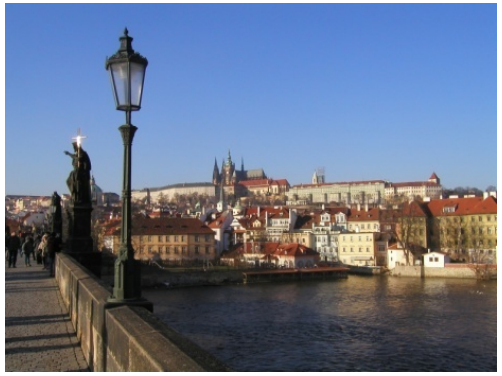
Pedirhythm VII, Thessaloniki, Greece, 2017
PANEL: DEVICE I. Unique Aspects of Device Implantation in Children

Epicardial pacing – Can we avoid thoracotomy/sternotomy?

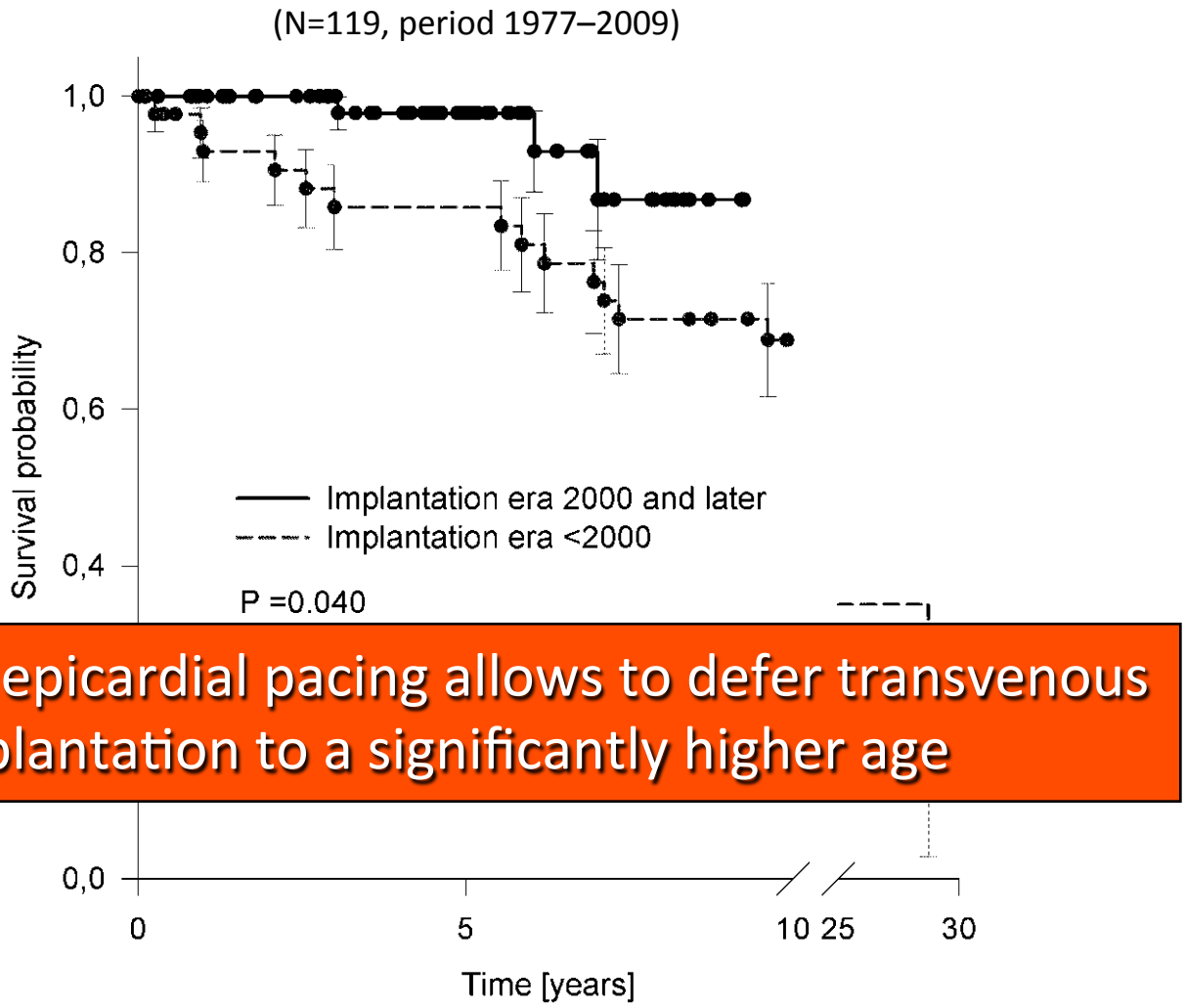
J. Janoušek

Children's Heart Center
University Hospital Motol
Prague, Czech Republic



Kardiocentrum

Epicardial pacing survival according to implantation era



Initial epicardial pacing allows to defer transvenous implantation to a significantly higher age

Kubuš P et al. Europace 2011

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION
American Heart Association
Circulation 2013;127:613-623

Permanent Cardiac Pacing in Children - Choosing the Optimal Pacing Site: A Multi-Center Study

