CRT 21 Virtual

Leveraging Device-Heart Interaction of the Impella Trans-valvular Pump to Manage Critically Ill Patients

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on behalf of
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Abiomed (Elazer Edelman, PI)

Scientific and clinical advisory boards:

Abiomed

Paragonix Technologies

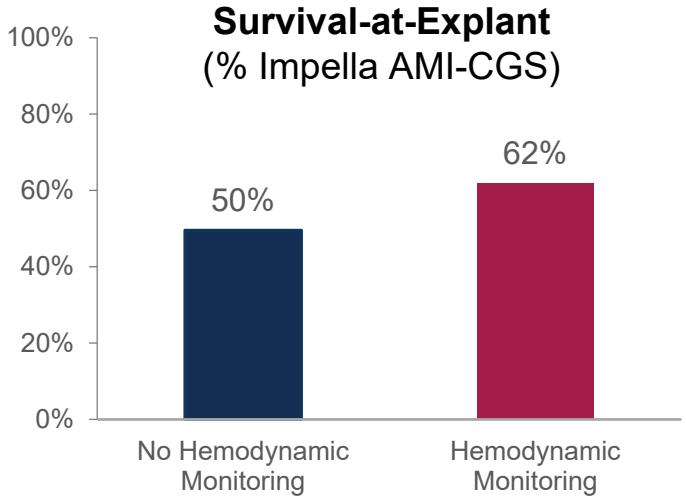
Consulting and Other:

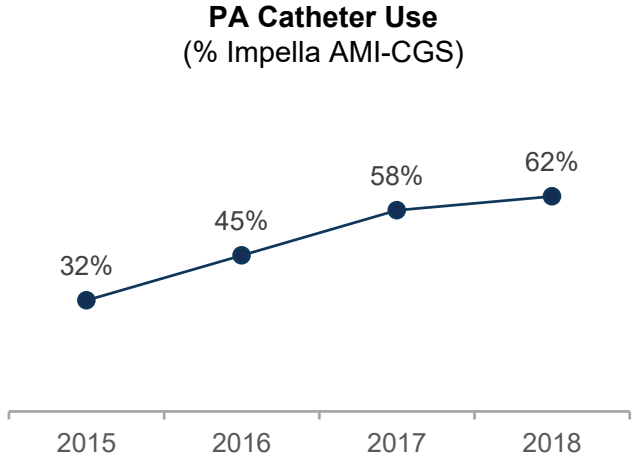
CBSET

X-COR Therapeutics

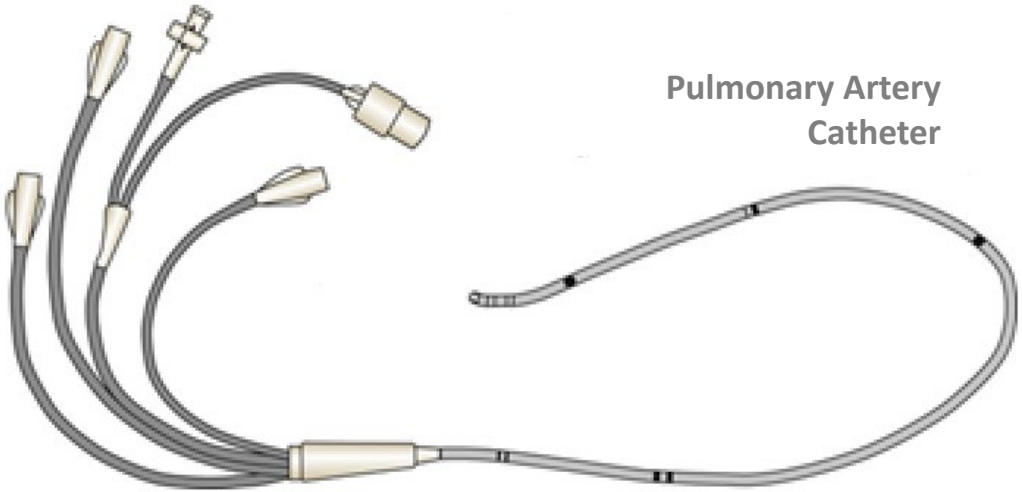
Hemodynamics are critical to managing MCS patients

