Innovazione e intelligenza artificiale: l'Impella SmartAssist

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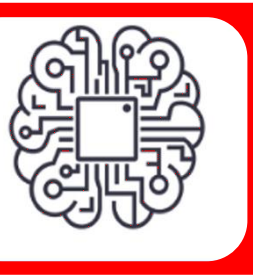
Artificial Intelligence

- The English mathematician Alan Turing, named by some as the father of artificial intelligence, developed the famous code breaking machine The Bombe for the British government, which broke the Enigma code, used by the German army in the Second World War.
- Artificial intelligence is a computer science field that studies the problem of building agents which take the best possible course of action in a specific situation.
- Cardiology is at the forefront of artificial intelligence revolution in medicine

The field of Artificial Intelligence

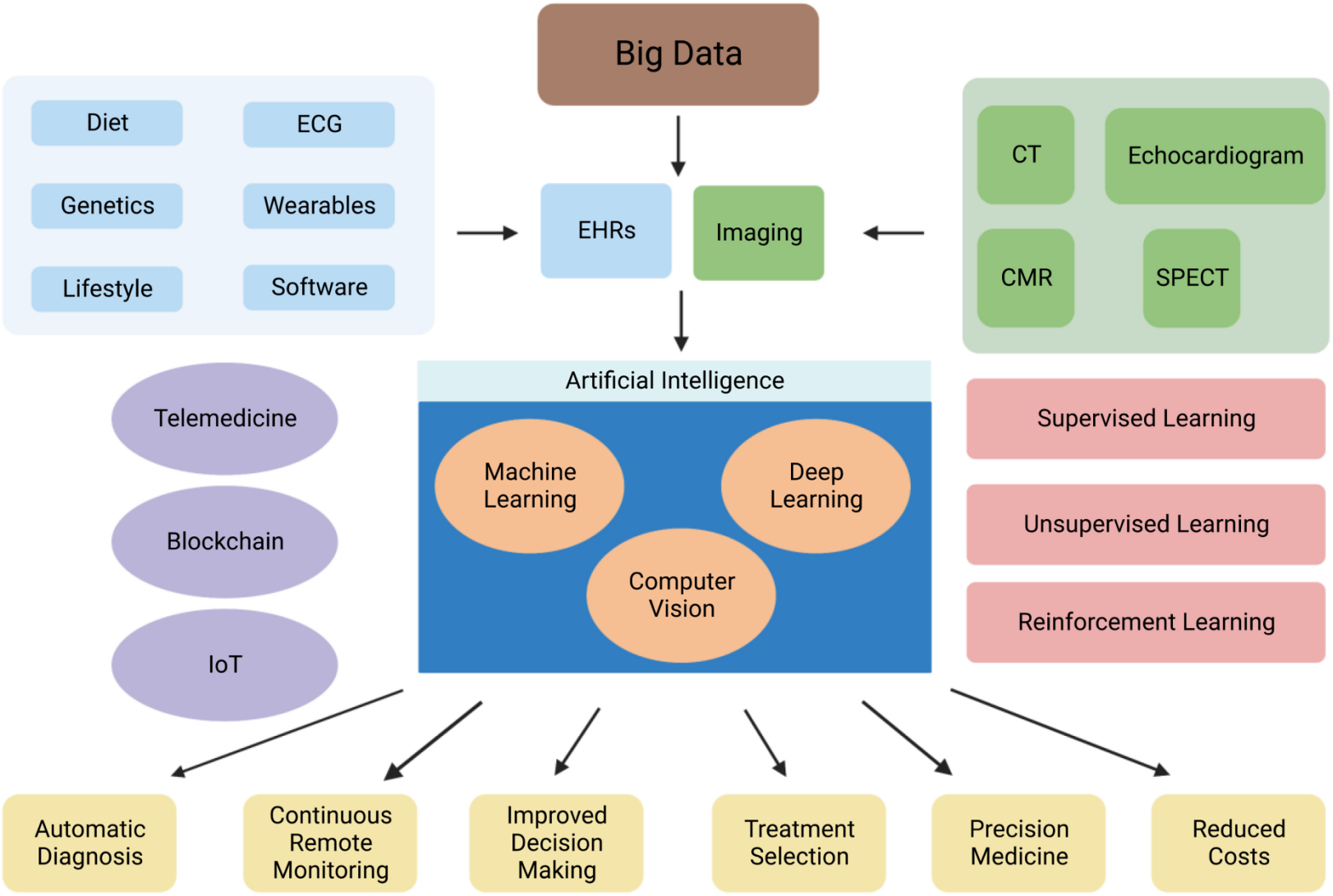


Artificial Intelligence: any technique that allows computer systems to mimic the human intelligence and behaviour