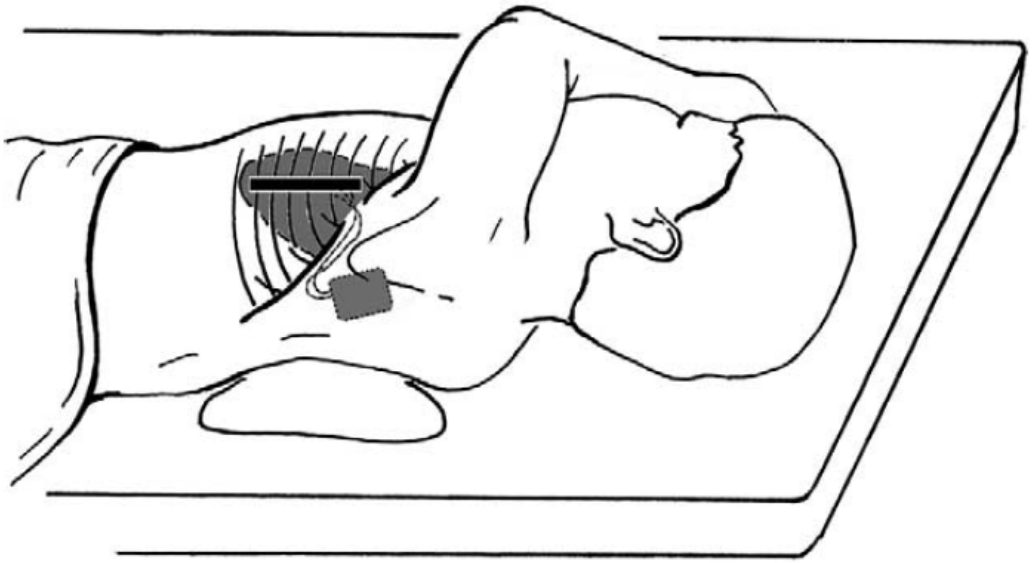
Factors associated with preservation of LV function (LV EF ≥55 %)

Variable in model	LV EF ≥55 %	LV EF <55 %	p-value	Odds ratio (95% CI)
Male gender	36·1 %	54·1 %	0·086	0·45 (0·18-1·12)
Congenital AV block	73·6 %	80·5 %	0·972	0·98 (0·29-3·35)
Maternal autoantibodies	41·1 %	49·3 %	0·103	0·37 (0·11-1·23)
Age at implantation [years]	4·24 (4·46)	4·69 (4·83)	0·323	0·94 (0·82-1·07)
LVA and LVLat pacing	**29·2 %**	**4·7 %**	**0·018**	**8·26 (1·46-47·62)**
DDD pacing	45·8 %	50·6 %	0·455	1·50 (0·52-4·33)
Pacing duration [years]	5·88 (3·78)	6·64 (4·30)	0·425	0·95 (0·84-1·08)
QRS duration [ms]	149 (22)	158 (23)	0·593	0·99 (0·97-1·02)

Left heart atrial and ventricular epicardial pacing through a left lateral thoracotomy in children: a safe approach with excellent functional and cosmetic results

Ali Dodge-Khatami, Alexander Kadner, Hitendu Dave, Mariette Rahn, René Prêtre and Urs Bauersfeld

Eur J Cardiothorac Surg 2005;28:541-545



Minimal invasive ASD surgery

What do we have right now?

- Current thoracoscopic techniques
  - Invented mainly
    - For epicardial left ventricular CRT leads
    - For epicardial ICD leads in children
  - Clinical experience – adults
  - Animal studies mimicking pediatric implantation

Human studies

Left ventricular apical pacing in children – feasibility and long-term effect on ventricular function

Kovanda J., Janousek J., Lozek M., Kubus P.

Accepted for AEPC 2017

- N=36 patients with CAVB
  - spontaneous (N=22)
  - surgical (N=14)
  - 18/22 spontaneous CAVB – subxiphoid approach
    - Weight median 10.4 (2.7 -34.0) kg

Video-Assisted Thoracoscopic Left Ventricular Pacing in Patients With and Without Previous Sternotomy

Ann Thorac Surg 2013

Katharine E. Nelson, MBBS, MRCP, Matthew G.D. Bates, MBChB, MRCP, Andrew J. Turley, MBChB, MRCP, Nicholas J. Linker, MD, FRCP, and W Andrew Owens, MD, FRCS (CTh)

Three ports were used.

The first was positioned in the midaxillary line, typically in the third of fourth intercostal space, for insertion of the thoracoscope, a second port was placed inferior to this, and a third port was placed anteriorly

A screw-in Myopore epicardial lead (Enpath Medical Inc, Minneapolis, MN), was placed into an unscarred area of myocardium as far posterior to the obtuse marginal arteries as possible. In the latter part of the series, the FasTac Flex device (Enpath Medical Inc) was available, and this facilitated more precise lead placement in patients with particularly dilated or displaced LVs.

Video-Assisted Thoracoscopic Left Ventricular Pacing in Patients With and Without Previous Sternotomy

Ann Thorac Surg 2013

Katharine E. Nelson, MBBS, MRCP, Matthew G.D. Bates, MBChB, MRCP, Andrew J. Turley, MBChB, MRCP, Nicholas J. Linker, MD, FRCP, and W Andrew Owens, MD, FRCS (CTh)

Variable[a]	Previous Sternotomy: Yes (n = 10)	Previous Sternotomy: No (n = 22)	*p* Value
Operative time, min	88 ± 20	68 ± 19	0.03
Open thoracotomy	1 (10)	0 (0)	0.31
Significant threshold rise[e]	4 (40)	8 (36)	>0.99
Intervention for rise[f]	0 (0)	1 (5)	>0.99
Lead disabled for threshold rise	1 (10)	1 (5)	0.53
Lead revision	0 (0)	1 (5)	>0.99