- Hemodynamic monitoring is critical to managing cardiogenic shock patients[1,2,3]
- Improved outcomes observed with HD monitoring of in current era of medicine[4]
- PA catheters have inherent limitations[5] and risks[6], magnified by infrequent use[7]
- Hemodynamic metrics guide shock protocols[8,9] but PAC use has plateaued[1,3,4]





Existing technology carries inherent limitations and risks



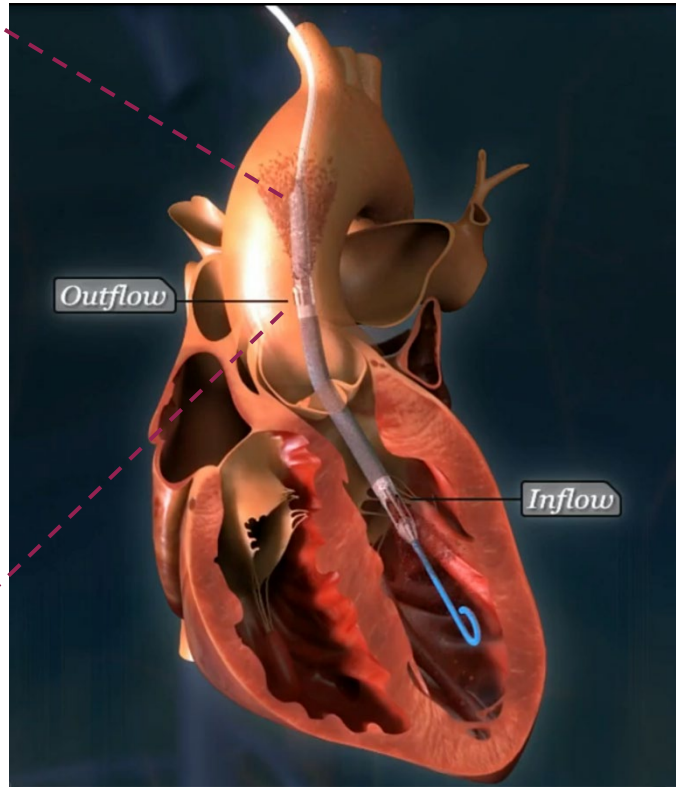
- Poor repeatability
- Discreate sampling
- Irrelevant timescale
- Indirect LVEDP (wedge)
- Variable with valve disease
- Risk of adverse events
- Additional access to manage

Marik *Ann of Intensive* Care 2013; Chang, Edelman, et al. *Sci Trans Med* 2018; Chang, Edelman, et al. *Transact on Biomed Eng* 2020

