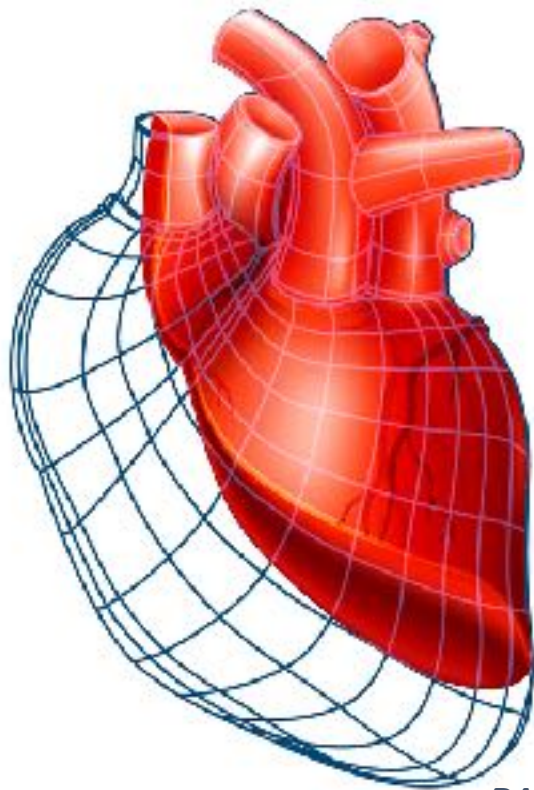




3D HEART MODELING

YOUR STRUCTURAL HEART 3DPRINTED SOLUTION

PAR CE QUE LA REUSSITE DES VOS PROCEDURES INTERVENTIONELLES NOUS IMPORTE



Translational medicine

Medical three-dimensional printing opens up new opportunities in cardiology and cardiac surgery

Thomas Bartel^{1*}, Andrew Rivard², Alejandro Jimenez¹, Carlos A. Mestres¹, and Silvana Müller³

improved visualization for procedural planning, but provides substantial information on the accuracy of surgical reconstruction and device implantations. Peri-procedural 3D printing has the potential to set standards of quality assurance and individualized healthcare in cardiovascu-

Advanced percutaneous and surgical procedures in structural and congenital heart disease require precise pre-procedural planning and continuous quality control. Although current imaging modalities and post-processing software assists with peri-procedural guidance, their capabilities for spatial conceptualization remain limited in two- and three-dimensional representations. In contrast, 3D printing offers not only improved visualization for procedural planning, but provides substantial information on the accuracy of surgical reconstruction and device implantations. Peri-procedural 3D printing has the potential to set standards of quality assurance and individualized healthcare in cardiovascular medicine and surgery. Nowadays, a variety of clinical applications are available showing how accurate 3D computer reformatting and physical 3D printouts of native anatomy, embedded pathology, and implants are and how they may assist in the development of innovative therapies. Accurate imaging of pathology including target region for intervention, its anatomic features and spatial relation to the surrounding structures is critical for selecting optimal approach and evaluation of procedural results. This review describes clinical applications of 3D printing, outlines current limitations, and highlights future implications for quality control, advanced medical education and training.

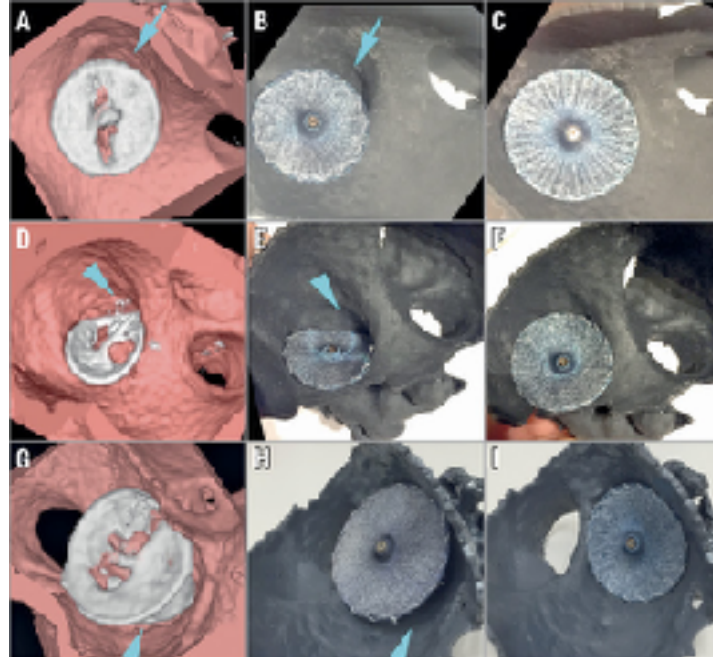
Keywords

3D printing • Structural heart disease • Congenital heart disease • Cardiac surgery • Interventional cardiology

PAR CE QUE LA REUSSITE DES VOS PROCEDURES INTERVENTIONELLES NOUS IMPORTE

WHO ARE WE?





CLINICAL RESEARCH
INTERVENTIONS FOR VALVULAR DISEASE AND HEART FAILURE

Stereolithography 3D Printer

Left atrial appendage occlusion simulation based on three-dimensional printing: new insights into outcome and technique



Vlad Ciobotaru^{1,4}, MD; Nicolas Combes², MD; Claire A Martin^{3,4}, MD, PhD; Eloi Marijon⁵, MD; Eric Maupas¹, MD; Augustin Bortone¹, MD; Eric Bruguère², MD; Jean-Benoît Thambot³, MD, PhD; Emmanuel Teiger⁶, MD, PhD; Pénélope Pujadas-Berthault¹, MD; Julien Ternacle⁶, MD; Xavier Iriart¹, MD

1. Hôpital Privé «Les Franciscaines», Nîmes, France; 2. Pediatric and Adult Congenital Heart Disease Department, Clinique Pasteur, Toulouse, France; 3. CHU Bordeaux, Bordeaux, France; 4. Papworth Hospital NHS Trust, Cambridge, United Kingdom; 5. Hôpital Georges Pompidou, IEGP, Paris, France; 6. CHU Henri Mondor, Créteil, France

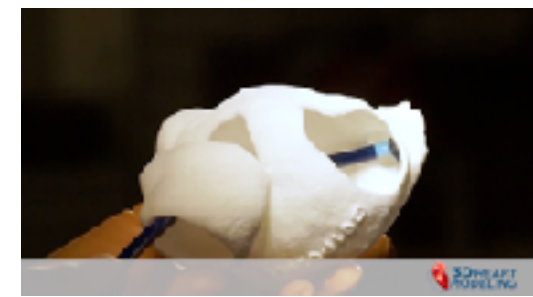
EuroIntervention 2018;14(1-9) published online 14 March 2018

76 patients (21 patients prospective)
4 centres

	Group 1 Conventional imaging N=55	Group 2 Conventional imaging+3D printed model N=21	p-value
Peri-device leaks	15 (27%)	1 (5%)	0.006
Off-axis	14 (25%)	1 (5%)	0.010
Devices per procedure	1.20	1.05	0.047
Failed implantation	1	0	NS
Fluoroscopy dose (mGy·cm ²)	7,291 (1,811-12,734)	1,978 (1,548-4,800)	0.029
Fluoroscopy time (min)	19 (13.4-23)	13.5 (11.1-15)	0.012
Sizing changed by 3D-printed model ¹	17 (31%)	8 (38%)	0.75
Puncture site oriented alternatively to postero-inferior as per 3D-printed model	18 (33%)	10 (47%)	0.35
Data presented as median (interquartile range). *Clinical decision would have changed in Group 1 if 3D model sizing had been applied.			

« LAA-Print Registry »

ClinicalTrials.gov **PRS**
Protocol Registration and Results System



<u>Unique Protocol ID:</u> *	RECHMPL17_0230
<u>Brief Title:</u> *	<i>Use lay language.</i> Left Atrial Appendage Occlusion Guided by 3D printing
<u>Acronym:</u>	LAA-Print registry
<u>Official Title:</u> *	National Longitudinal Registry for Mid-Term Clinical Outcome And Procedure Efficacy Evaluation In Using A Novel Preprocedural Planning Method For Left Atrial Appendage Occlusion Guided By 3D Printing
<u>Study Type:</u> *	☒ <u>Observational</u> Supported by : Boston, Philips, ☐ <u>Interventional</u> region Occitanie, AG2R fondation ☐ <u>Expanded access</u>



- First **prospective study** evaluating 3D printing in structural heart (LAAC)
- Large (>200patients), **multicentric** , (16 centres)
- Clinical aim: to predict procedural risk
- to Improve Safety: by decreasing operating time and complications

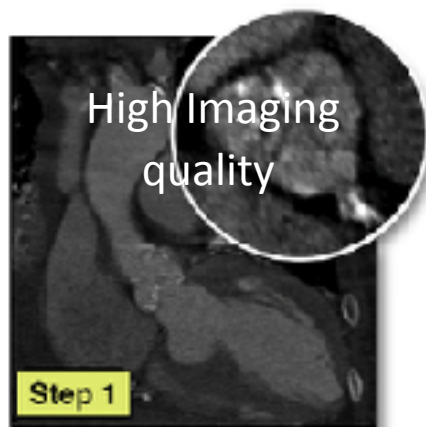




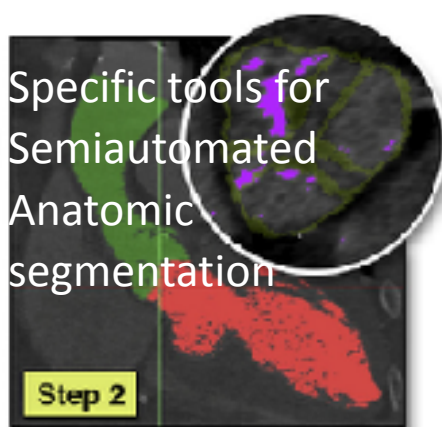
3D Printing Models Enhance Communication with the patients



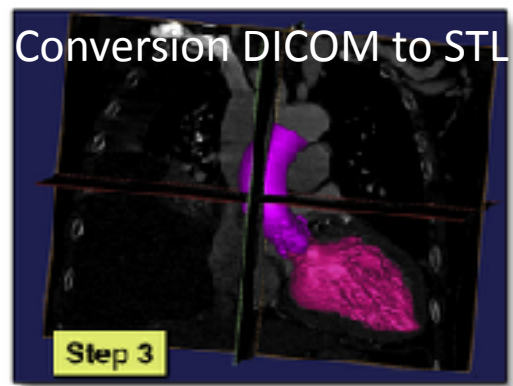
Signal intensity
Contrast
Spatial resolution



CT Images



Segmentation



3D Reconstruction

MRI or



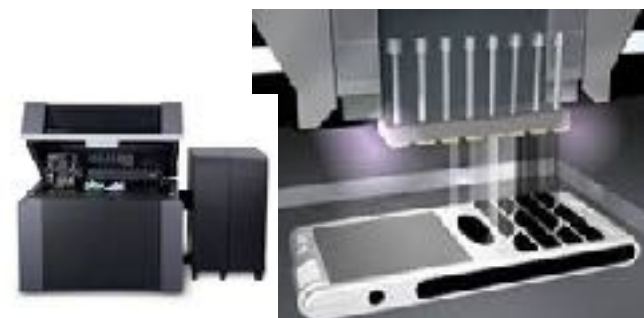
Digital Patient-specific
3D Model



Multi-material 3D Printed
Patient-specific Model

Materials that can
mimic
Mechanical
properties of human
tissue

Off-Line
Workstation
STL modelling
: smoothing,
extraction,
shell, layers,
cutting



CASE STUDIES



Après atriotomie droite

INSPECTION

Distance tricuspide-AP suffisante

Pas d'anomalie valvulaire AV

TUNNELISATION POSSIBLE +

Elargissement CIV

RESULTAT :

