



# Investigating physiology and pathology in the (very large!) equine heart

Prof John A Keen

## Juggling the day job with special clinical and research interests!

progress.









### **The Athletic Heart**

#### • Horse is bred for performance

- Selective adaptation > speed and stamina
- Physiological adaptations

#### • Efficient cardiovascular system is paramount

- Major determinant of VO<sub>2</sub> max
- Equine: > 200ml  $O_2$  per kg per minute (100 l/minute)

#### • Heart has evolved at expense of other systems?

selected for horses with good CVS





### **The Athletic Heart**

- Structural, electrical and functional modelling that accompanies exercise training
  - Cardiac enlargement and bradycardia
- Positive Impact: on performance
  - Conductive oxygen delivery (CO = HR x SV)
  - Max HR 'immovable'
  - stroke volume: increases with training
    - Cardiac capacity vs cardiac function
    - Intimately related





### **Clinical Consequences of the Athletic Heart**

- Prodigious blood flow>> high lung blood pressures
   >>>>EIPH!
- Development of valve regurgitation
  - >>largely inconsequential
- Development of arrhythmias

   >>>POOR PERFORMANCE
   >>>>SUDDEN DEATH



From: Cardiovascular Physiology Concepts, Klabunde







### **Racing and The Equine Athlete**





Royal (Dick) School of Veterinary Studies

### Equine Athletic (TB) Heart: Aim

- to maximise our understanding of the structure and function of the equine athletic heart, in health and disease
- Our ongoing hypotheses:
  - The TB heart adapts in response to exercise and training with changes in heart muscle deformation and ventricular volume
  - These changes may increase the risk of cardiac related disease
    - Sudden Cardiac Death
    - Atrial Fibrillation
    - Exercise Induced Pulmonary Haemorrhage
  - What tools can we use?







### The future of equine imaging?...I wish ;) !







## Echocardiography in the horse: basic cardiac structure...2DE vs 3DE









# Some work we have done: 3DE assessment of LV, RV and LA volumes...

- Using software tools available for assessing volumes
- Assumptions of the algorithms?
- Can we believe the software?
- · Lack of a 'gold standard'