Impella as a Therapeutic Tool → Impella as a Diagnostic Tool

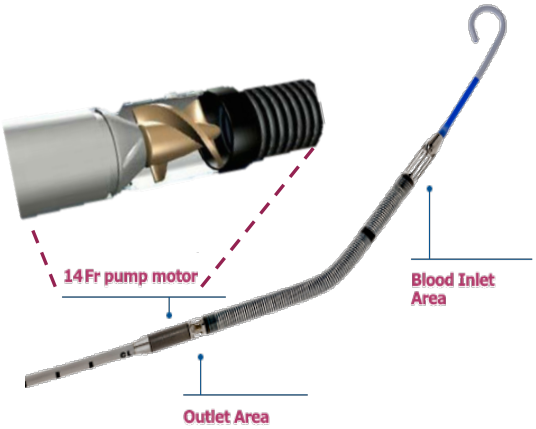
Unique position

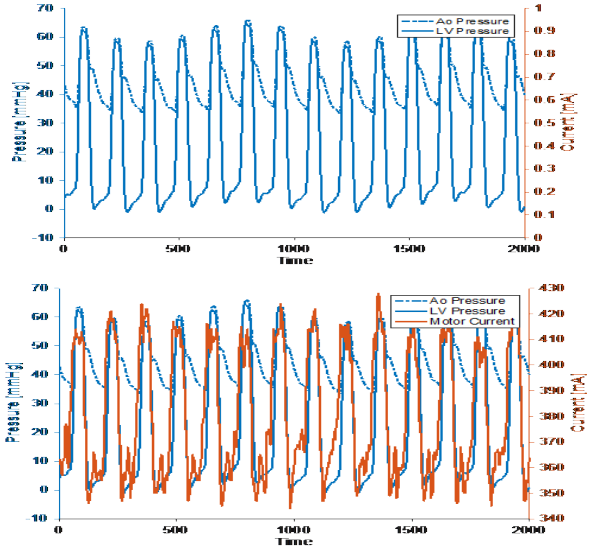
1. Indwelling
2. Works in concert with the heart
3. Rotor-motor size and design



Impella LVEDP: Pump responds to variable loading

- Impella pump operates to maintain a fixed rotational speed (e.g. 23k-44k RPM → P1-P8)
- Impella motor current responds to variable load on the device pump
    1. Pressure head
    2. Flow





$$\tau = H * d$$

$H \equiv$ Pressure Head

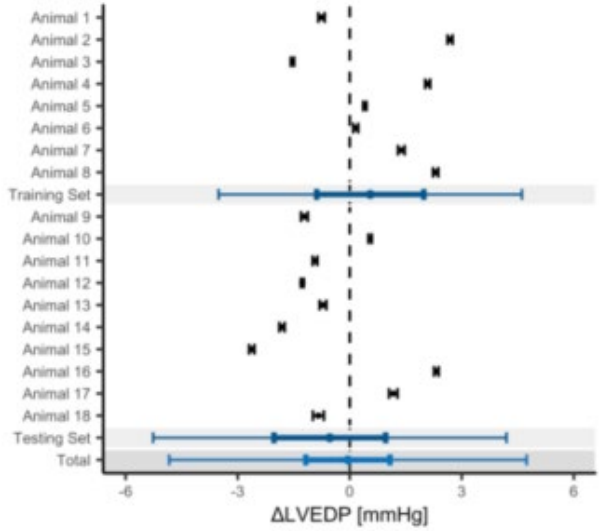
d $\equiv$ Volumetric Displacement

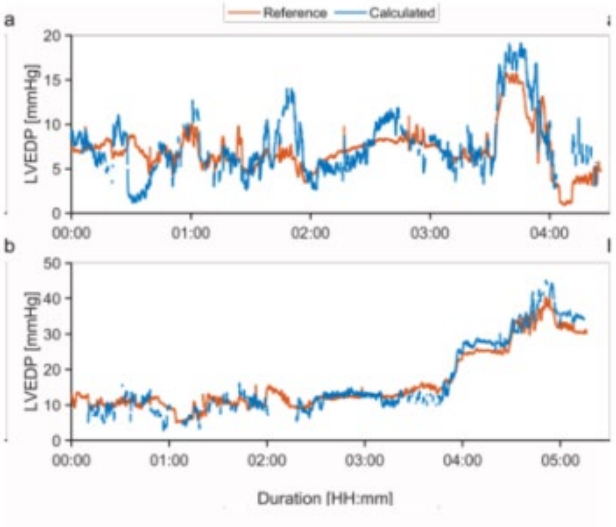
$$P = \frac{\tau * \omega}{\eta} \qquad \eta \equiv \text{Efficiency}$$

$$I_{electrical} \propto \frac{\tau}{\eta_{combined}}$$

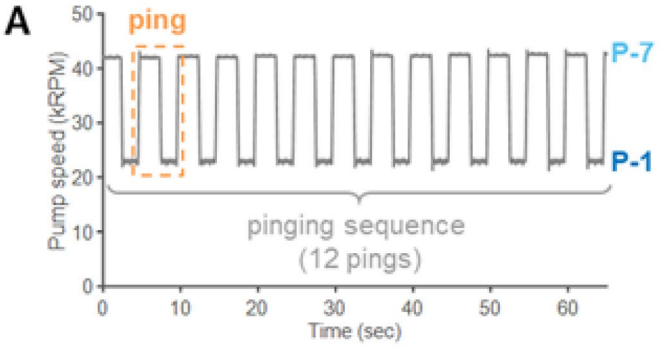
Impella LVEDP measurement validated in preclinical studies