Voies de sortie OK

A Metras, E Fournier, N

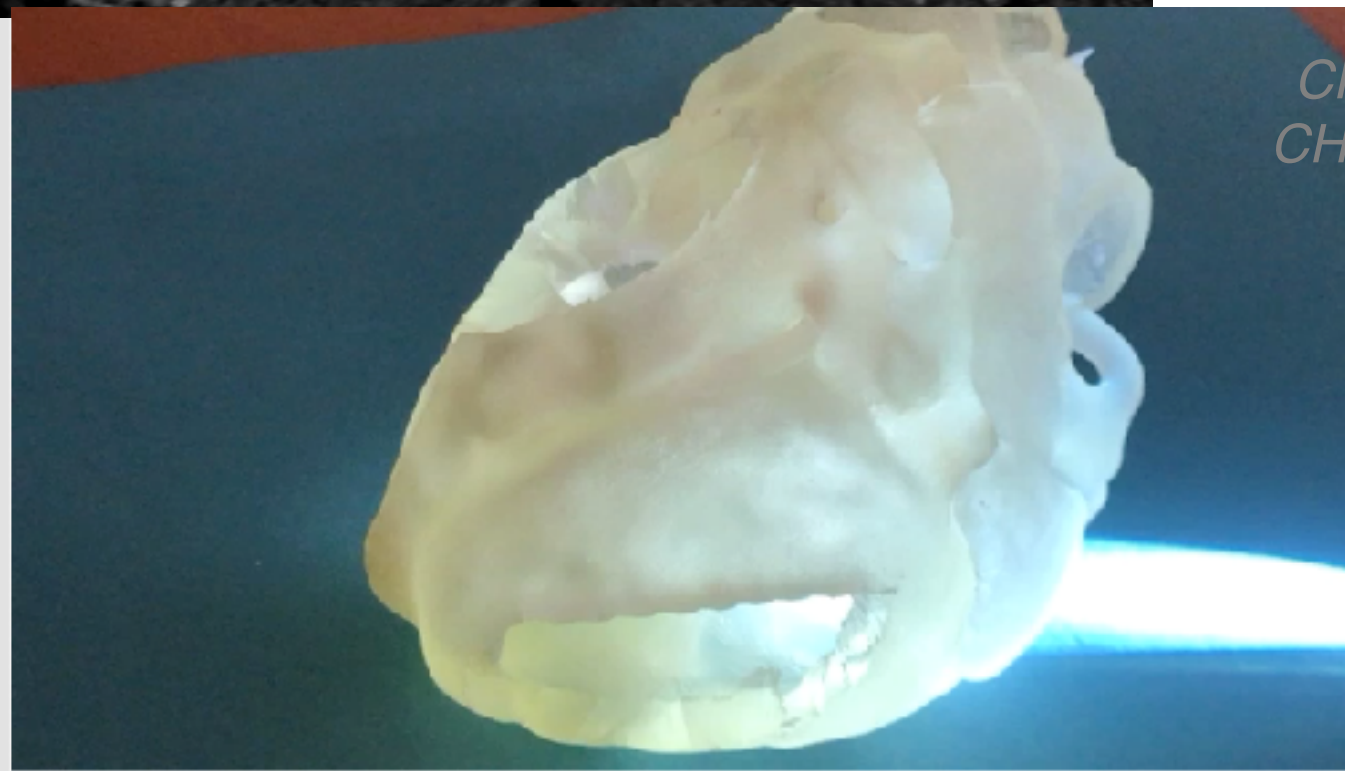
Tafer, X Iriart, F

Roubertie, LA Arzac, B

Kreitmann

CHU Bordeaux

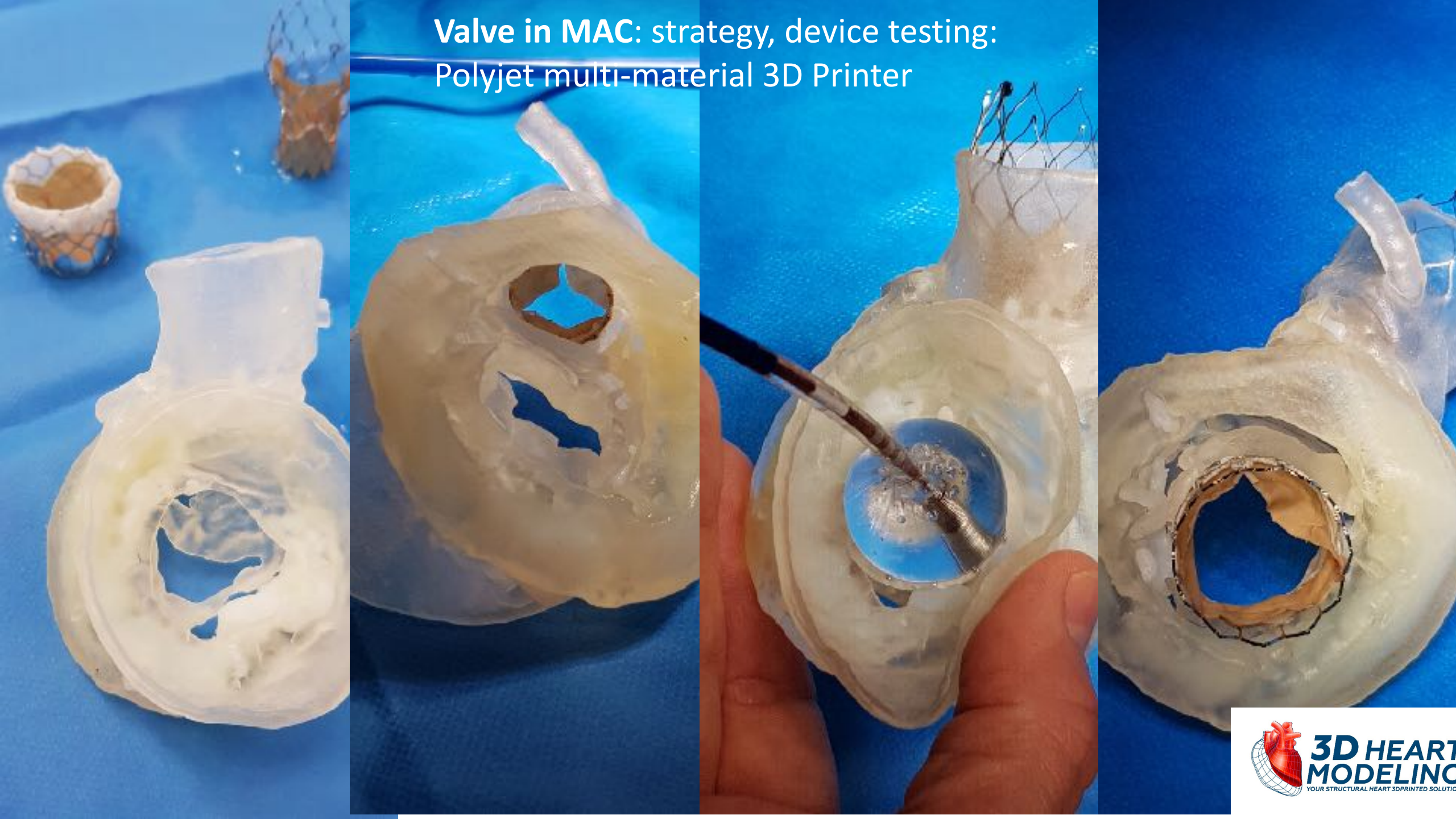
CHU La Réunion



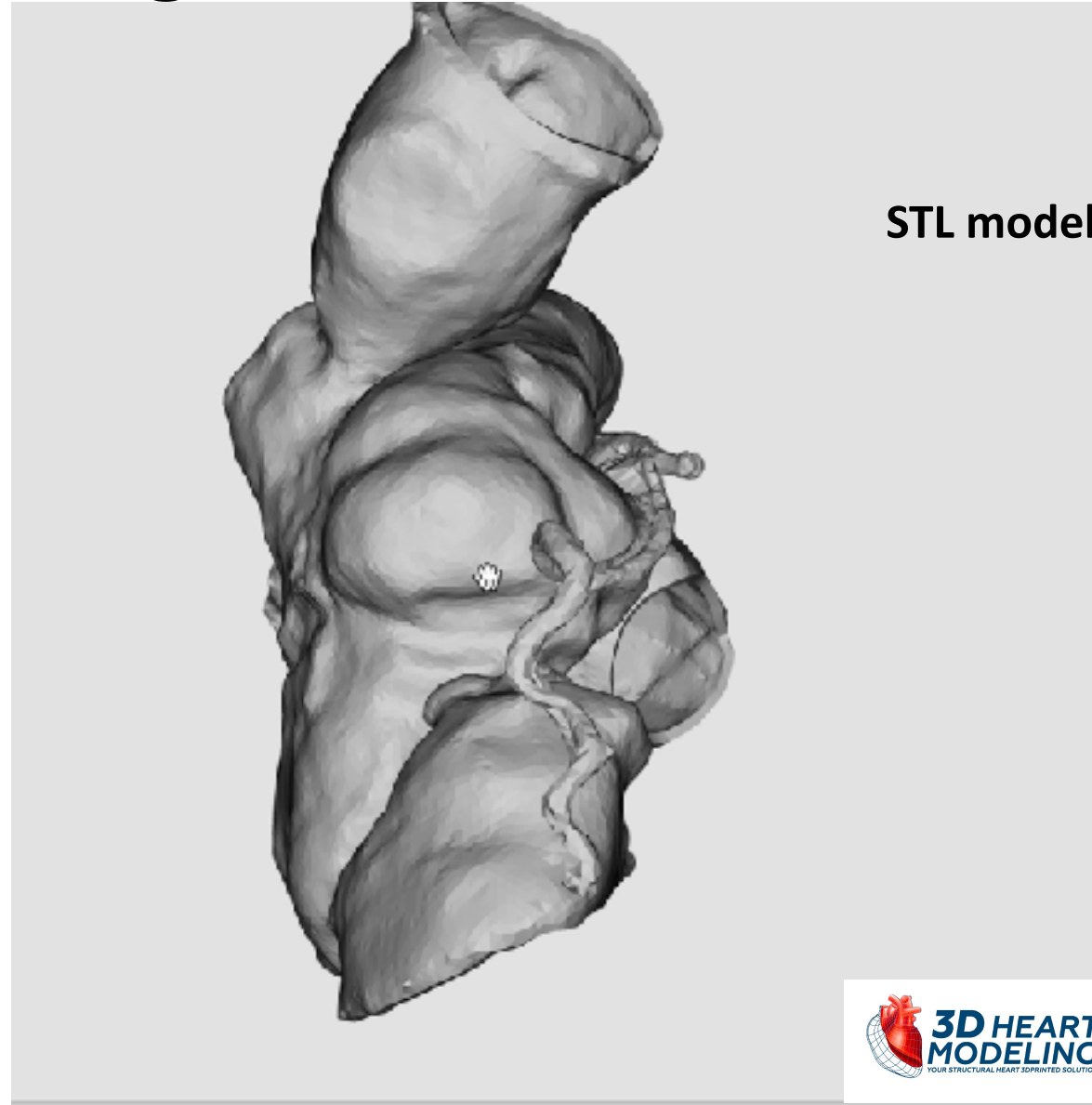
Journées d'automne
2018

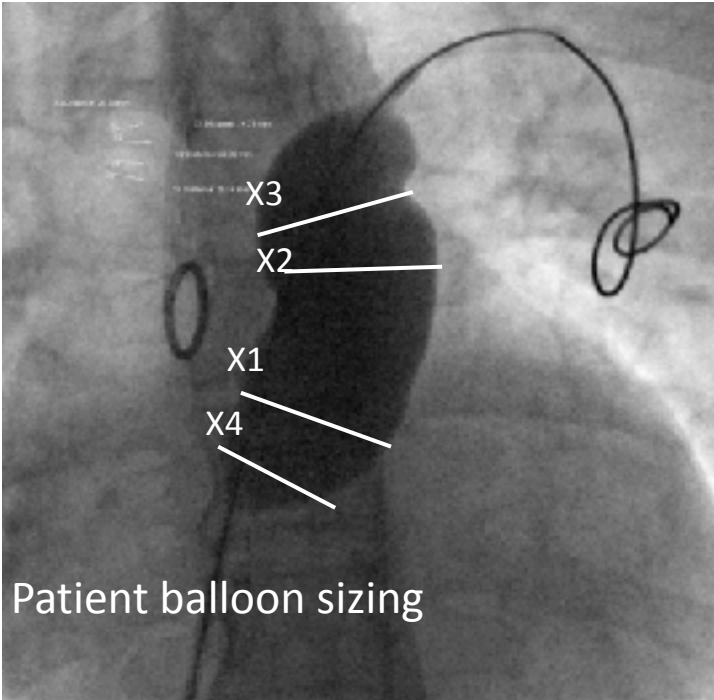
Société Française de
Chirurgie
Thoracique