Machine Learning: subset of AI, that uses statistical techniques to enable machines to learn from data and improve with experience

Deep Learning: subset of ML, in which multilayered neural networks learn from vast amounts of data

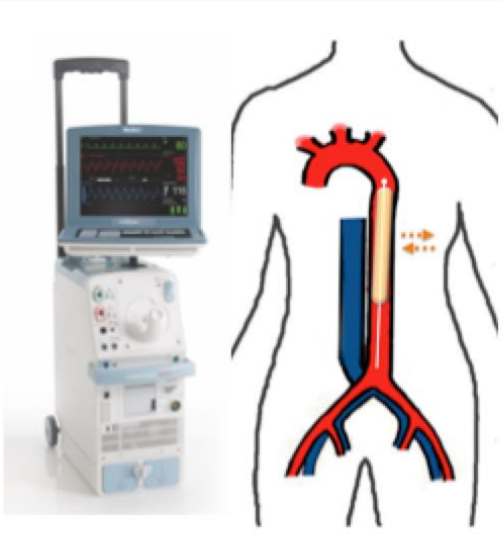
Artificial Intelligence & Cardiology



Karatzia L et al Frontiers 2022

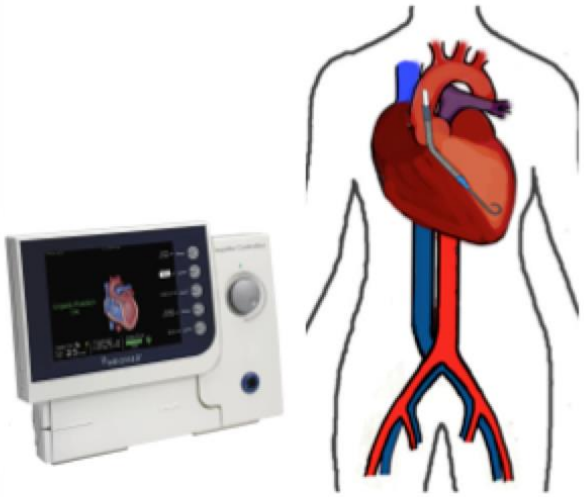
AI & Left ventricle support

IABP



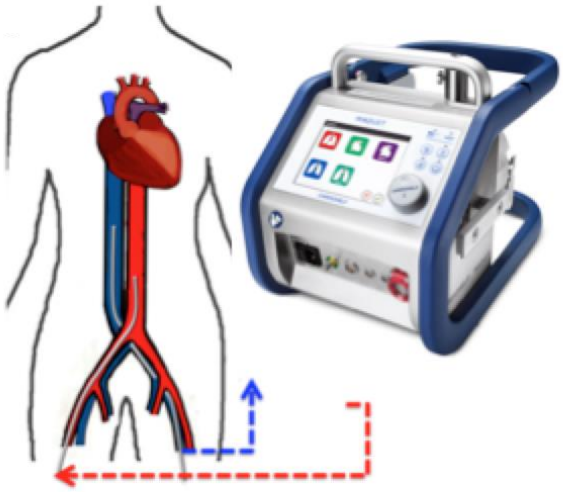
French	8-9
Cardiac Work	–
Mean AP	↑
Cardiac Output	↑
Coronary Blood Flow	↑
LV Unloading	↑

Impella



French	13 (2.5) – 14 (CP)
Cardiac Work	↓
Mean AP	↑
Cardiac Output	↑↑
Coronary Blood Flow	↑↑
LV Unloading	↑↑