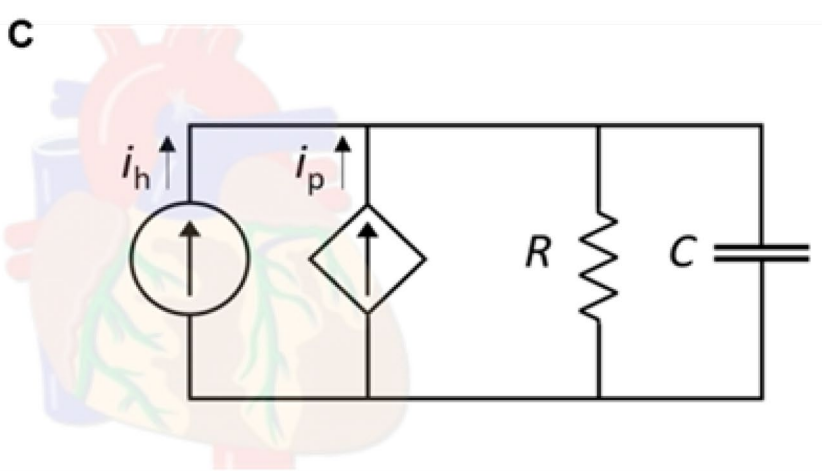
- Performance evaluated in N=18 acute preclinical studies
- Strong correlation with Millar pigtail reference (r>0.80, bias < 1 mmHg)
- Improved accuracy vs. indirect (wedge) measurements (4 vs. 6 mmHg RMSE)
- Consistent trending in LVEDP over elevated and depressed physiologic states





Impella CO: Novel method to directly measure SVR





D

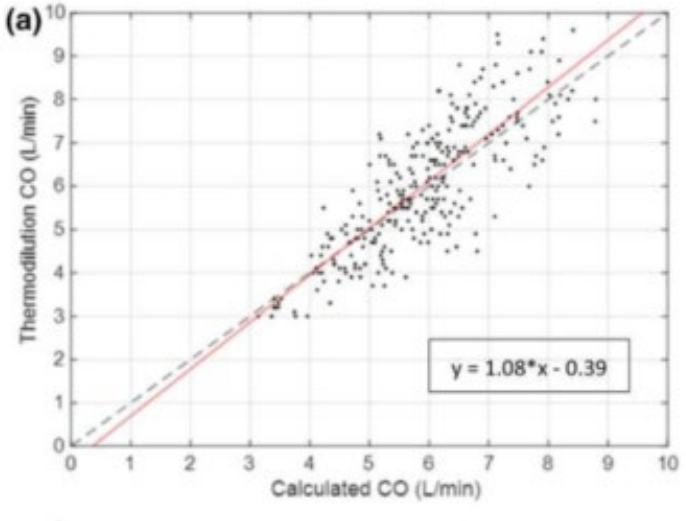
$$i_{heart} + i_{pump} = \frac{P}{R} + C\frac{dP}{dt}$$

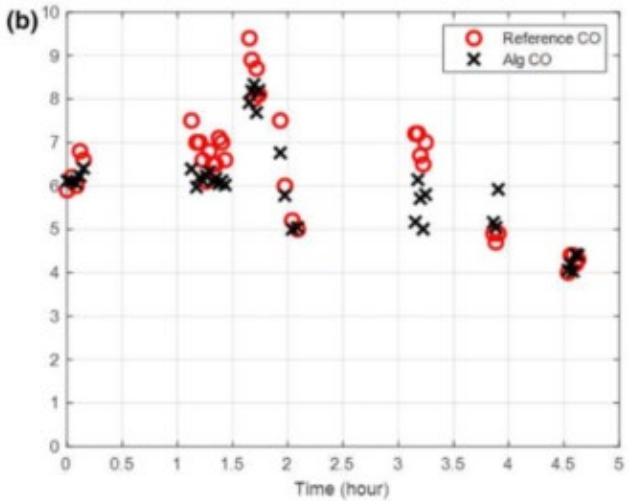
$$P = P_0 e^{-\frac{t}{RC}} + i_{pump}R$$