Valve in MAC: strategy, device testing: Polyjet multi-material 3D Printer

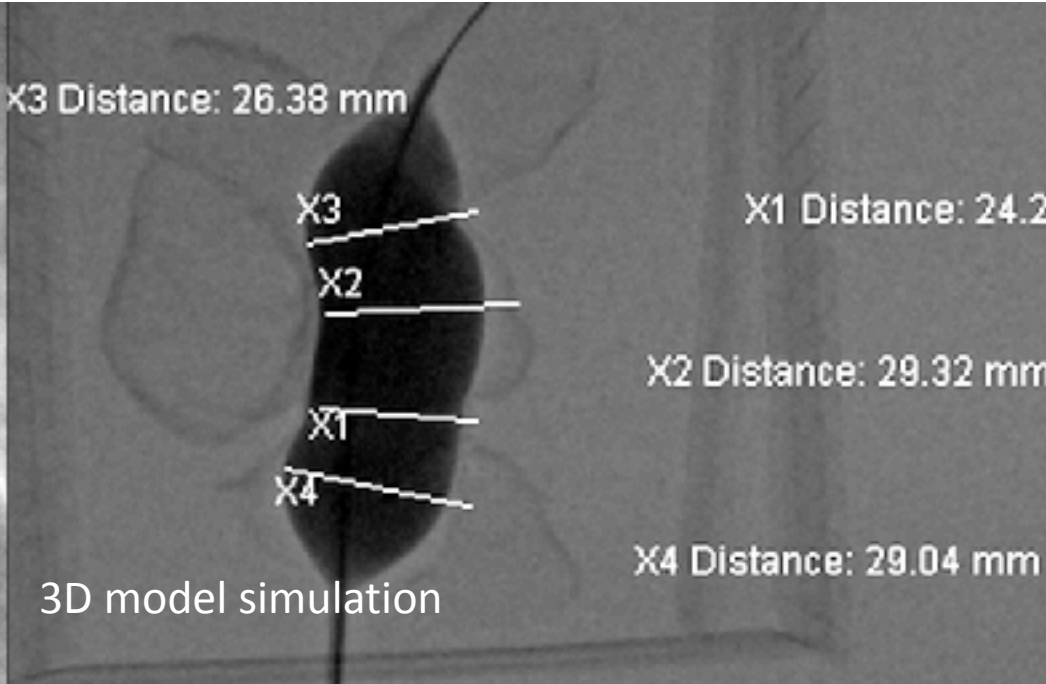


Percutaneous pulmonary valve implantation in large right ventricular outflow tract

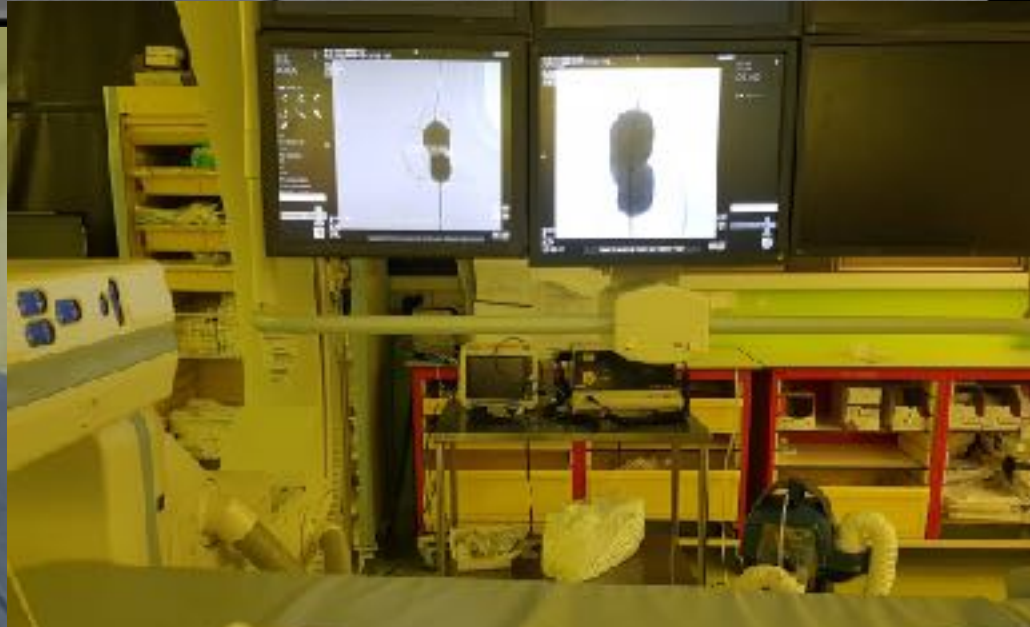
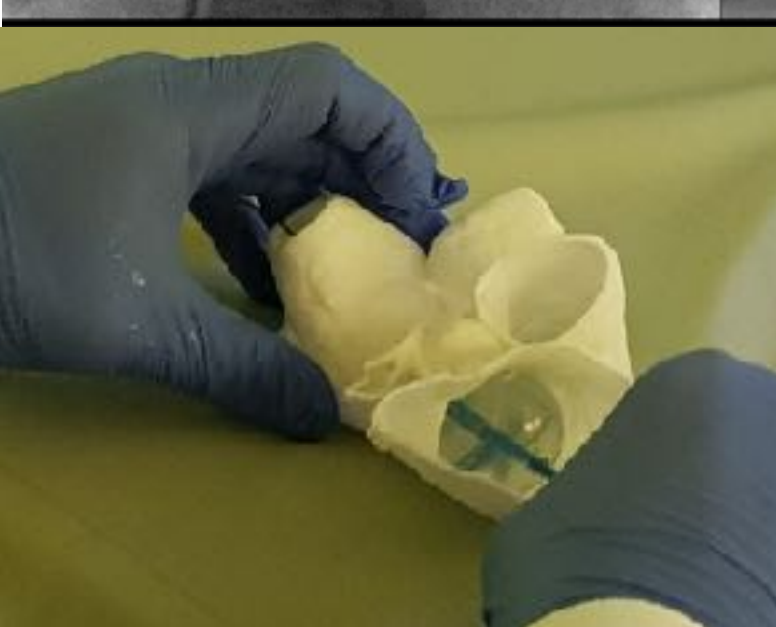




