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● *Original Contribution*

TRANSESOPHAGEAL ECHOCARDIOGRAPHY IN SWINE: ESTABLISHMENT OF A BASELINE

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Abstract—The porcine model is a commonly used animal model in cardiovascular research. Along with new innovative operative techniques, choice of the optimal imaging technique is crucial. Transesophageal echocardiography (TEE) is a reliable imaging tool is highly important in a large number of experimental evaluations. But so far, TEE data for swine are limited, and few standard values have been established for the porcine model. The experience and baseline results for TEE in 45 swine are presented in this study. A full TEE examination was conducted in 45 German landrace or German large white swine, with an average body weight of 49 ± 3 kg, before experimental off-pump mitral valved stent implantation. Additionally hemodynamic measurements were evaluated. The valve implantation procedure was guided solely by real-time 3-D TEE. Baseline values of standard echocardiographic parameters are provided and, where appropriate, compared with human reference values. TEE proved to be an adequate imaging technique in this experimental porcine animal model. The baseline TEE and hemodynamic parameters established for the widely used porcine model can serve as a reference in future studies. (E-mail: Katharina.Huenges@uksh.de) © **2016 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Transesophageal echocardiography, Porcine model, Mitral valve.**

INTRODUCTION

The encouraging results obtained with transcatheter aortic valve implantation (TAVI) procedures have spurred increasing interest in novel transcatheter therapies for the treatment of other valvular heart diseases in the beating heart. Current research is focused on new therapeutic options for the treatment of insufficient mitral valves.

Choosing the appropriate imaging technique is an important issue with great influence on the feasibility and outcome of such procedures, even during experimental studies. Real-time 3-D transesophageal echocardiography (RT-3-D-TEE) has been used to guide different minimally invasive cardiac interventions with promising results, and as a diagnostic method for various cardiac pathologic morphologies (Becerra et al. 2009; Nunez-Gil et al. 2011; Uno et al. 2009). Two-dimensional transesophageal echocardiography (2-D-TEE) has become very important in routine diagnosis, and RT-3-D-TEE is widely used in functional evaluation.

Because of the similarities of the human and the porcine cardiovascular systems, the porcine model is frequently chosen for experimental cardiovascular research (Abduch et al. 2014; Ren et al. 1997; Sundermann et al. 2016). Notably, the anatomy of the mitral valve is comparable in humans and swine (van Rijk-Zwikker et al. 1994). However, to date, published data on echocardiographic parameters in swine are very limited.

Transthoracic echocardiography (TTE) in swine can be challenging because of the keel-shaped thorax and is not applicable in certain minimally invasive surgical interventions where the heart is exposed. In such procedures, TEE is the method of choice and provides better-quality images of the cardiac structures.

Our experience with echocardiography and hemodynamics in swine is described here. The aim of this study was to establish a large set of baseline values for cardiac TEE and hemodynamic parameters of swine with an average weight of 50 kg.

METHODS

The main focus of this study was the establishment of baseline cardiac TEE parameters of the experimental

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porcine model. These were determined before implantation of a nitinol mitral valved stent, in a catheter-based off-pump procedure in our well-established porcine model (Attmann et al. 2011; Lozonschi et al. 2008; Lutter et al. 2009, 2010).

Forty-five German Landrace or German large white pigs, or crossbreds thereof, weighing an average of 49.16 ± 2.82 kg (range: 46–57.5 kg, females: n = 43, and males: n = 2), were evaluated. All animals received humane care, as approved by the Center for Experimental Animal Research at the University of Kiel, Kiel, Germany, in compliance with the *Guide for the Care and Use of Laboratory Animals* prepared by the Institute of Laboratory Animal Resources, National Research Council, and published by the National Academy Press, revised in 2011.