CO = MAP / SVR

Impella CO measurement validated in preclinical studies

- Performance evaluated in N=12 acute preclinical studies
- Strong correlation with bolus thermodilution, equivalent measurement accuracy (PE < 30%)
- Improved repeatability vs. individual thermodilution injections (6 vs. 18%)
- Consistent trending in CO over elevated and depressed physiologic states

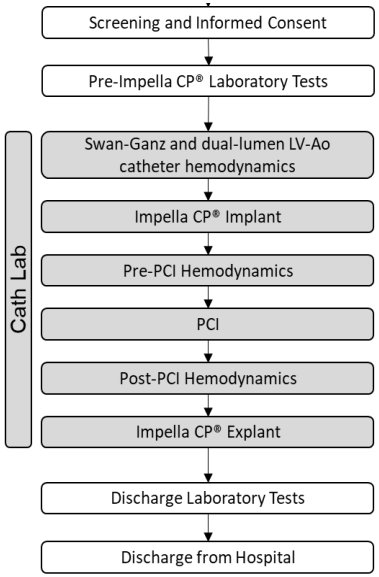




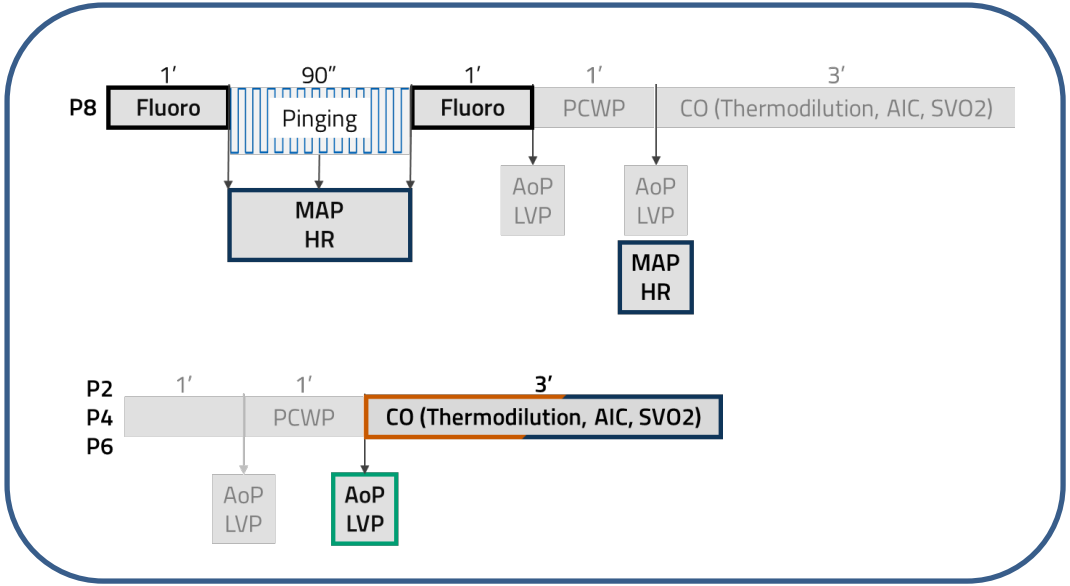
Currently enrolling in prospective clinical study