Patient balloon sizing

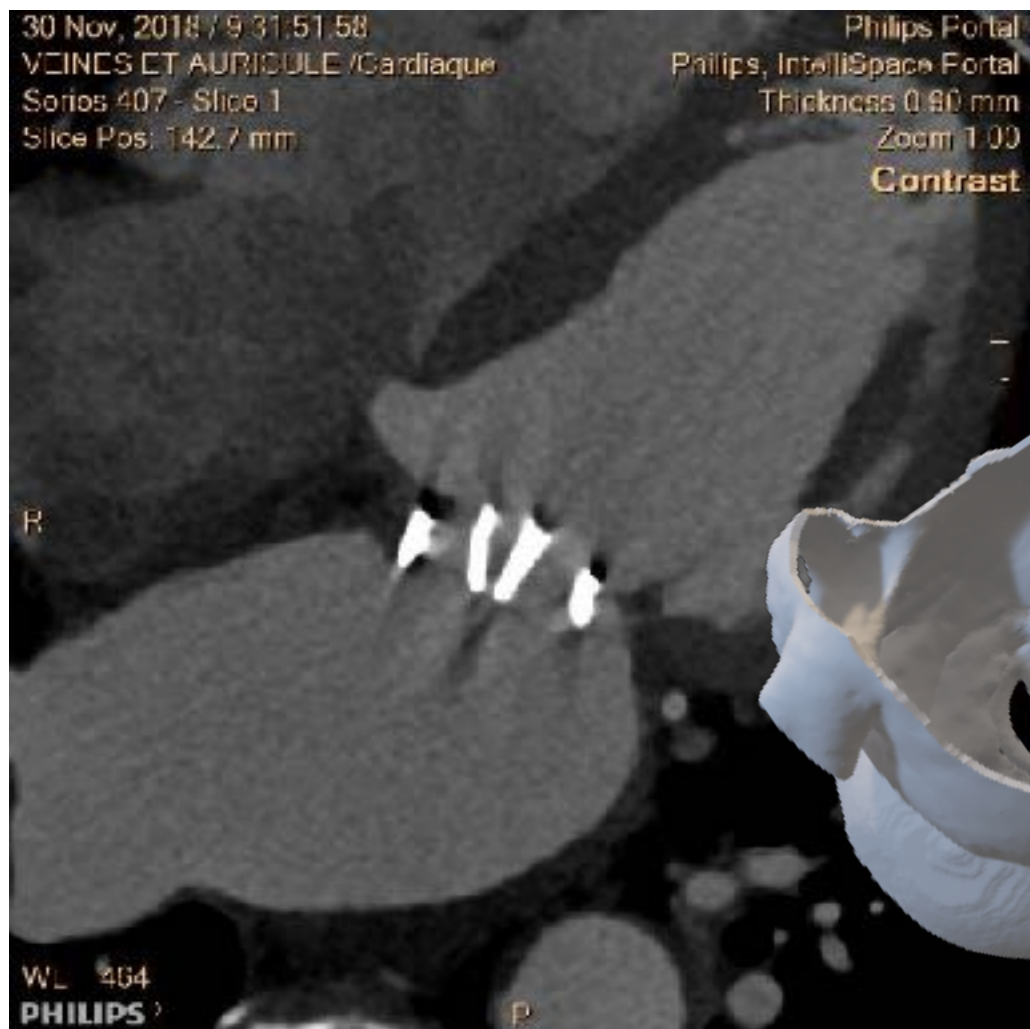


3D model simulation



Dr S Hascoet Hospital MLLG

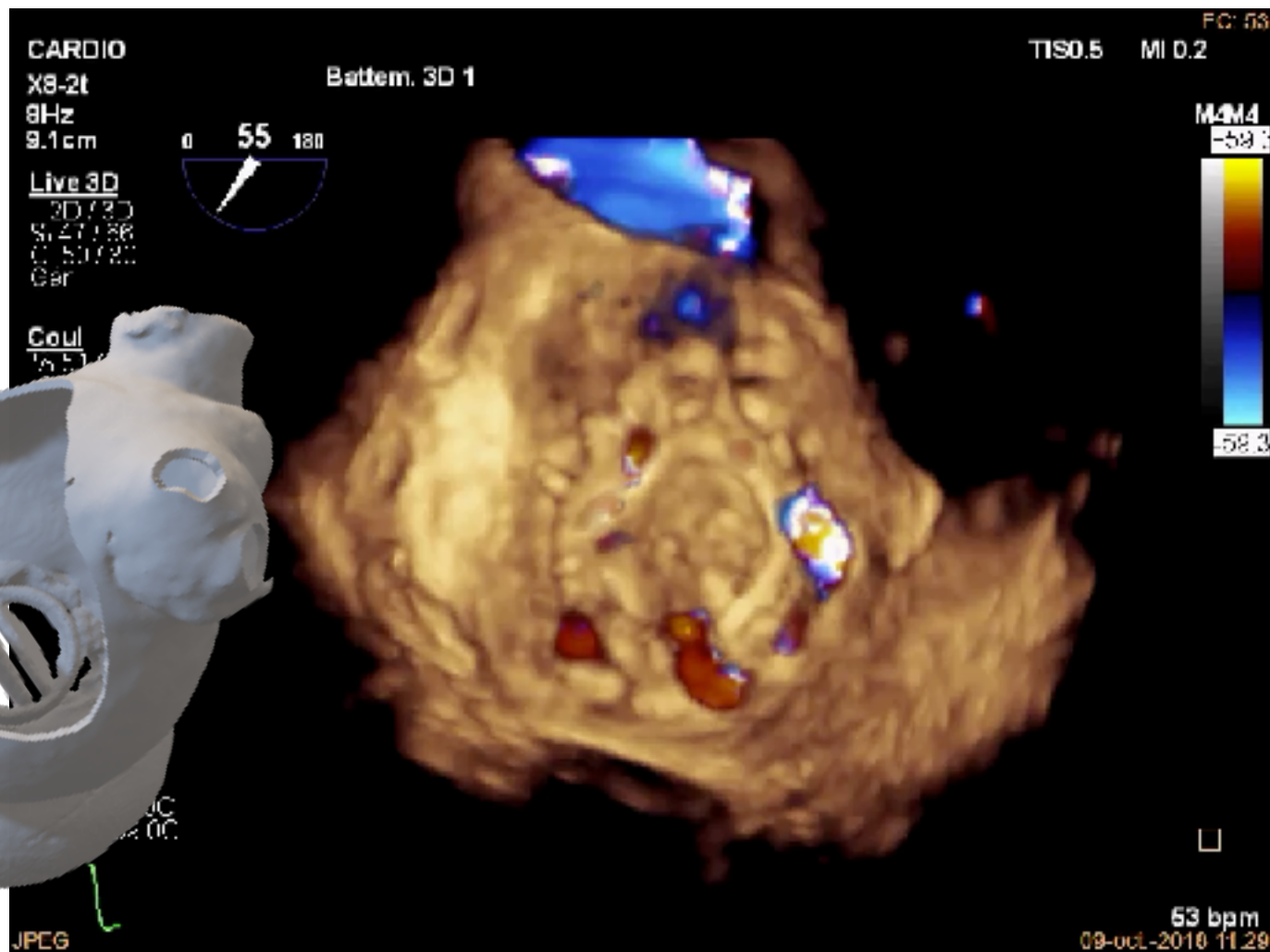
Data from "Pulmonary-Print» registry/ ABSTRACT submitted FCPC2019 Tours



CT pre-procedural

Modified protocol

High spatial resolution: pitch, FOV, reduce metal artefact



3DTEE pre-procedural

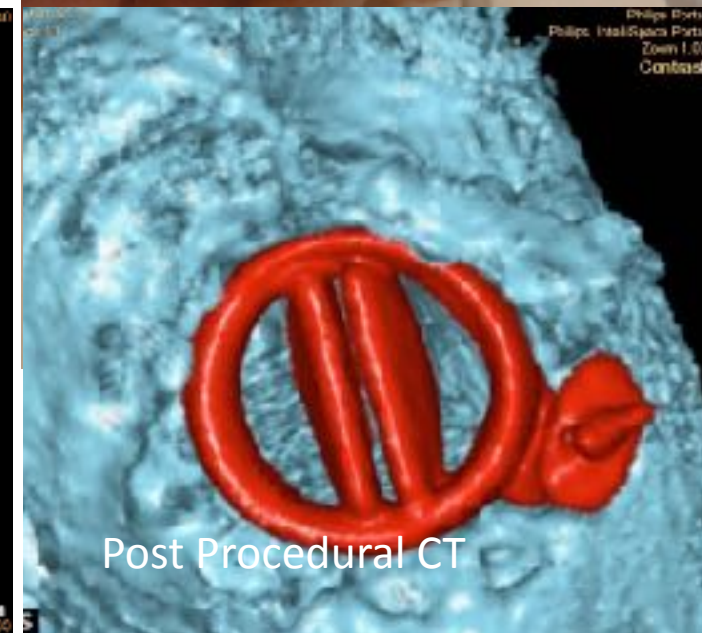
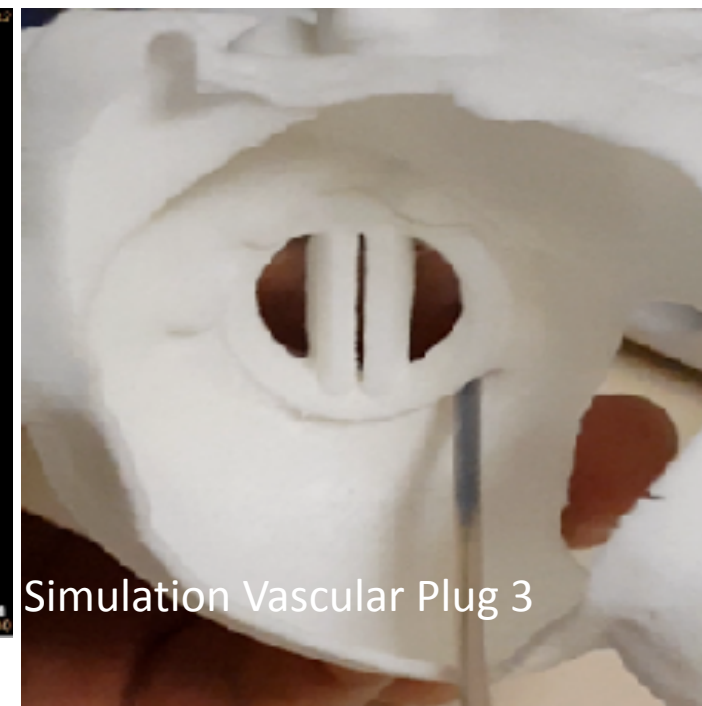
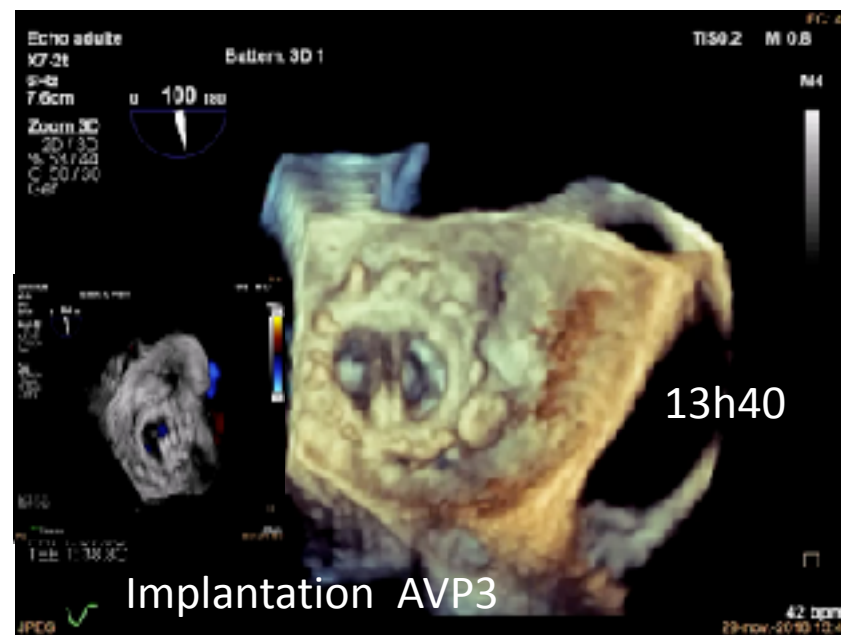
High 3D Imaging frame,

In face view



Serial testing : AVPII, ASD, PDA, AVPIII

Operators: Dr Victor Tadros Dr Sebastien Armero Dr Vlad Ciobotaru



Operators: Dr Victor Tadros Dr Sebastien Armero Dr Vlad Ciobotaru



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CLINICAL RESEARCH

Multimodality imaging guidance for percutaneous paravalvular leak closure: Insights from the multi-centre FFPP register

Imagerie multi-modalités des fuites paravalvulaires : données de l'observatoire multicentrique FFPP

Sébastien Hascoet^{a,*}, Grzegorz Smolka^b,
François Bagate^{c,d}, Julien Guihaire^a, Agathe Potier^a,
Khaled Hadeed^e, Yoan Lavie-Badie^f,
Hélène Bouvaist^g, Claire Dauphin^h, Fabrice Bauerⁱ,
Mohammed Nejjar^j, Remy Pillière^c, Eric Brochet^k,
Lionel Mangin^l, Guillaume Bonnet^m, Vlad Ciobotaruⁿ,
Guillaume Leurent^o, Najib Hammoudi^p,
Adel Aminian^q, Clement Karsenty^{r,s,t},
Christian Spaulding^r, Sébastien Armero^{s,t},
Frederic Collet^s, Didier Champagnac^u,
Julien Ternacle^d, Martin Kloeckner^a,
Benoit Gerardin^a, Marc-Antoine Isorni^a

^a Faculté de médecine Paris-Sud, hôpital Marie Lannelongue, université Paris-Sud, Paris-Saclay, 92150 Le Plessis Robinson, France

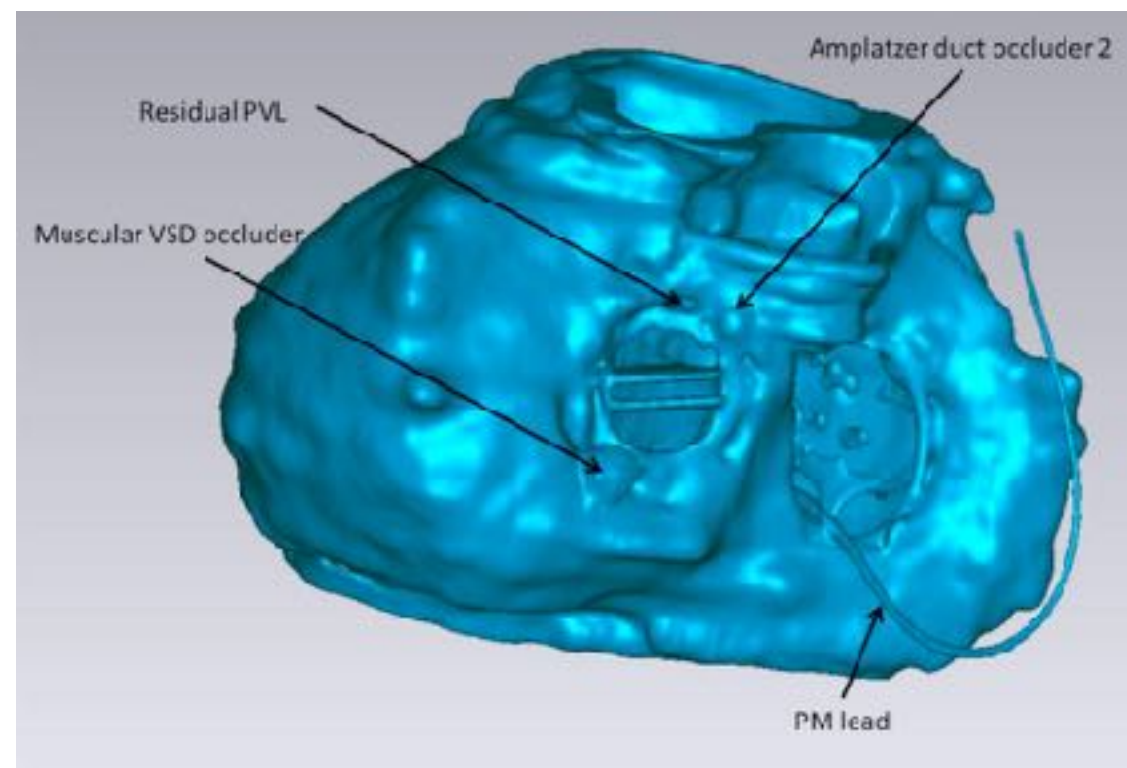
^b Department of cardiology, medical university of Silesia, 40055 Katowice, Poland