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FEASIBILITY AND REPEATAB	BILITY OF THREE-DIMEN	SIONAL Deal Time 2 D Echecordia graph	w a naval mathed of	
ECHOCARDIOGRAPHIC ANALYSIS OF EQUINE LEFT		EFT Real-Time 3-D Echocardiograph	Real-Time 3-D Echocardiography - a novel method of	
VENTRICULAR VOLUME		Right Ventricular Volume Quant	Right Ventricular Volume Quantification in the Horse	
R. C. Jago <sup>1</sup> , J. C. Reed <sup>1</sup> , K. Blissitt <sup>1</sup> , L. Young <sup>2</sup> , R. Shave <sup>3</sup> and J. A. Keen <sup>1</sup>		J.C. Reed <sup>1</sup> , R.C. Jago <sup>1</sup> , K. Blissitt <sup>1</sup> , L.E. You	J.C. Reed <sup>1</sup> , R.C. Jago <sup>1</sup> , K. Blissitt <sup>1</sup> , L.E. Young <sup>2</sup> , R. Shave <sup>3+4</sup> , J. Keen <sup>1</sup>	
1. The Royal (Dick) School of Veterhary Studies and Roslin Institute, The University of Edinburgh, UK 2. Specialist Exulte Cardioloxy Sensions. UK		<sup>1</sup> Royal (Dick) School of Veterinary Studies & The Roylin Institute, University of Edini	<sup>1</sup> Royal (Dick) School of Veterinary Studies & The Roslin Institute, University of Edinburgh, <sup>2</sup> Specialist Equine Cardiology Services, Moulton,	
3. University of British Columbia, Okanagan, Carlada Introduction	Results	Suffolk, <sup>3</sup> Cardiff Metropolitan University, Cardiff, <sup>4</sup> University of	British Colombia, Kelowna, Canada	
Left ventricular (LV) stroke volume in equine echocardiography is currently estimated using various 2D or Doppler methods. Three-dimensional echocardiography (3DE) volume analysis detects	Comparison of volumes	INTRODUCTION	WHAT IS REAL-TIME 3D ECHOCARDIOGRAPHY?	
endocardial borden in a pyramidal volume of data which can be maniputated and interrogated from any social joins of view and would provide volume measurements independent of geometric assumptions and plane positioning errors.	Three-dimensional derived volumes differed statistically significantly from     Stroke Volume (ml) EDV (ml)	Al other methods     Algo ventricular volame quantification is difficult in the torse due to the ellipsoid geometry of the ventricular volame quantification is the discussion of the discu	RT-30 echocardiography collects a pyramidal data-set Single beat recording acquires a full volume data-set with each consecutive cardiac cycle while multi-beat acquisition	
Objectives	3D 1119 (nz) 1587 (na) SMOD 665 (ca) 1082 (na) 1 719 cm 11082 (na)	460 cm The airs of this study were: 1. To investigate the famility & repeatability of four RT-3D methods of values quantification 200 cm 201 cm	collects a partial volume data-set with each cardiac cycle Stabiling with instances with multi-beat acquisition bat benefits are improved spacial and temporal resolution	
Assess the feasibility and repeatability of the equine LV volume using 3DE     Compare the stroke volume (SV), and disatcle volume (EDV) and and systolic volume (EDV)	Doppler 1272 (H) n/a Table 1. Mean and 60 (In brackets) for each metho	to compare in Los-visione entrees any russes more ungener entrees source dollares		
magnitude and repeatability of 20E to analysis by Simpson method of discs (SMCD), area length (AL) and Doppler methods	10 vs 1M00 20 1	METHODS .		
Methods Two echocardographic examinations were repeated within the same day on 18 National Hunt	800 000 000 000 000 000 000 000 000 000	KT-3D recordings from right & left parasternal views     Single-bear and malto-bear acquisition with 2 bears	Measurements were performed     using a commercially swilable	
Thoroughbred racehorses in training (6.9 +i- 1.9 years, 624 +i-39 kg, 1 mare and 17 geldings) Acquisition		Pulsed www Dopper and 20 recordings of the painmary artery for Valuely Time Integral (VIT) bard of the values exclusion	Integration     Integration	
30 datasets from the right parasternal long axis views of the LV (Fig. 1) were acquired in single and multi-beat acquisitions using a 30		Cardina da evaluada from lett weencuar tearman     diameters     weence	2. Marters were placed at the tricaspid value annulus and right ventricular ware	
vourie phased array mank transducer			3. Automatic measurements were recorded following identification of endocentrial bonders	
2D right parasternal long axis views of the aorta (Fig. 2) an	Received: 23 June 2020 Accepted: 3 December 2020		4. Massai measurements were recorded following visual correction of endocential	
parasternal five-chambered long axis views were accured for I dameter and pulsed wave Doppler of the LV outflow tract (LVOT) 3), respectively	DOI: 10.1111/eyi,13408 bokan			
Poure 2	GENERAL ARTICLE	Equine Veterinary WILEY	were bilinded to echocardiographer, horse and previous results The widthe-subject writance.	
Measurement		• 0	determined by a 1-Way ANOVA, was used to quantify text reliability	
estimate the EV SV - art x LVOT velocity time integral				
Figure 4. Using the same cardiac cycles as the 3DE, volumes	Real-time three-dimensional echocardiography for left			
calculated from the right parasternal long axis of the UV using th area length (AL) and single plane Simpson method of discs (SMOC	atrial volume assessment in Thoroughbred racehorses:			
			FMBM 12 253.04 225.71 0.001 FMBA 12 672.79 198.03 -6.000 LABM 12 309.09 157.79 -6.001	
	Observer variability and comparison with two-dimensional		A LABEA 12 442 122 315 8 1 0 001 LABEA 12 1232 411.64 0.001	
using 20 LV volume quantification software	echocardiography		F Noters (m) LBB: 1.07 Tight for Animality, UBB: 1.07 Tight for Noters F Noter (m) LBB: 1.07 Multi for Animality, UBB: 1.07 Multi for Animality, UBB: 1.07 Multi for Noters	
and the second			N	
The mean of three non-consecutive castilac cycles were calculated for each method     Intra-observer measurement variability was determined by repeated of-line measurement	Francesca C E Worsman <sup>1</sup>	│ Zack I Miller <sup>2</sup> │ Darren I Shaw <sup>1</sup>	chocardiography is a feasible method of right ventricular volume	
one examination on two different days <ul> <li>Acquisition variability was determined by comparison of repeated acquisitions</li> </ul>	John A Keen <sup>1</sup>		D methods underestinate stroke volume when compared to the dated Doppler method, reliability is as important is cross- segitudinal studies and the low within-day and between day	
• BBSRC FRRC			se L-RV method supports the use of this method to evaluate uses longitudinally	
	<sup>1</sup> The Royal (Dick) School of Veterinary		r-onserver measurement variability should be further investigated by told varied here to the billion that you is table for an effective start period	
	Studies, University of Edinburgh, Roslin,	Abstract	The sets of size Projectory, of Buddews	
	Midlothian, UK <sup>2</sup> Companion Care Vets Gloucester	Background: Left atrial size predicts cardiac morbidity and mortality in humans and	unon	
	Gloucester, Gloucestershire, UK	dogs. Real-time three-dimensional echocardiography (3DE) may be reliable for as-		
	Correspondence	Objectives: To determine intra- and interobserver variability estimates of 2DE-LAV		
	F. C. F. Worsman, The Royal (Dick) School of Veterinary Studies, University of Edinburgh.	and compare it to that of 2DE-LAV estimates.		
	Roslin, Midlothian, UK.	Study design: Method comparison.		
	Criment and SmanligeAseed.ed.ac.uk	Methods: 3DE datasets were obtained from 40 horses, then graded for quality, cre-		
	Funding The primary author's residency and the	ating a final study population of 22 horses. The 3DE and 2DE maximum LAV (LAV $_{\rm max})$		
	study funded by the Horserace Betting Levy Board.	and minimum LAV (LAV $_{\rm min}$ ) were measured, and left atrial emptying volume (LA EV)		
		and left atrial ejection fraction (LA EF) were calculated, from the same 3D dataset		
		a modified Simpson's method of discs. 3DE LAV measurements were repeated by a		
		a method of about oblight method while repeated by a		