SMART PUMP STUDY

SmartPump Study Flow



Data Collection: Synchronized, High Quality HD Reference Data



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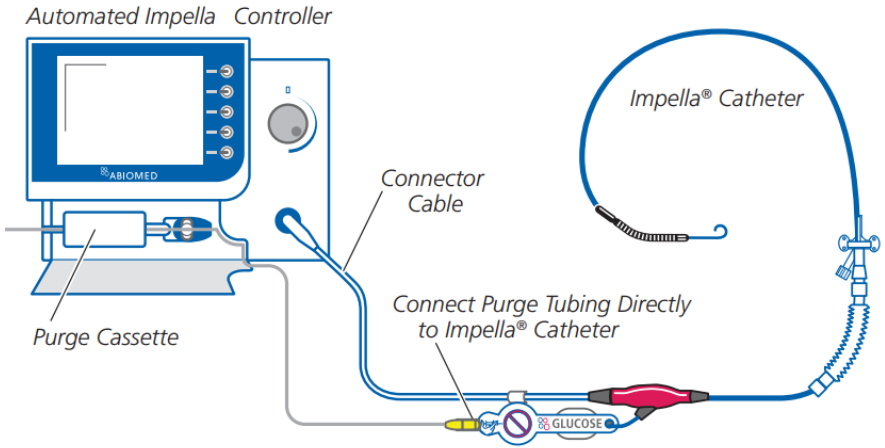
Design of the Impella *Hemodynamics Platform*

Built on the
Impella CP with **SmartAssist** platform

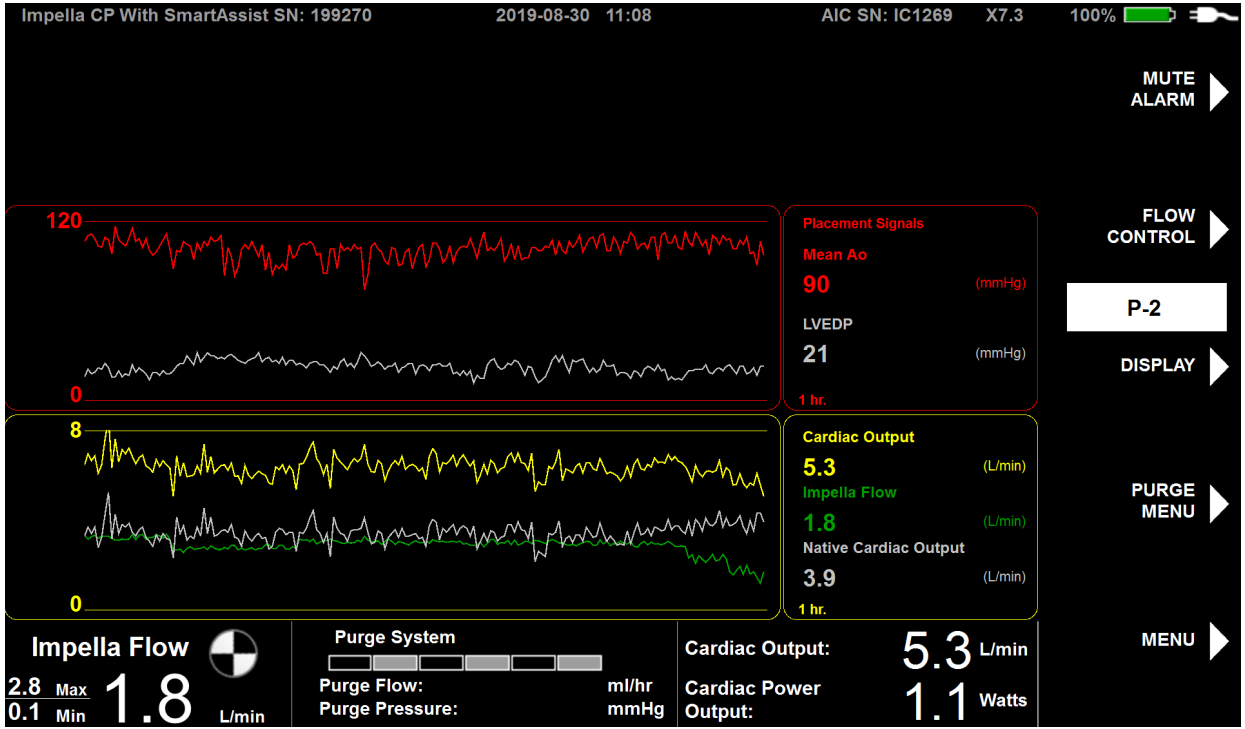


With **new** (investigational) **features**:

Cardiac Output
Continuous
Accurate
Internal calibration

LVEDP
Continuous
Accurate
Self calibration

Continuous metric trends can improve patient management

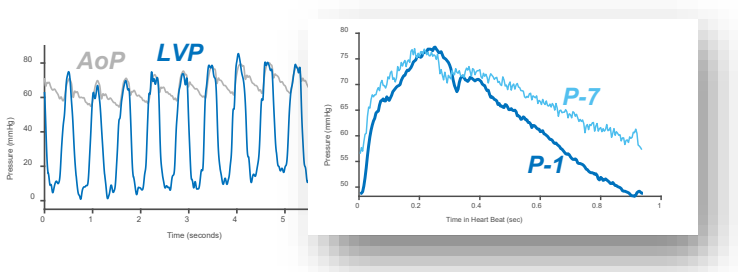


Continuous LVEDP, MAP, and CO

Pump flow vs. Native Heart CO

High-res, synchronized trends

Innovation fueled by academic-industry collaboration

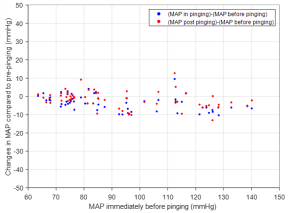


Mechanisms to measure LVEDP, CO translated to Impella system

Criteria No.	Description
1	Successful pinging calibration
2	The presence of an Impella position alarm
3	Sustained ventricular arrhythmias requiring cardioversion or temporary pacing
4	Severe hypotension
5	Device malfunctions
6	Device failures

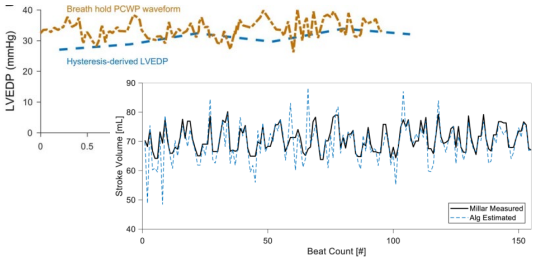
Subject No.	Safety Criteria					
	1	2	3	4	5	6
1	7/7**	0/7	0/7	0/7	0/7	0/7
2	8/8	0/8	0/8	0/8	0/8	0/8
3	7/7**	0/7*	0/7	0/7	0/7	0/7
4	8/8	0/8	0/8	0/8	0/8	0/8
5	8/8	0/8	0/8	0/8	0/8	0/8
6	8/8	0/8	0/8	0/8	0/8	0/8
7	8/8	0/8	0/8	0/8	0/8	0/8
8	8/8	0/8	0/8	0/8	0/8	0/8
Total	62/62	0/62	0/62	0/62	0/62	0/62

*Denominators reflect number of subjects evaluated. Numerators reflect number of subjects that met the safety criteria outlined in Table 2.7
**denotes that one (1) pinging attempt (at max flow, PB) was not attempted (due to pump suction)
* denotes minor repositioning after pinging caused by subject's movement, no position alarm was triggered



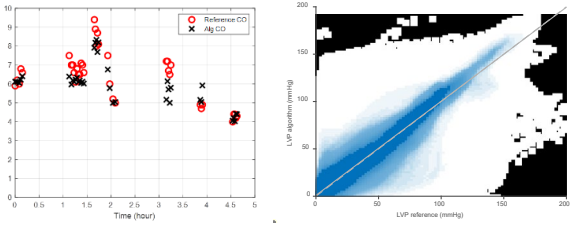
First-in-Human – 8 patients
Evaluated safety and feasibility

Foundational research in device-heart interactions



Chang et al., STM 2018 *Chang et al., IEEE 2019*

Preclinical – 20 validation studies
Proving equivalence to diagnostic devices



Keller et al., IEEE TBME *Keller et al., Annals BME 2020*
2020

SMART PUMP STUDY

QUESTIONS

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