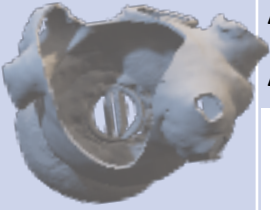
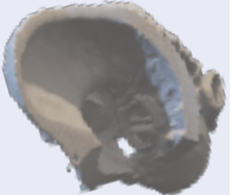
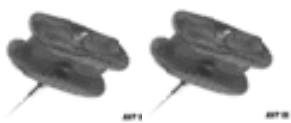
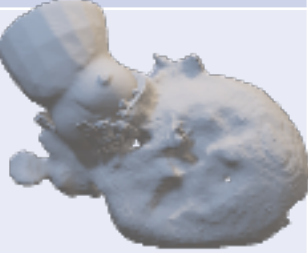
^c Centre de réanimation et d'intervention cardio-vasculaire, clinique Ambroise Paré, 92200 Neuilly-sur-Seine, France

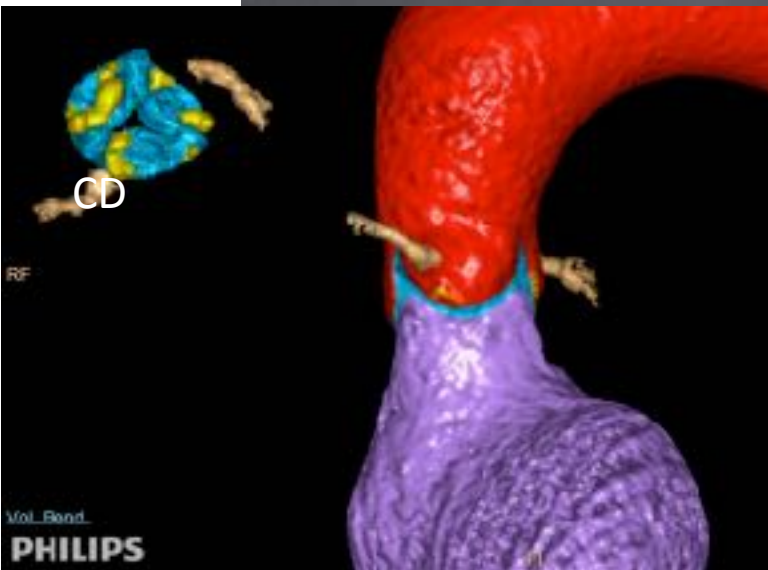
^d Hôpital Henri-Mondor, cardiologie, Assistance publique des Hôpitaux de Paris, Inserm U955, 94010 Créteil, France

^e Hôpital des enfants, cardiologie pédiatrique, centre hospitalier universitaire de Toulouse, 31059 Toulouse, France

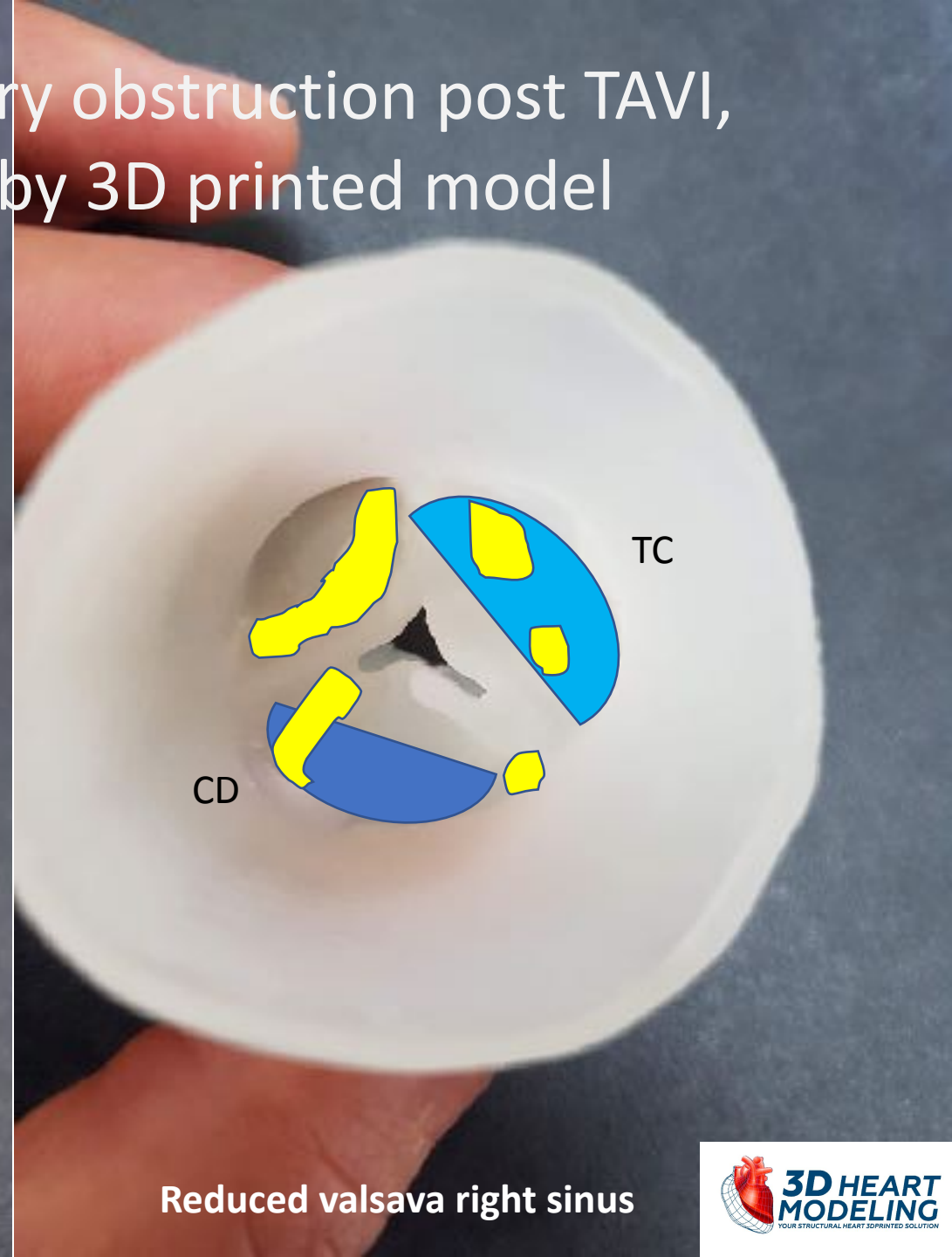
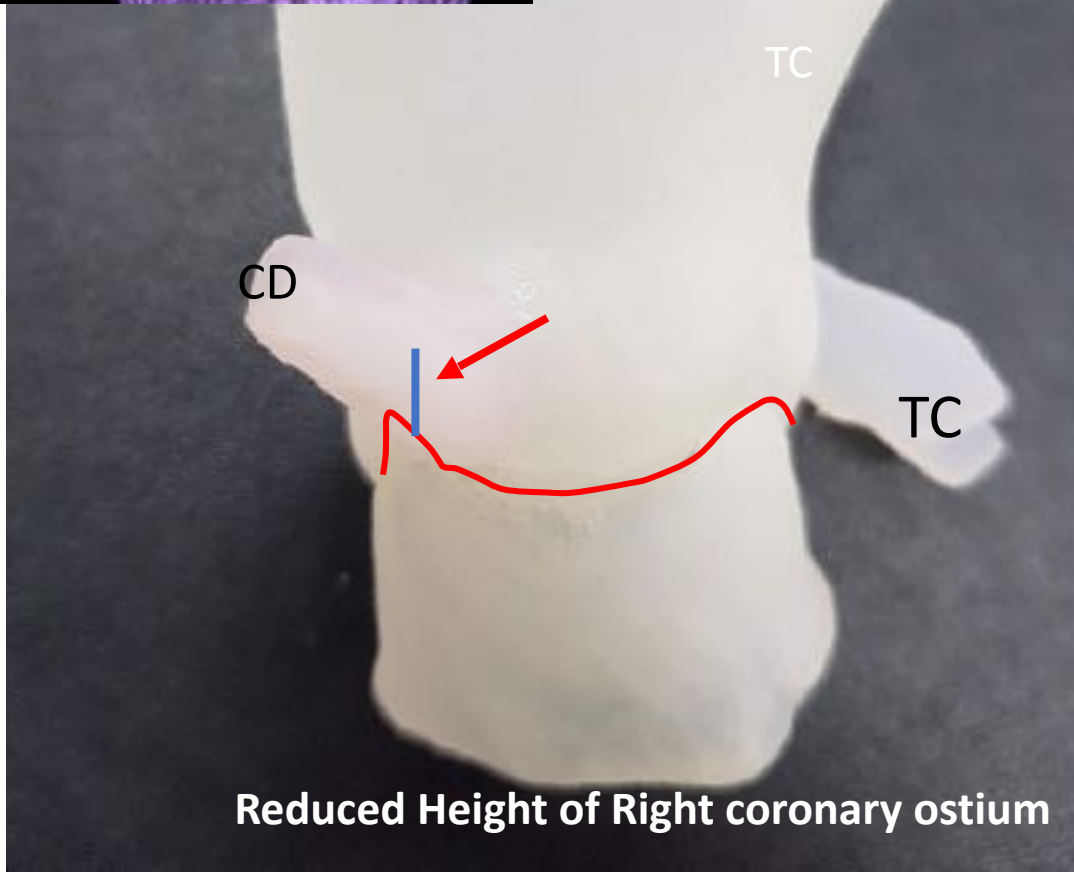
“FFPP-Print” Registry



FFPP-Print Registry	Pre-tested	3D printing Choice	Implanted	Removed	Final Choice	Time
Case 1 PVL Mitral 	AVPII, ASD, PDA, AVPIII 10/14 	AVPIII 	AVPIII 12mm	0	AVPIII 	57min
Case 2 PVL Mitral 	AVPII AVPIII 9/14 ASD 	AVPIII 	AVPIII +AVPII	ASD 	AVPIII+ AVPII 10/12mm 	100min
Case 3 PVL Aortic 	AVPII AVPIII 10/14 	none	AVPIII 10/14 	AVPIII14 	AVPIII Emergency surgery: disc blocked 	105min
Case 4 IVC postTAVI 	AVPIII AVPII VSD8/12/16mm 	VSD16mm 	VSD8mm 16mm	VSD8mm 	VSD16mm 	90min
Case 5 PVL Aortic 	AVPII 8/12mm 	AVPII 	AVPII	0	AVPII 	50min