### **Echocardiography: assessing cardiac function**

- Subjective assessment
- Using altered chamber dimensions
- Using haemodynamics/ blood flow (PW Doppler)
- STRAIN: Using tissue motion/deformation
  - Tissue Doppler Imaging (TDI)
  - Speckle Tracking Echocardiography (STE)





## Work assessing function of the Thoroughbred left ventricle: rotation and twist







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# **Composite graph: function of the Thoroughbred left ventricle**









# Assessing function using speckle tracking in the equine left atrium: do the software assumptions hold true?











# A deeper dive into the fibre structure of the Equine Athletic Heart?

- Myocardial fibre pattern underpins electrical and mechanical function
- Fibre disarray associated with cardiac disease
  - e.g. atrial fibrillation
  - ventricular arrhythmias
- Can we use advanced imaging tools to evaluate the equine myocardium?





Pashakhanloo et al 2016



### Ex vivo imaging of the equine heart

- MSc project: left atrium
  - Iodine contrast CT @ Preclinical imaging Adriana Tavares
  - DT-MRI @ EI/QMRI Lucy Kershaw
- Re-developing atrial and ventricular MRI protocol/sequences
  - Lucy Kershaw
  - Collaboration: Liryc, Bordeaux
- Develop alongside electrophysiology studies







THE UNIVERSITY of EDINBURGH The Royal (Dick) School of Veterinary Studies

> Professor John Keen Dick Vet Equine Hospital R(D)SVS University of Edinburgh john.keen@ed.ac.uk