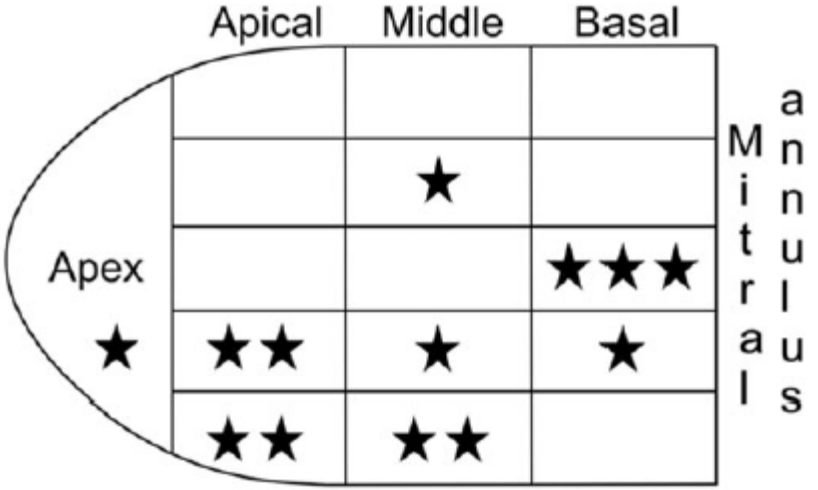
High-Density Epicardial Activation Mapping to Optimize the Site for Video-Thoracoscopic Left Ventricular Lead Implant

ROSTISLAV POLASEK, M.D.,* IVO SKALSKY, M.D.,† DAN WICHTERLE, M.D., PH.D.,† TOMAS MARTINCA, M.D.,† JANA HANULIAKOVA, M.D.,* TOMAS ROUBICEK, M.D., PH.D.,* JAN BAHNIK, M.SC.,* HELENA JANSOVA, M.SC.,† JAN PIRK, M.D., PH.D.,† and JOSEF KAUTZNER, M.D., PH.D.†

JACC 2014

A standard, 3-port thoracoscopic approach was used for LV free wall mapping, and subsequent LV lead implantation.

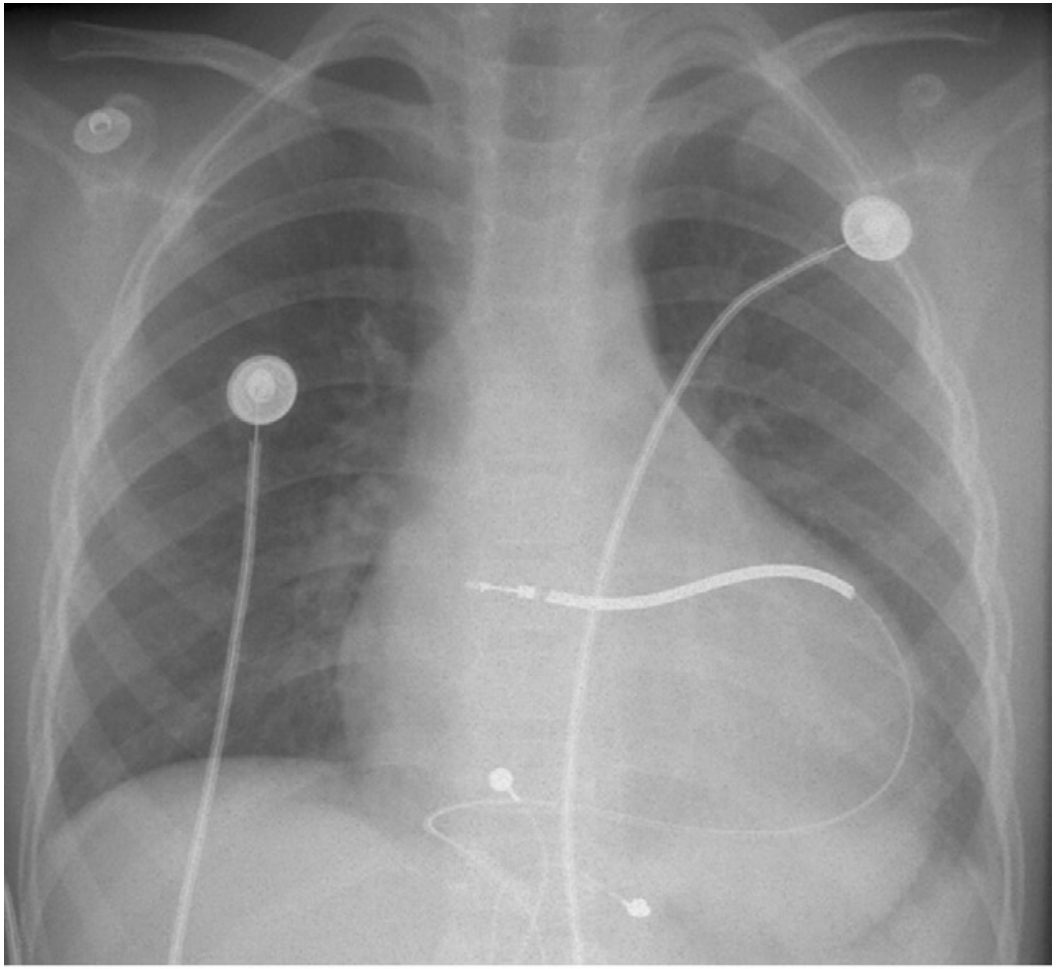
A bipolar, sutureless epicardial pacing lead (Myopore©, Greatbatch Medical, NY, USA) was implanted at the site with maximum QLV.



Novel Minimally Invasive, Intrapericardial Implantable Cardioverter Defibrillator Coil System: A Useful Approach to Arrhythmia Therapy in Children

Tain-Yen Hsia, MD, Scott M. Bradley, MD, Martin J. LaPage, MD, Sean Whelan, MD, J. Philip Saul, MD, Jeremy M. Ringewald, MD, and John H. Reed, MD