Risk of coronary obstruction post TAVI,
predicted by 3D printed model



JACC: CARDIOVASCULAR IMAGING

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ISSN 1936-878X/\$36.00

<http://dx.doi.org/10.1016/j.jcmg.2017.05.002>

EDITORIAL COMMENT

3-Dimensional-Printed Models for TAVR Planning

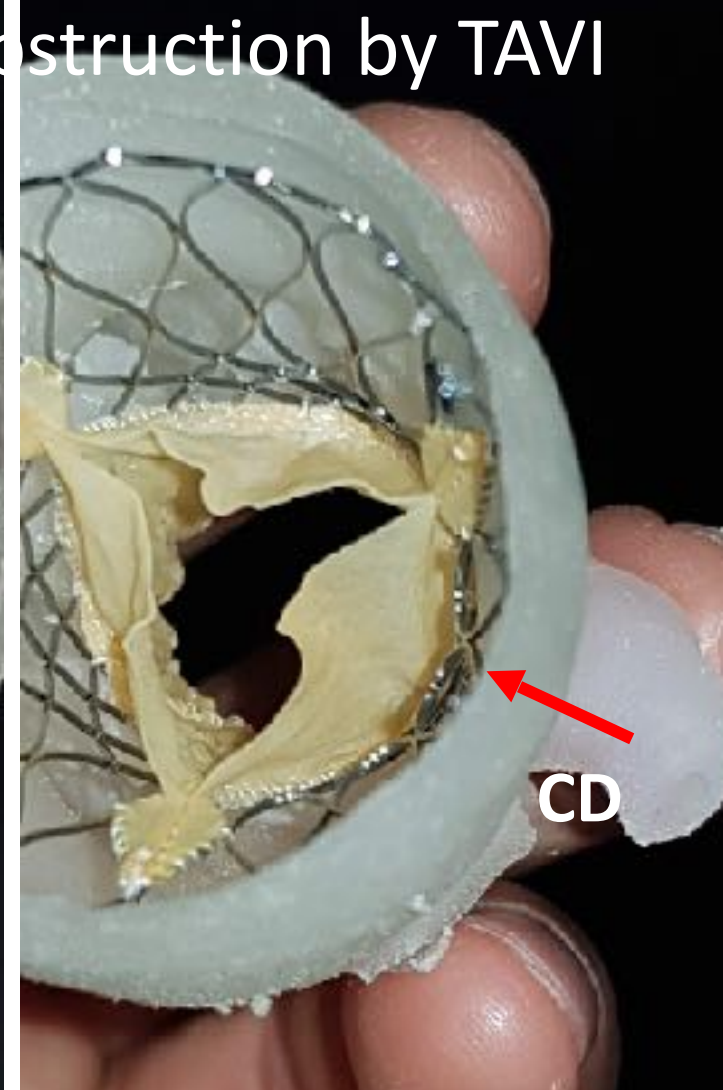
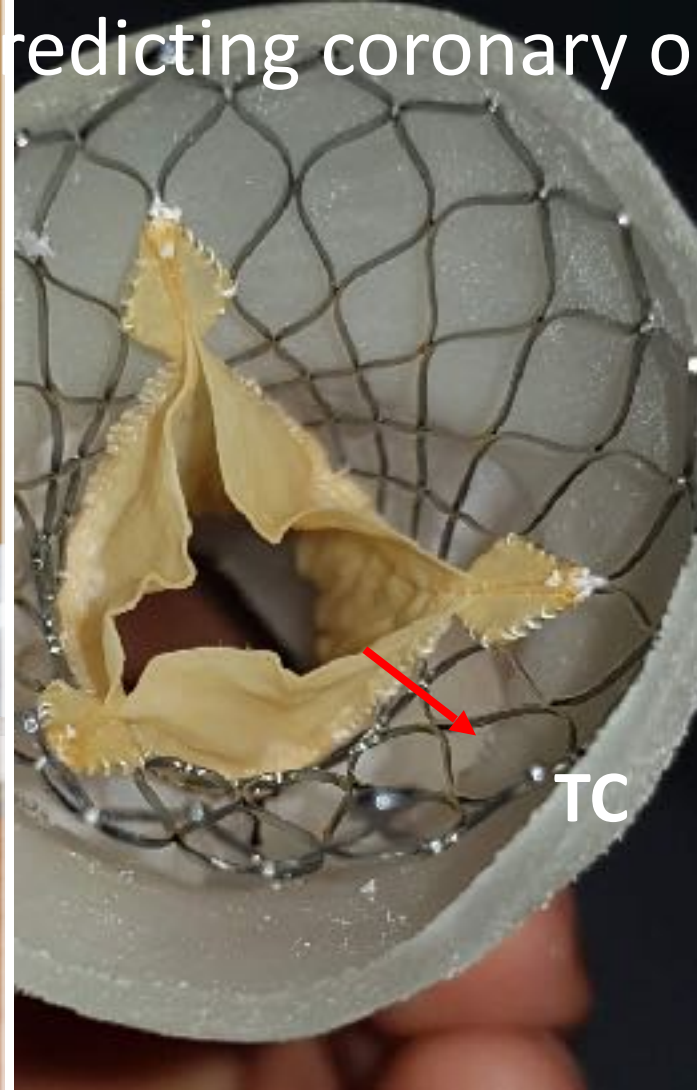
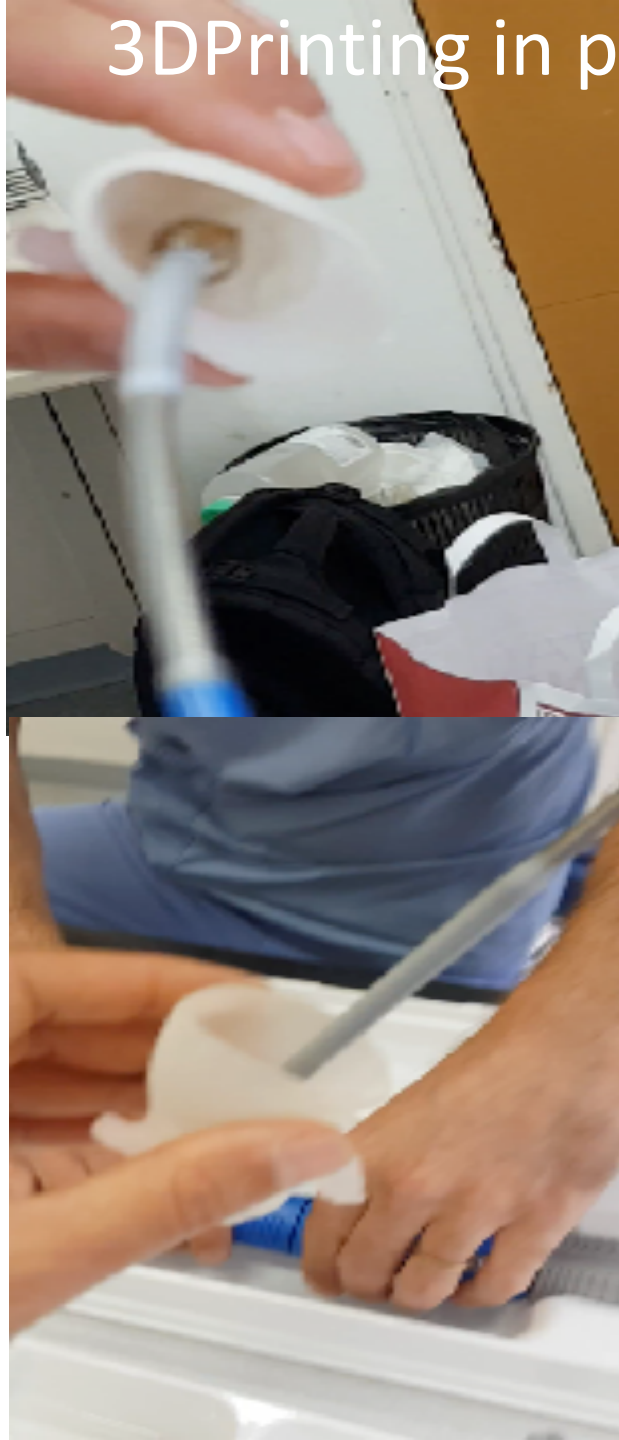
Why Guess When You Can See?*



3DPrinting in predicting coronary obstruction by TAVI

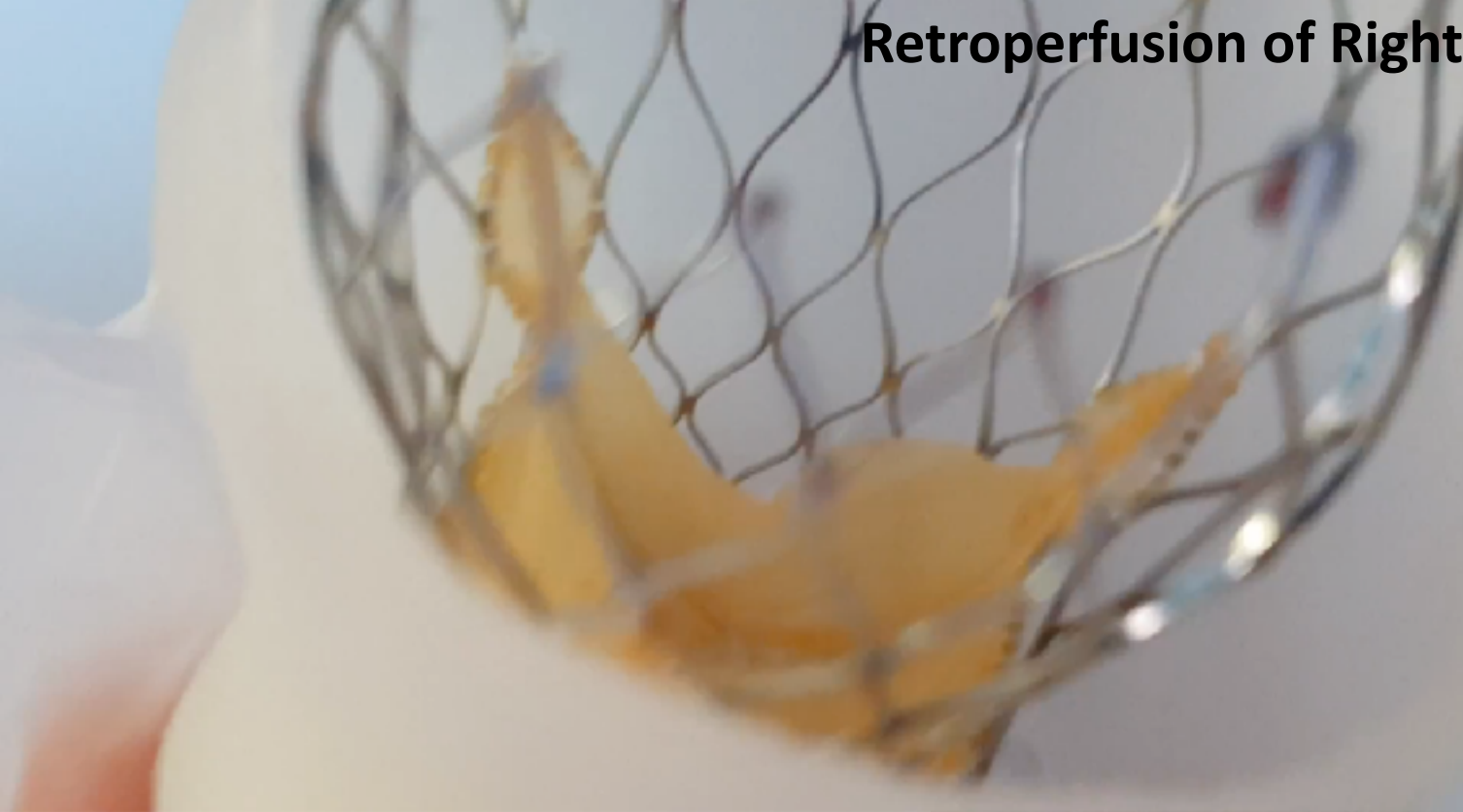
Medtronic
Evolut^R N°26

Check
For Implantation
depth



Coronary neosinus
Right neosinus quasi inexistant !!