ECMO



French	15/17 A 21/23 V
Cardiac Work	↑
Mean AP	↑
Cardiac Output	↑↑↑
Coronary Blood Flow	↑↑↑
LV Unloading	–/↓

Russo G et al Cardiol J. 2022

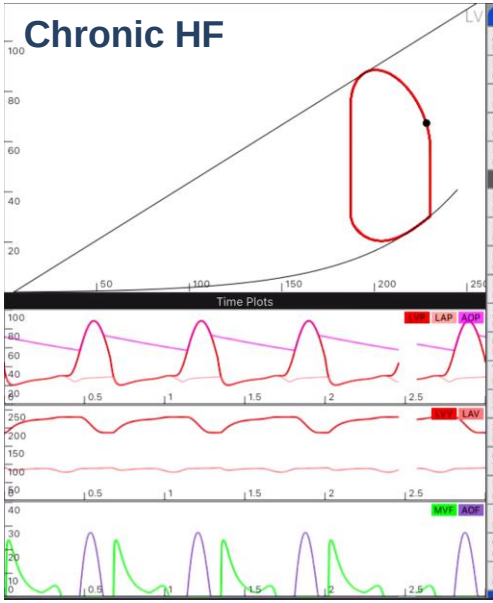
PV Loop

Normal

Hemodynamics		
AoP mmHg	124/61 (83)	
PAP mmHg	30/12 (15)	
LAP mmHg	16/7 (11)	
RAP mmHg	8/2 (3)	
PWP/CVP mmHg	12	6
	LV	RV
EDV ml	140	117
EDP mmHg	16	8
ESV ml	52	30
ESP mmHg	104	19
SV ml	89	89
CO L/min	5.35	5.35
VAD L/min	0.00	0.00
EF %	64	76
SW mmHg·ml	9245	2029
CPO Watts	0.98	0.18
PVA mmHg·ml	11854	2280
MVO2 ml/min	22.43	2.69
CBF/g ml/min/g	-----	
Pperi mmHg	0	

PV Loop

Chronic HF



Hemodynamics		
AoP mmHg	89/57 (68)	
PAP mmHg	49/29 (33)	
LAP mmHg	30/21 (27)	
RAP mmHg	5/2 (3)	
PWP/CVP mmHg	28	4
	LV	RV
EDV ml	230	84
EDP mmHg	30	5
ESV ml	194	46
ESP mmHg	87	41
SV ml	43	43
CO L/min	3.87	3.87
VAD L/min	0.00	0.00
EF %	19	51
SW mmHg·ml	2533	1824
CPO Watts	0.58	0.28
PVA mmHg·ml	9764	2477
MVO2 ml/min	22.73	4.27
CBF/g ml/min/g	-----	
Pperi mmHg	0	

Normal

Hemodynamics		
AoP mmHg	124/61 (83)	
PAP mmHg	30/12 (15)	
LAP mmHg	16/7 (11)	
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CBF/g ml/min/g	-----	
Pperi mmHg	0	

PV Loop

Normal

Hemodynamics		
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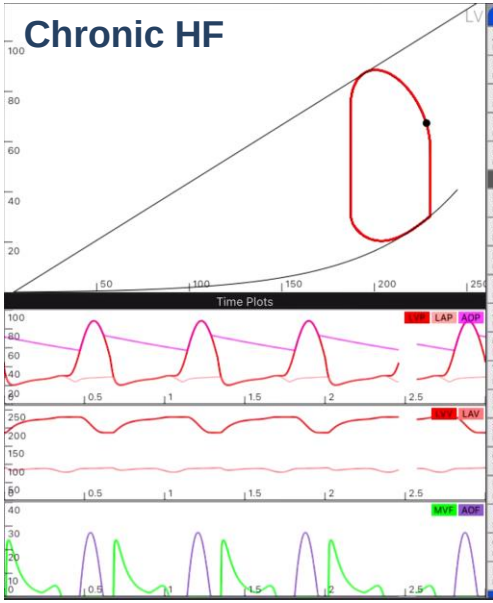
CBF/g ml/min/g	-----	
Pperi mmHg	0	