Ann Thorac Surg 2009;87:1234 –9



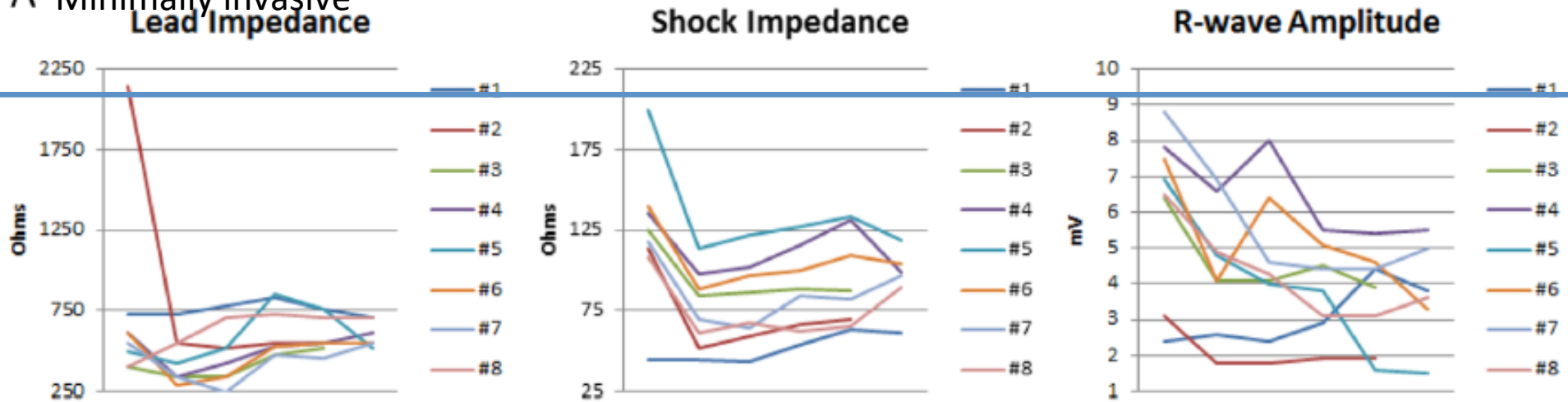
- N=7
- Median age 5 yrs
- Median weight 14 (8-46) kg
- Small subxiphoid incision

Animal studies

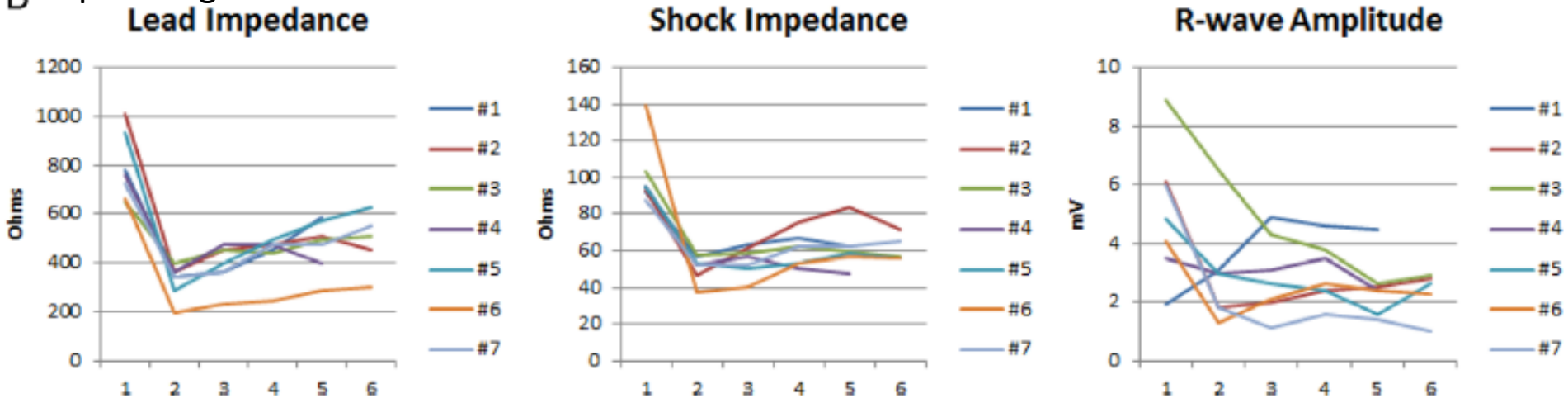
Minimally invasive percutaneous pericardial ICD placement in an infant piglet model: Head-to-head comparison with an open surgical thoracotomy approach

Bradley C. Clark, MD,[*†] Tanya D. Davis, MD,[‡] Magdy M El-Sayed Ahmed, MD, MSc,[§] Robert McCarter, ScD,[‖] Nobuyuki Ishibashi, MD,[§] Christopher P. Jordan, MD,[¶]

A Minimally invasive



B Open surgical



Minimally Invasive Resynchronization Pacemaker: A Pediatric Animal Model

Ann Thorac Surg 2013

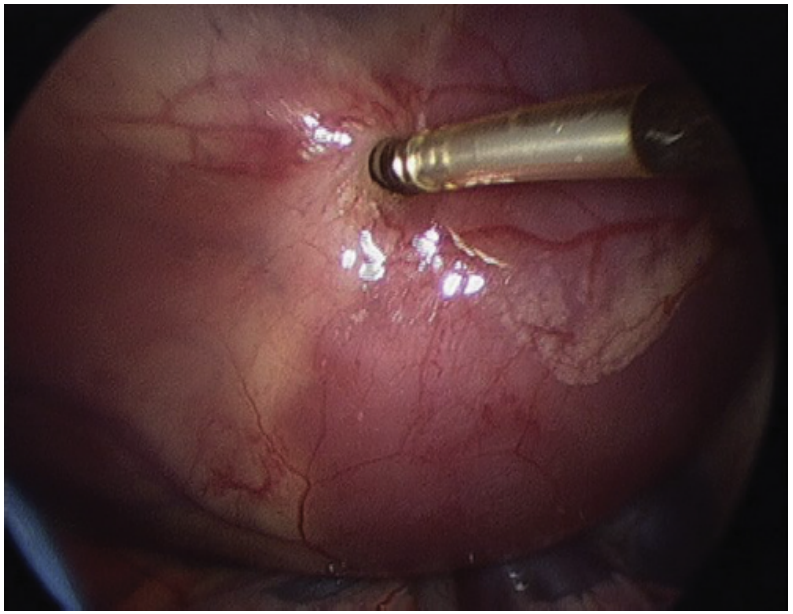
Christopher P. Jordan, MD, Kyle Wu, MD, MBA, John P. Costello, MD, Nobuyuki Ishibashi, MD, Axel Krieger, PhD, Timothy D. Kane, MD, Peter Kim, MD, PhD, and Charles I. Berul, MD

Children's National Medical Center, Washington, DC

5 piglets, weight 4-5 kg

The pericardial space was then accessed through a subxiphoid approach under direct thoracoscopic visualization by inserting a micropuncture pericardiocentesis needle (7 cm) into the pericardial space.

a guidewire was delivered followed by a microdilator, and an S4 sheath (40 cm, 8F) with dilator was then introduced over the wire. Landmark structures were visualized with the thoracoscope.



