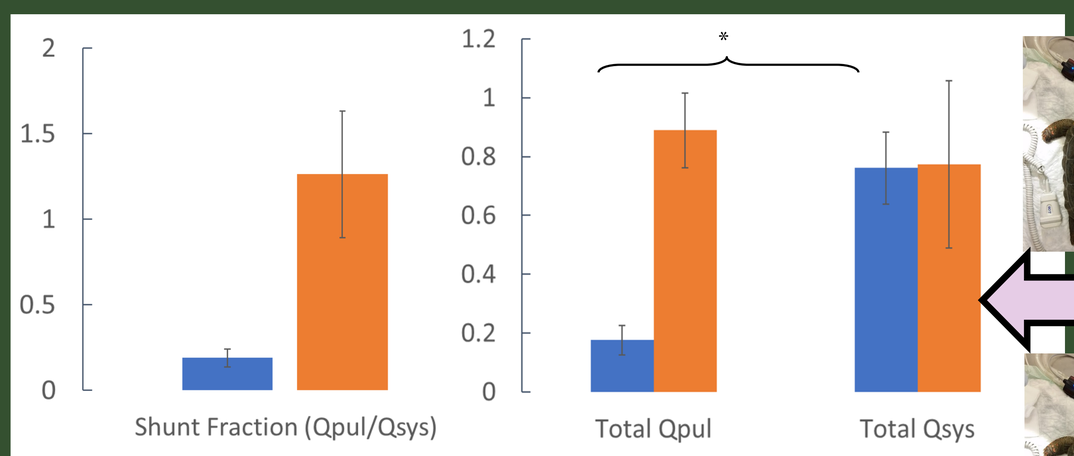
Method: Repeatably define a cross section of the outflow tract, identify vessels and gather flow data across heart cycle.



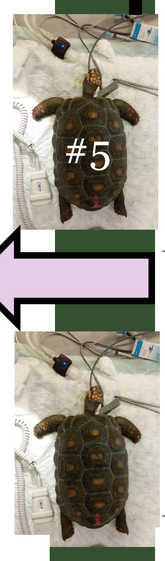
Aim 3: Manipulate flow

Method: Randomised cross over design n=5
Atropine (1mg/kg) vs saline
Flow calculation:
2 blinded observers,
Interobserver variability 6%

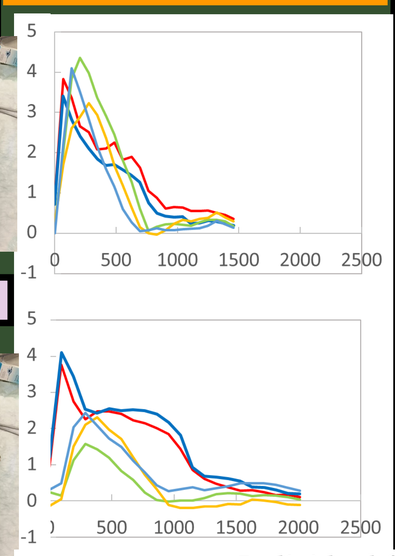
Results: Atropine reversed shunt direction (Q_{pul}/Q_{sys}) significantly increasing pulmonary flow (Q_{pul}).



Mean ±std values



Atropine | **Saline**

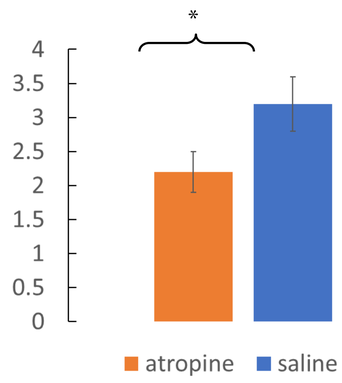


Individual flow profiles

Experimental impact: Atropine administration significantly reduced the level of inhaled anaesthetic required to maintain anaesthesia in the face of nociception.

Minimum anaesthetic concentration required of Isoflurane (mean ± std)

Paired cross over randomised study



Work carried out under Danish Experimental Animal Inspectorate (permit # 2015-15-0201-00684)

The authors wish to thank Heidi Meldgaard Jensen and Claus Wandborg for animal care.
Funding is gratefully acknowledged by Catherine Williams from,
AARHUS UNIVERSITET COPENHAGEN novo nordisk fonden
and Eve Greunz is supported by a grant from Annie and Ottos Johs. Detlefs' Foundation.

1. Crossley, D., Altimiras, J. & Wang, T. Hypoxia elicits an increase in pulmonary vasculature resistance in anaesthetised turtles (Trachemys scripta). J. Exp. Biol. 201, 3367–3375 (1998).
2. Jensen, B., Moorman, A. F. M. & Wang, T. Structure and function of the hearts of lizards and snakes. Biol. Rev. Camb. Philos. Soc. 89, 302–36 (2014).
3. Joyce, W., Williams, C. J. A., Crossley, D. A. & Wang, T. Venous pressures and cardiac filling in turtles during apnoea and intermittent ventilation. J. Comp. Physiol. B . 188, 1–10 (2017).