Chronic HF



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PVA mmHg·ml	9764	2477
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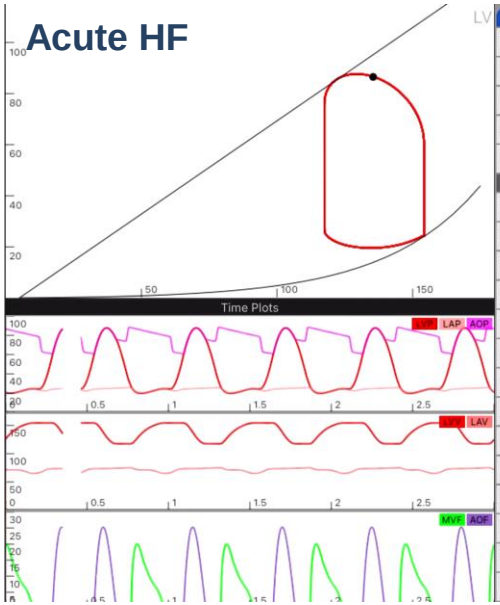
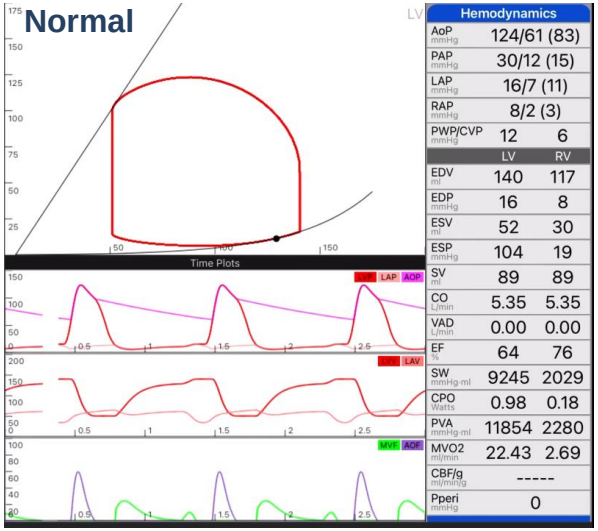
CBF/g ml/min/g	-----	
Pperi mmHg	0	

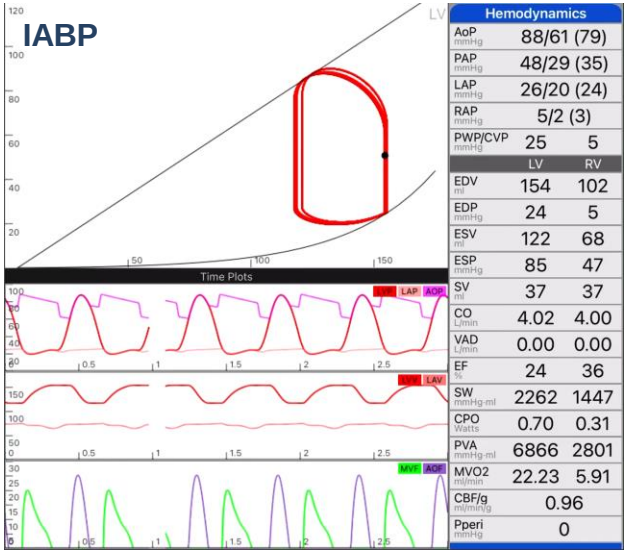
Acute HF



Hemodynamics		
AoP mmHg	88/61 (79)	
PAP mmHg	48/29 (35)	
LAP mmHg	26/20 (24)	
RAP mmHg	5/2 (3)	
PWP/CVP mmHg	25	5
	LV	RV
EDV ml	154	102
EDP mmHg	24	5
ESV ml	121	68
ESP mmHg	85	47
SV ml	37	37
CO L/min	4.02	4.02
VAD L/min	0.00	0.00
EF %	24	36
SW mmHg·ml	2261	1453
CPO Watts	0.70	0.31
PVA mmHg·ml	6860	2807
MVO2 ml/min	22.22	5.92
CBF/g ml/min/g	0.96	
Pperi mmHg	0	