Medtronic 3830 SelectSecure is a thin bipolar, steroid-eluting, polyurethane-coated, lumenless screw-in active-fixation pacing lead typically utilized (and labeled) for transvenous pacing. The pacing lead was fixed to the LV epicardium and alternatively to the left atrial appendage

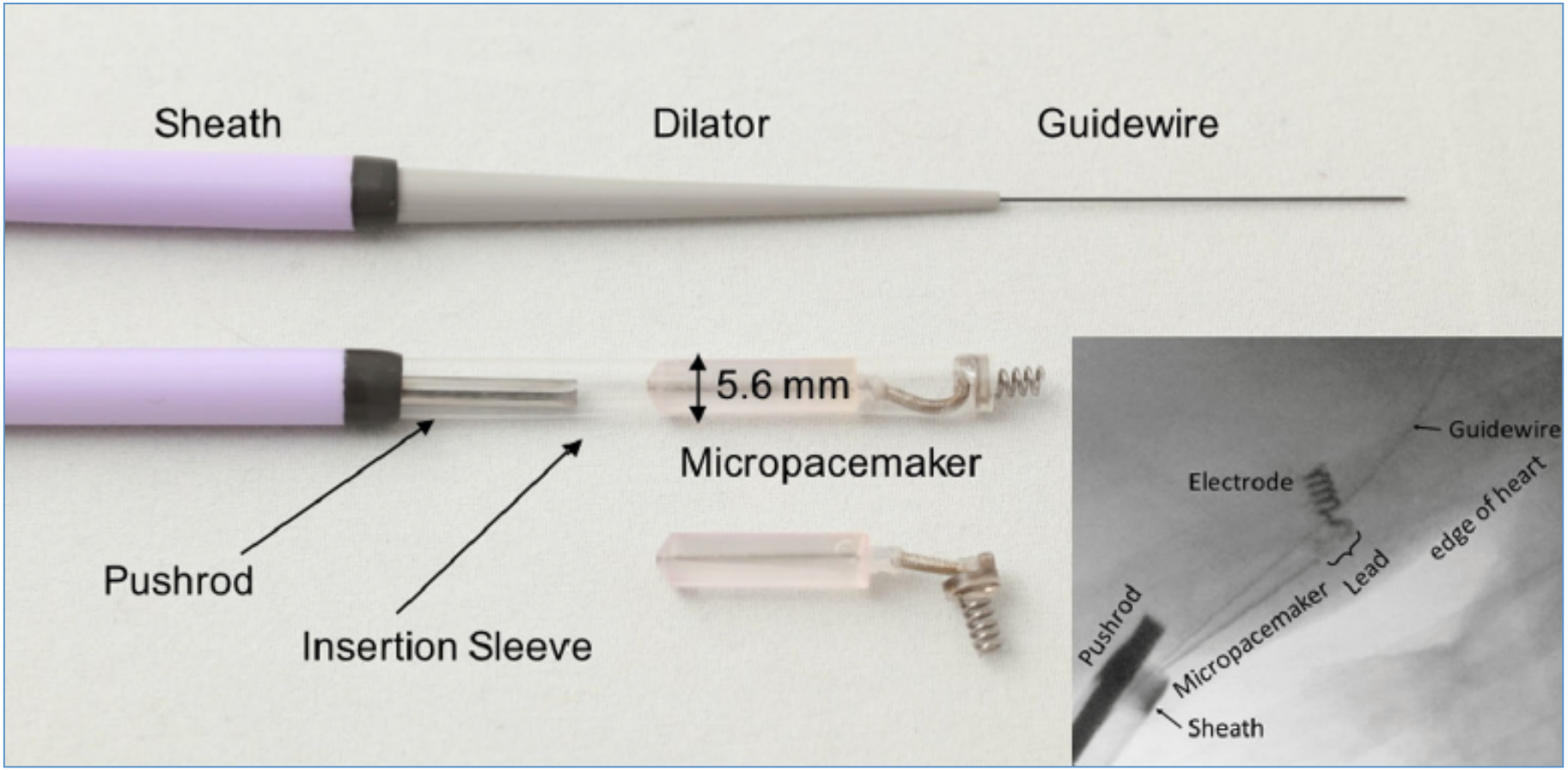
Where may be the (bright?) future?