Retroperfusion of Right Coronary



Perfusion mark on
the covering skirt
below the leaflet
insertion

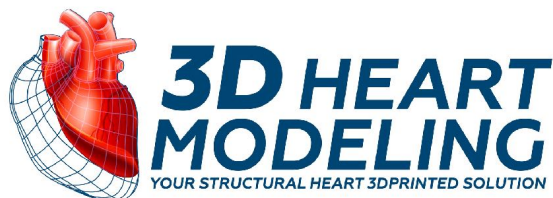


Conclusion:
TAVR Medtronic Evolut 26
Induce right coronary obstruction

Présentation filiale d'écho JESFC2019



OUR STRENGTHS



BREVET D'INVENTION

Code de la propriété intellectuelle - Livre VI



DÉSIGNATION D'INVENTEUR(S)

15 rue des Minimes - CS 50001 - 32677 Courbevoie Cedex

INPI Direct : 0820 210 211 (Service 0,10 €/min + prix appel)

Pour déposer par Mailbox : 80 101 56 66 88 00

Vos références pour ce dossier	11G177 BT1 FR
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TITRE DE L'INVENTION	
Titre	REPRODUCTION TRIDIMENSIONNELLE D'UN TISSU ANATOMIQUE D'INTERET ET SON PROCEDE D'OBTENTION
LE(S) DEMANDEUR(S)	3D HEART MODELING
DÉSIGNED(NT) EN TANT QU'INVENTEUR(S)	
INVENTEUR 1	
Nom	GLOBOTARU
Prénom	Vlad
Rue	7 Rue des Tourlanelles
Code postal et ville	30132 CAISSARGUES
Pays	FR
DATE ET SIGNATURE	
Signé numériquement par	Subject: FR, CABINET BREV ET SUD, Alain RHEIN (Brev et Sud); Issuer: FR, INPI, INPI-EN-LIGNE 1.1
Date	27 December 2017
Signataire	Mandataire

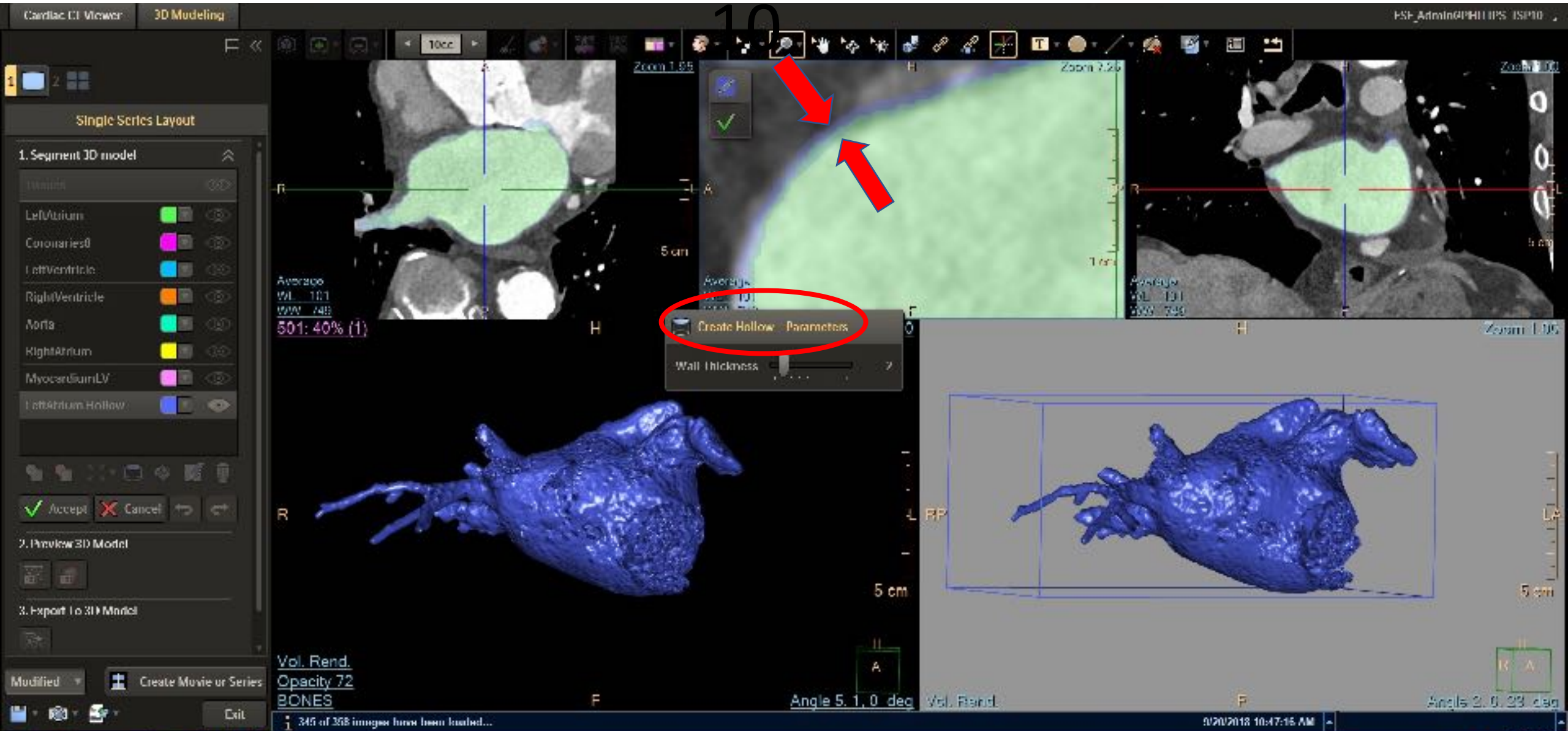
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AG2R LA MONDIALE

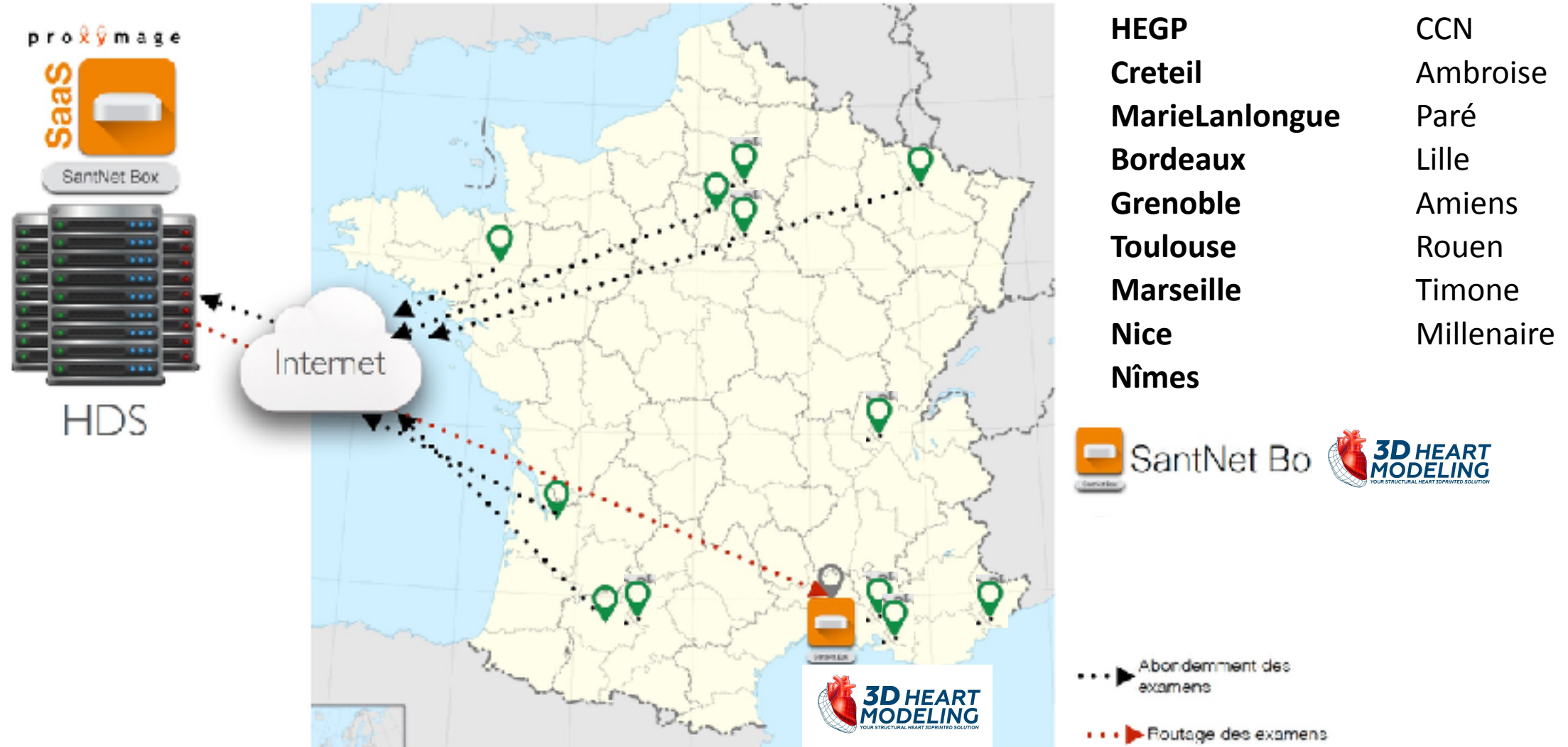
3DPrinting ongoing development:

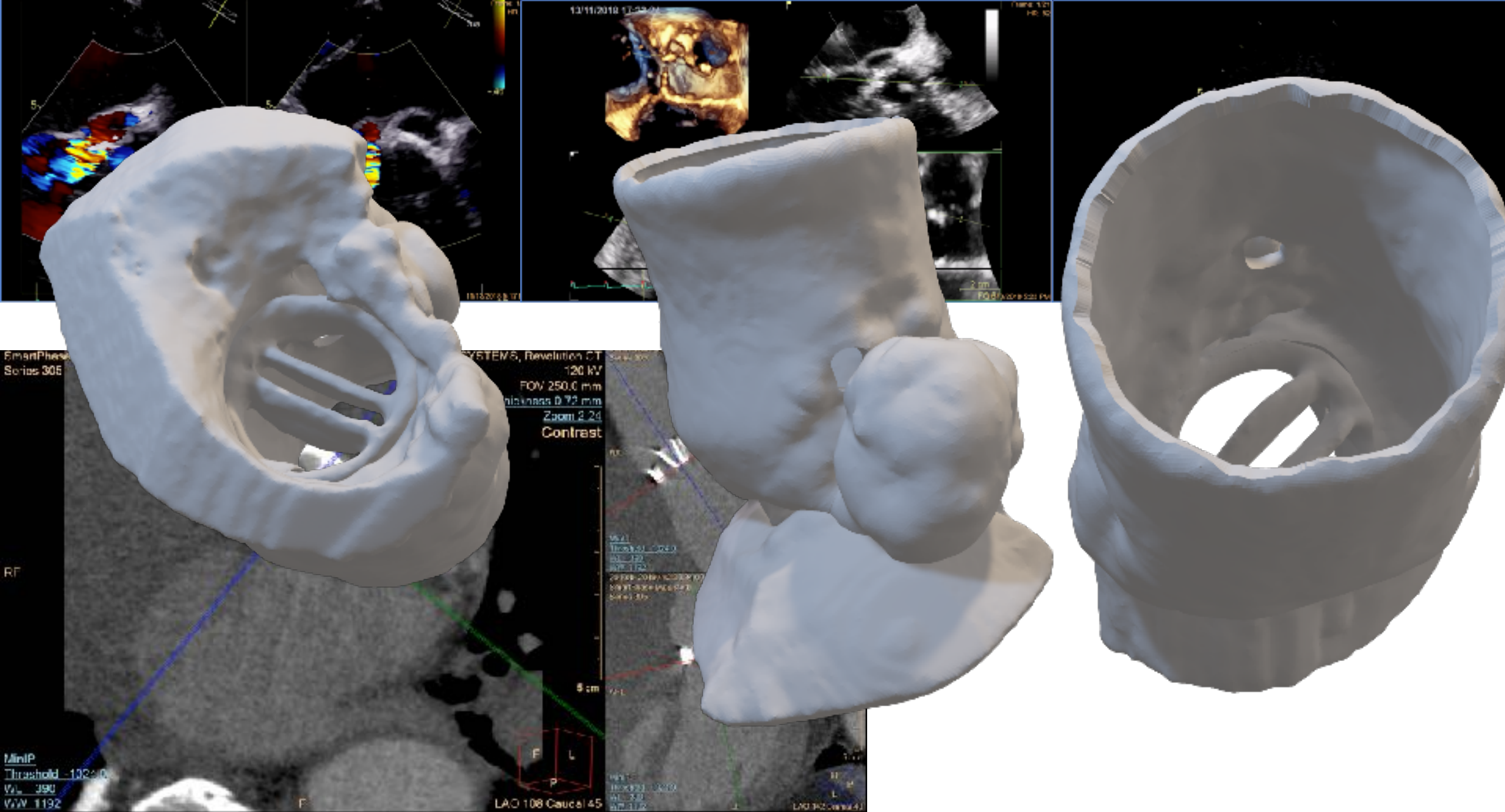
Co-development : Software for STL tools: 3D model ISP10 Philips