Evaluation procedure

Swine were placed in dorsal recumbence with the limbs fixed. General total intravenous anesthesia (propofol, B. Braun, Melsungen, Germany; and fentanyl, Janssen-Cilag, Neuss, Germany) and continuous five-lead electrocardiogram (ECG) monitoring (original Datex Ohmeda, now GE-Healthcare, Chalfont, St. Giles, England), as well as invasive pressure measurements for hemodynamic evaluation, were conducted, as previously described (Pokorny et al. 2014).

A full TEE examination according to an institutional protocol was conducted before the lower mini-sternotomy, which affords the best access to the apex of the heart in the porcine model. The focus of the assessment was global heart function, valve performance and detection of possible valvular regurgitation.

Echocardiography

Echocardiographic evaluation was carried out using multiplane 3-D TEE device (Philips iE33 xMatrix in combination with the Phillips RT-3-D TEE-probe X7-2 t, Philips Healthcare, Bothell, WA, USA) (Fig. 1). A self-made teething ring was used for TEE probe protection. Best imaging of the native mitral valve was achieved at the mid-esophageal probe position and a beam rotation of 40°–80° with slight acclination in live 3-D-mode. The tricuspid valve was best imaged at 106°–115° with slight acclination and a clockwise rotation of approximately 30°. A four-chamber view (4CV) was obtained in midesophageal position at 0°–10° in the RT 3-D probe by slightly rotating clockwise. TEE standard views in human clinical practice and the experimental porcine study are compared in Table 1.

Echocardiography conditions in the porcine model were evaluated and graded before and immediately after mitral valve stent implantation as follows:

- Excellent: All structures are visualized with clear contours and can be easily identified.
- Good: Structures are mostly of good contrast (distinct) and can be identified.
- Sufficient: Main structures can be visualized and evaluated.
- Poor: Visualization of structures is possible to only a limited degree. Evaluation of parameters is limited.
- Not Possible: Visualization of structures is not possible even in different views, and evaluation or guidance cannot be conducted.

Heart function

Heart function—systolic and global ventricular function—was assessed as follows.

Systolic left ventricular function. The left ventricular ejection fraction (LVEF) was determined by different methods, and the results were compared: LVEF was measured in the 2 2CV by Simpson's rule. It was then defined by using the 3CV for measuring end-diastolic (EDV) and end-systolic (ESV) volumes. Whenever possible, LVEF was determined in both views. In humans, an LVEF ≥55% is considered in the physiologic

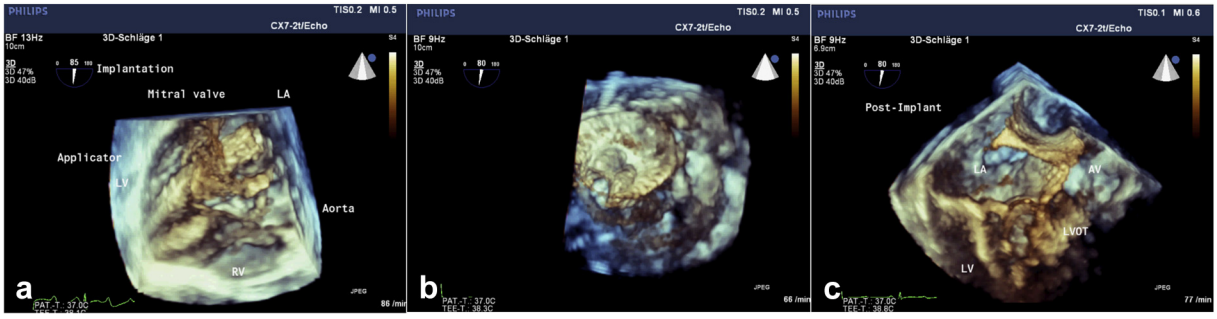

Fig. 1. Three-dimensional transesophageal echocardiography images revealing the guidance during mitral valved stent implantation (a) Applicator in the left ventricle (LV) and left atrium (LA) before stent deployment. (b) Atrial view of the deployed mitral valved stent. (c) Lateral view of the mitral valved stent.