- Leadless epicardial micropacemaker
- Optogenetic pacing
- Human biological pacemakers

Analytical Modeling for Computing Lead Stress in a Novel Epicardial Micropacemaker

Cardiovascular Engineering and Technology (2017)

Li Zhou,[1] Yaniv Bar-Cohen,[2] Raymond A. Peck,[1] Giorgio V. Chirikian,[1] Brett Harwin,[1] Ramen H. Chmait,[3] Jay D. Pruetz,[2,3] Michael J. Silka,[2] and Gerald E. Loeb[1]



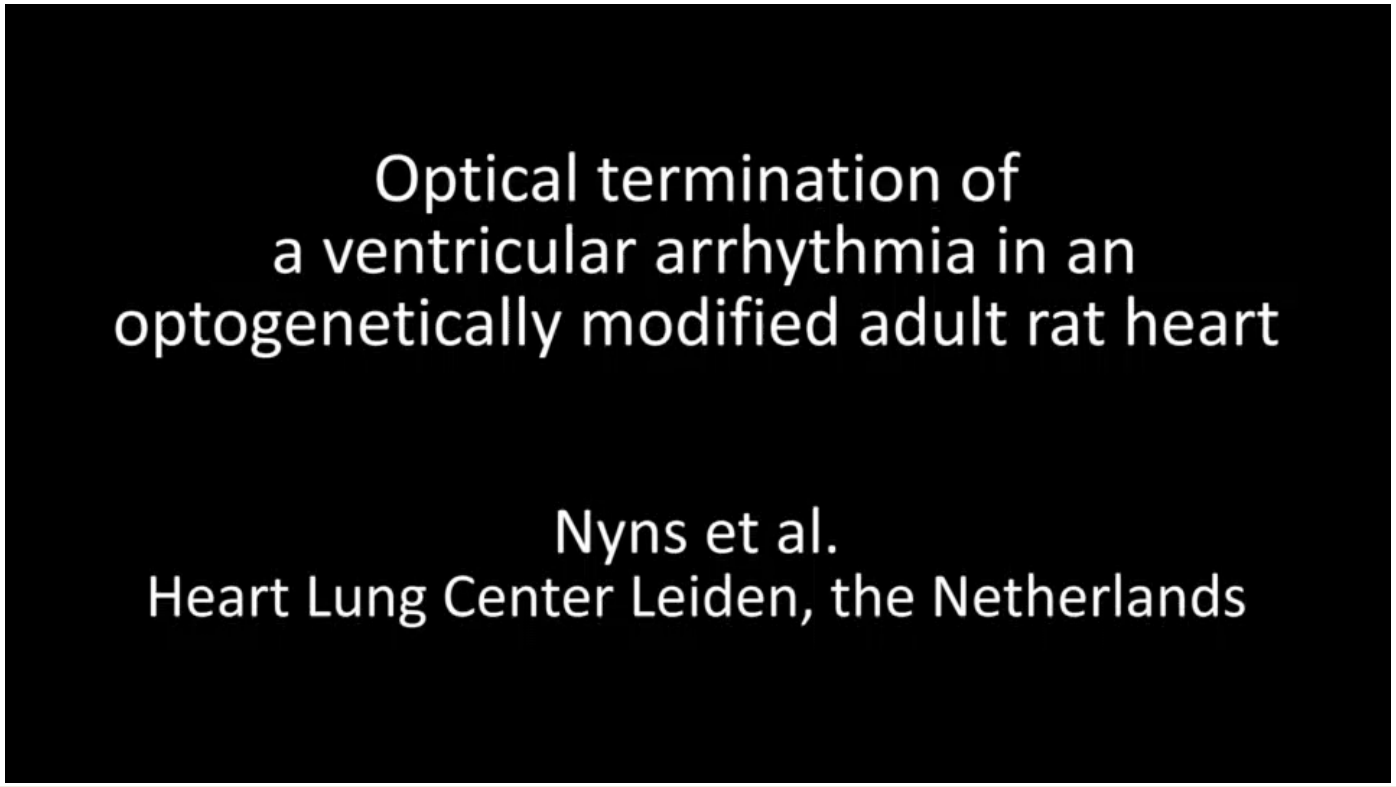
European Heart Journal Advance Access published December 23, 2016

European Heart Journal (2016) **00**, 1–5
doi:10.1093/eurheartj/ehw574

EHJ BRIEF COMMUNICATION
Arrhythmia/electrophysiology

Optogenetic termination of ventricular arrhythmias in the whole heart: towards biological cardiac rhythm management

Emile C.A. Nyns[1], Annemarie Kip[1], Cindy I. Bart[1], Jaap J. Plomp[2], Katja Zeppenfeld[1], Martin J. Schalij[1], Antoine A.F. de Vries[1†], and Daniël A. Pijnappels[1*†]



Systemic delivery of cardiotropic adeno-associated virus vectors, encoding the light-gated depolarizing ion channel red-activatable channelrhodopsin (ReaChR), resulted in global cardiomyocyte-restricted transgene expression in adult Wistar rat hearts allowing ReaChR-mediated depolarization and pacing.

Circulation

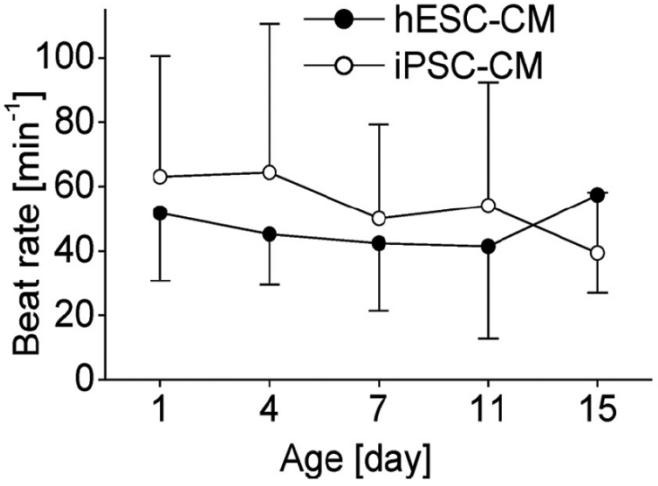
American Heart Association®

hESC-CMs iPSC-CMs 2012

Human Embryonic and Induced Pluripotent Stem Cell–Derived Cardiomyocytes Exhibit Beat Rate Variability and Power-Law Behavior