HostData Center

Data flux secured

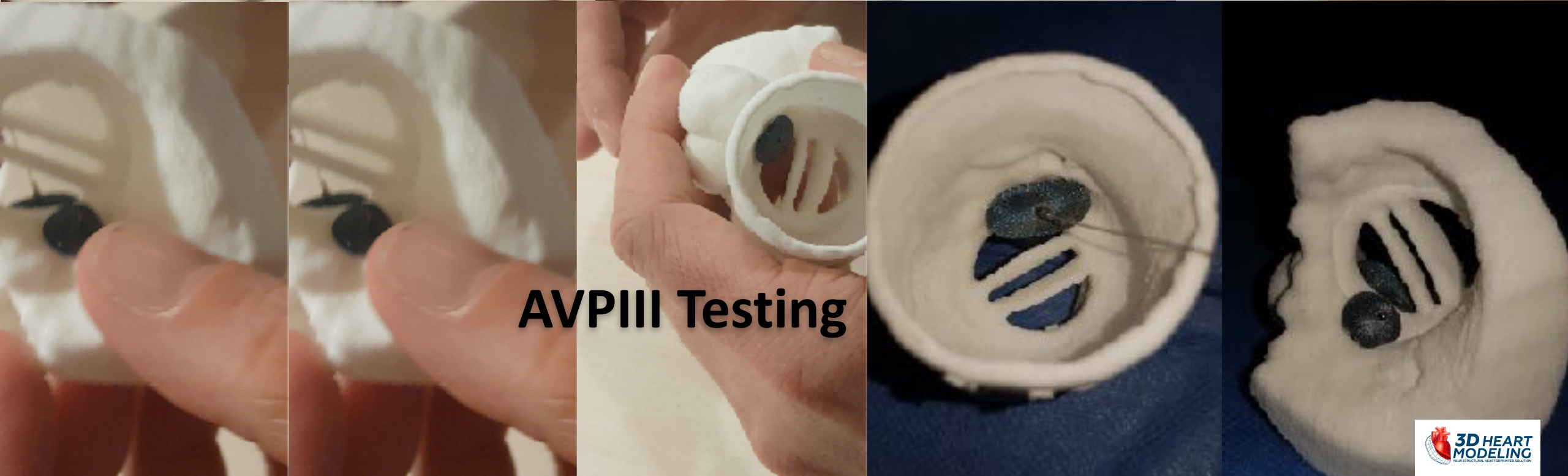




AVPII Testing



AVPIII Testing



Conclusion:

The key of a better treatment is anticipation

- Percutaneous procedures are going to increase and need multi modality imaging :
- However, uncertainty may exist in Decision-making process or planning.
- 3D-printed patient-specific adaptive and flexible models improve device sizing, by incorporating all anatomical variations.
- the use of 3D models permits critical preprocedural planning of the optimal procedure. This can potentially lead to improved patient outcomes.
- 3D printing allows a real time devices testing (high predictive value)



PEOPLE WHO TRUST US



Jacqueline Saw

Denver TCT 2017

I used to think of 3-D printing as a toy, but I
really do think now that there is utility.



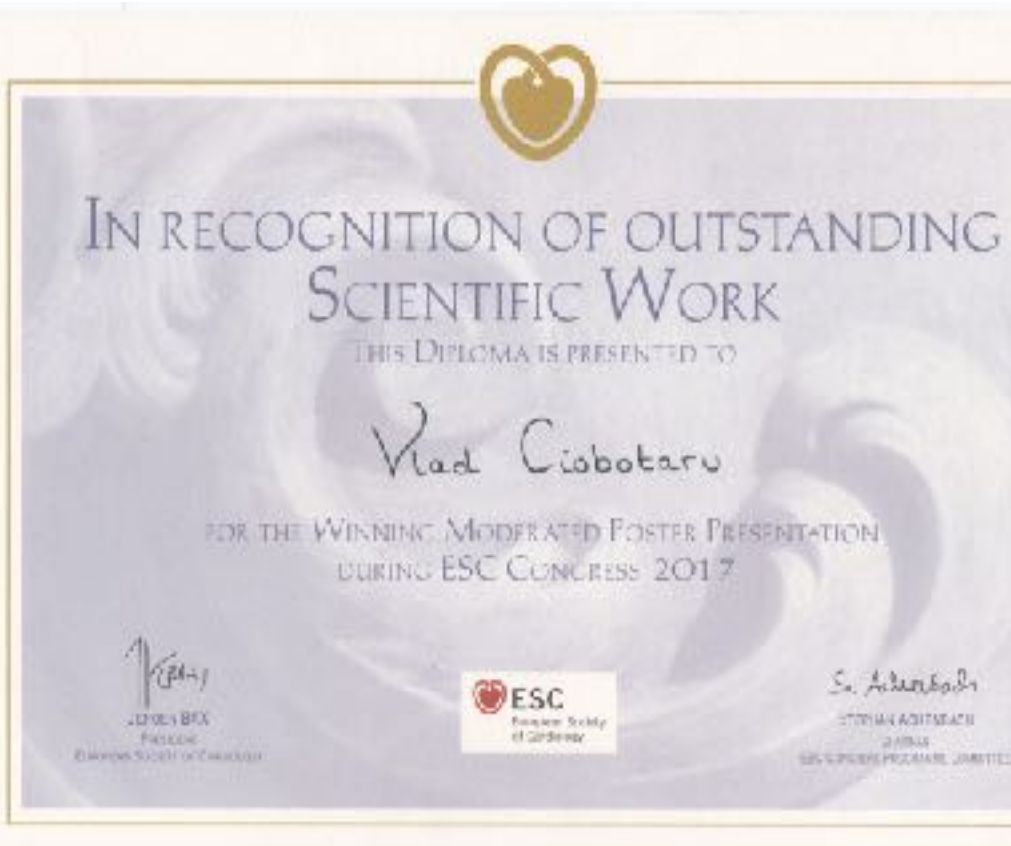
Gilles Lévy

Cardiologie Interventionnelle, Clinique du
Millenaire, Montpellier

Grand merci pour la pièce anatomique de
cette anomalie coronaire.
C'est très didactique.



AWARDS



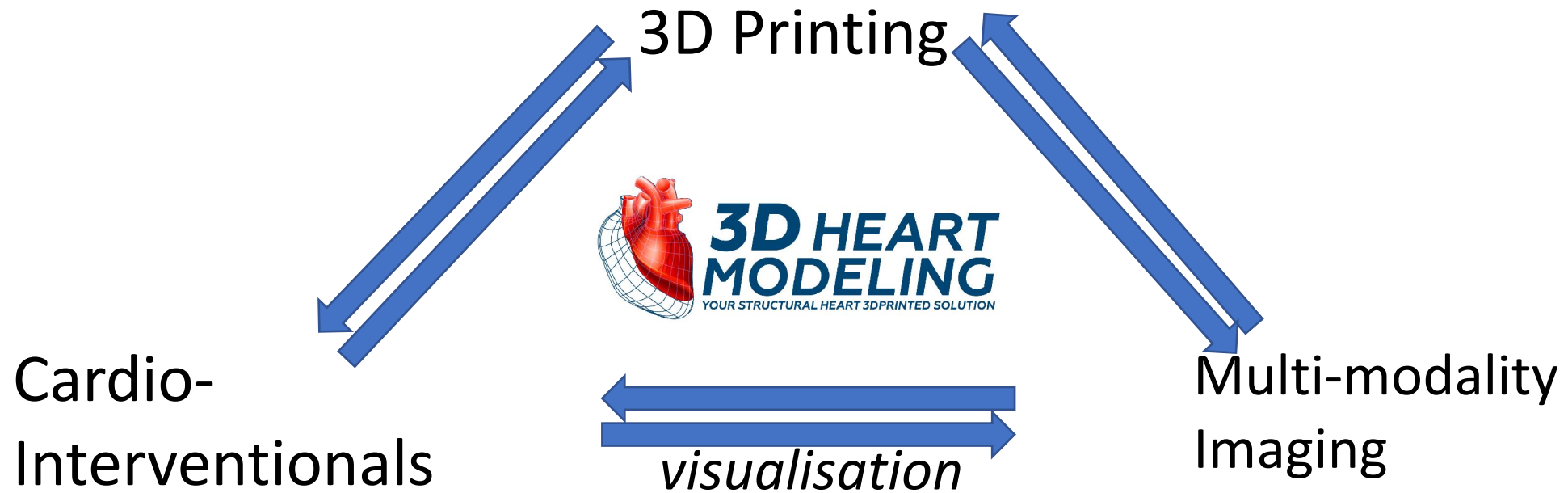
premier prix « e-cardiology »
ESC2017 Barcelone

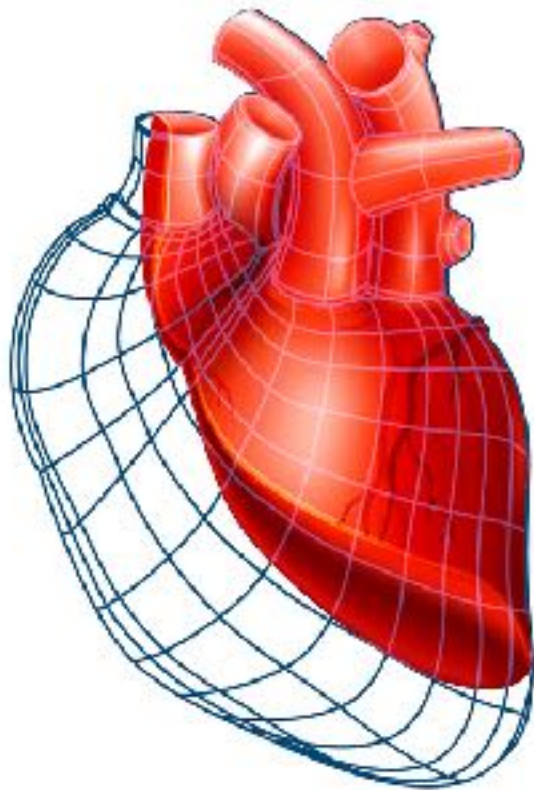


Prix « recherche et innovation » de la SFC2019 pour l'applicabilité de 3D printing en cardiologie

Conclusion:

3D printing leads to a paradigm shift in operating process





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