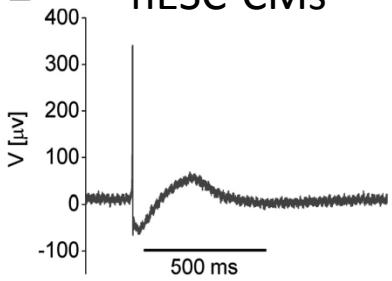
Yael Mandel, Amir Weissman, Revital Schick, Lili Barad, Atara Novak, Gideon Meiry, Stanislav Goldberg, Avraham Lorber, Michael R. Rosen, Joseph Itskovitz-Eldor and Ofer Binah

G The mean beat rate

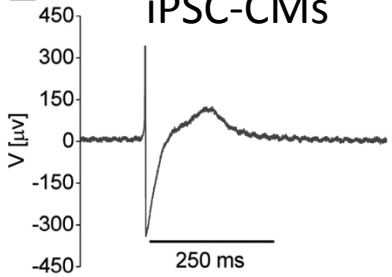


Activation spikes and repolarization waves

B hESC-CMs

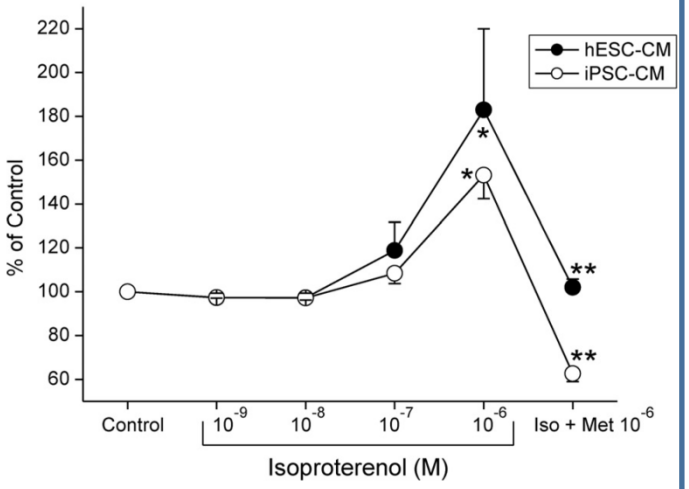


E iPSC-CMs



The chronotropic response

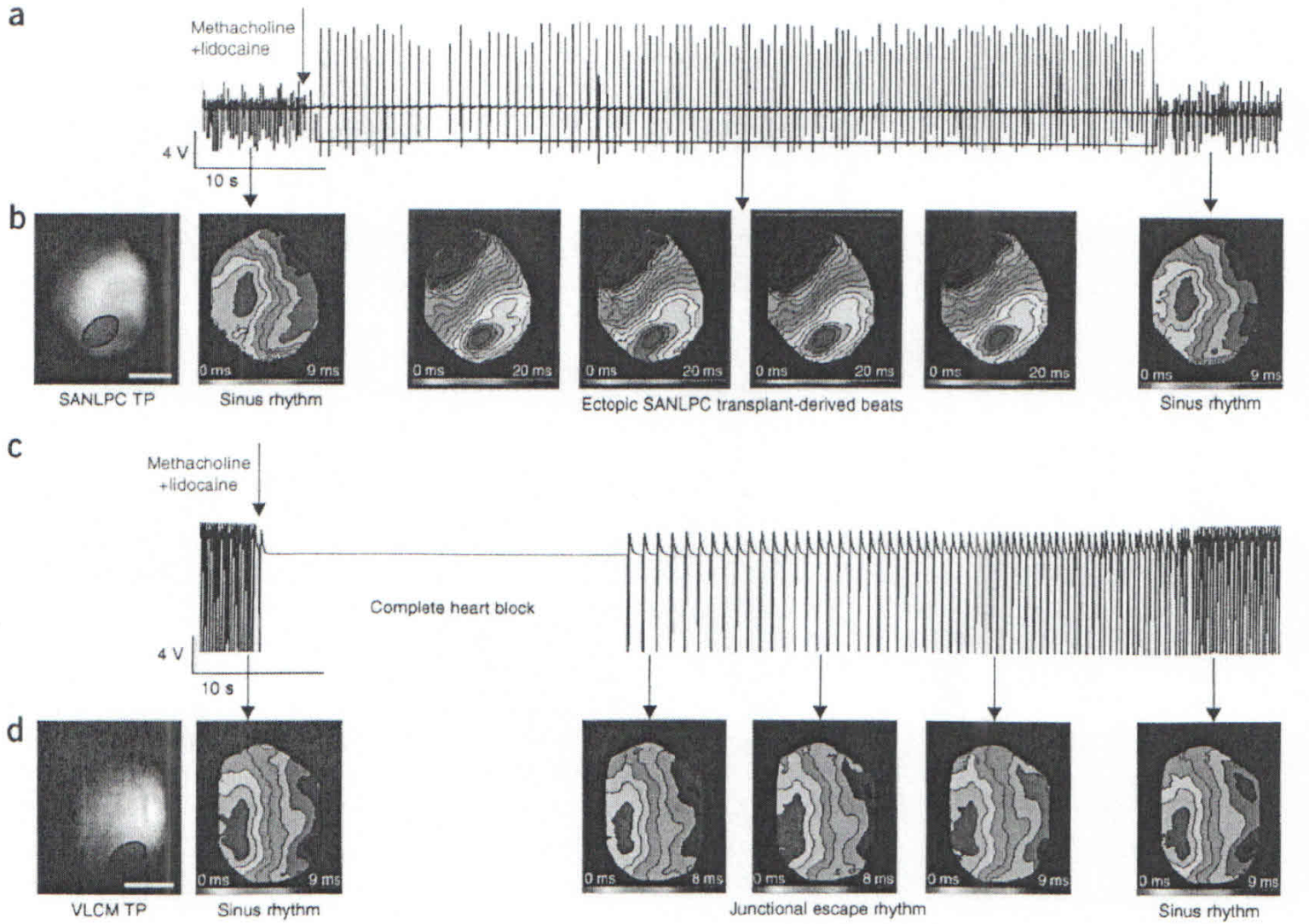
A Isoproterenol + Metoprolol



Sinoatrial node cardiomyocytes derived from human pluripotent cells function as a biological pacemaker

Nature Biotechnology 2017

Stephanie I Protze, Jie Liu, Udi Nussinovitch, Lily Ohana, Peter H Backx, Lior Gepstein & Gordon M Keller



Can we avoid thoracotomy/ sternotomy?

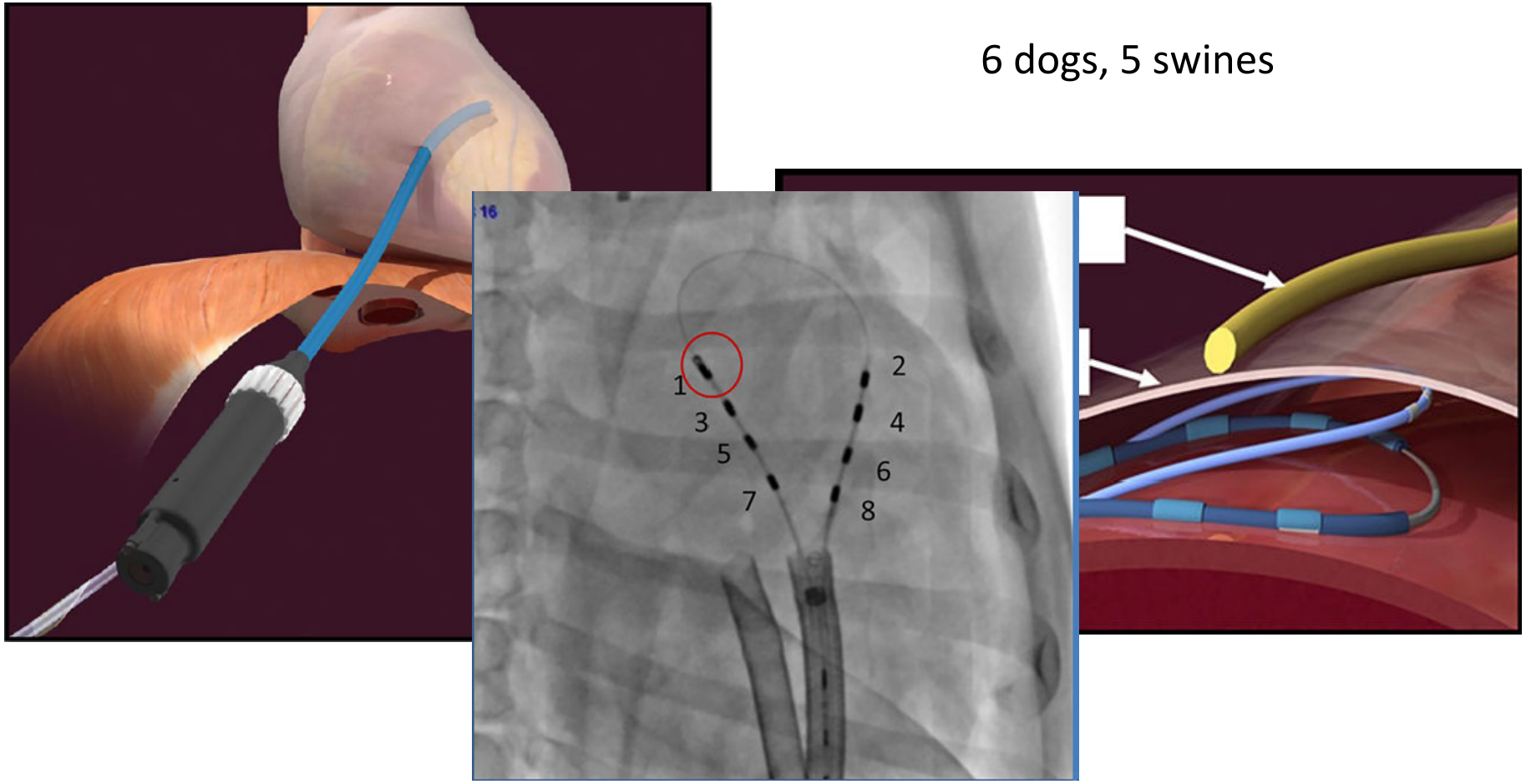
- Yes we can
  - Hardware not yet optimized
  - Suboptimal epicardial pacing leads for thoracoscopic implantation
- Future developments may completely change the way we are approaching cardiac pacing

Percutaneous Epicardial Pacing using a Novel Insulated Multi-electrode Lead

JACC – CE 2015

Faisal F. Syed, MBChB[1], Christopher V. DeSimone, MD, PhD[1], Elisa Ebrille, MD[1], Prakriti Gaba, BS[2], Dorothy J. Ladewig, BA[3], Susan B. Mikell, BA[3], Scott H. Suddendorf, RT[4], Emily J. Gilles, MS[3], Andrew J. Danielsen, MS[3], Markéta Lukášová, MSc[5], Jiří Wolf, MSc[5], Pavel Leinveber, MSc[5], Miroslav Novák, MD, PhD[5], Zdeněk Stárek, MD, PhD[5], Tomas Kara, MD, PhD[1,5], Charles J. Bruce, MD[1], Paul A. Friedman, MD[1], and Samuel J. Asirvatham, MD[1,6]

6 dogs, 5 swines



Human biological pacemakers

- Transfer of pacemaking genes to the heart
- Implantation of exogenous pacemaking cells
- Combination of gene and cell therapies
- Human induced pluripotent stem cell– derived cardiomyocytes
  - human somatic cells such as hair follicles or skin cells are reprogrammed to become pluripotent stem cells and are differentiated into cardiomyocytes
  - allows the creation of pacemaker cells from a patient's own tissue