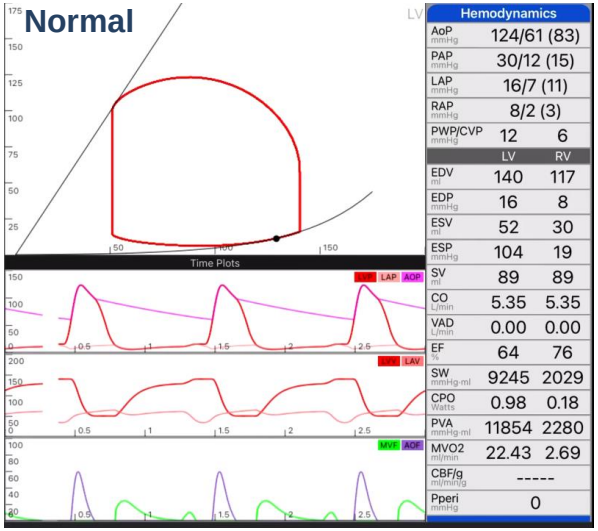
PV Loop & LV support





PV Loop & LV support

Normal



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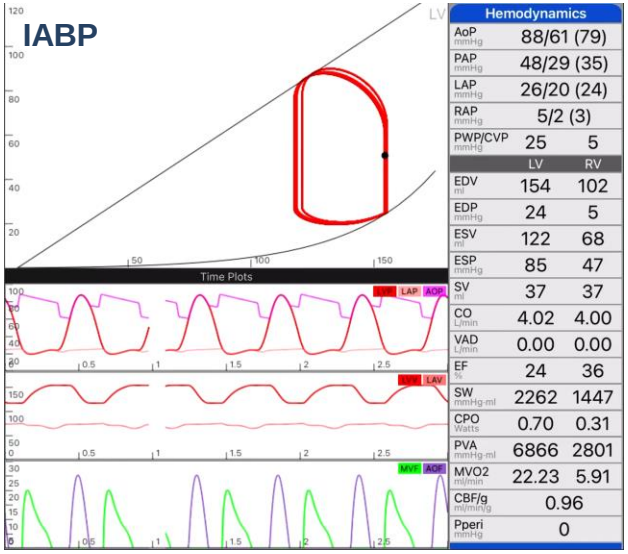
ESV ml	52	30
ESP mmHg	104	19
SV ml	89	89
CO L/min	5.35	5.35
VAD L/min	0.00	0.00
EF %	64	76
SW mmHg·ml	9245	2029
CPO Watts	0.98	0.18
PVA mmHg·ml	11854	2280
MVO2 ml/min	22.43	2.69
CBF/g ml/min/g	-----	
Pperi mmHg	0	

IABP



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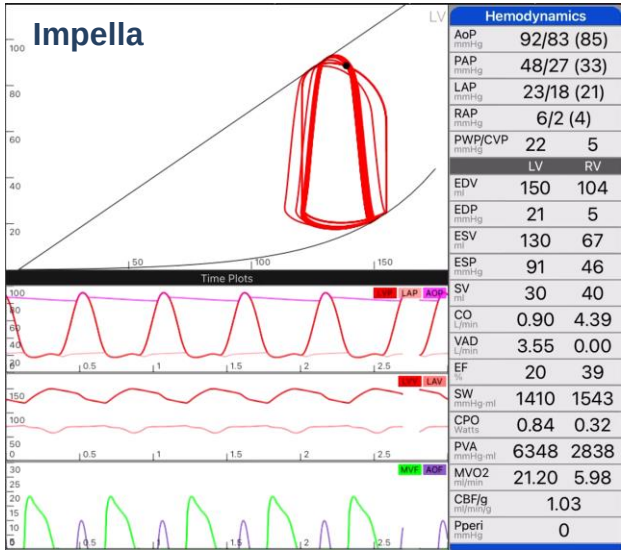
ESV ml	122	68
ESP mmHg	85	47
SV ml	37	37
CO L/min	4.02	4.00
VAD L/min	0.00	0.00
EF %	24	36
SW mmHg·ml	2262	1447
CPO Watts	0.70	0.31
PVA mmHg·ml	6866	2801
MVO2 ml/min	22.23	5.91
CBF/g ml/min/g	0.96	
Pperi mmHg	0	

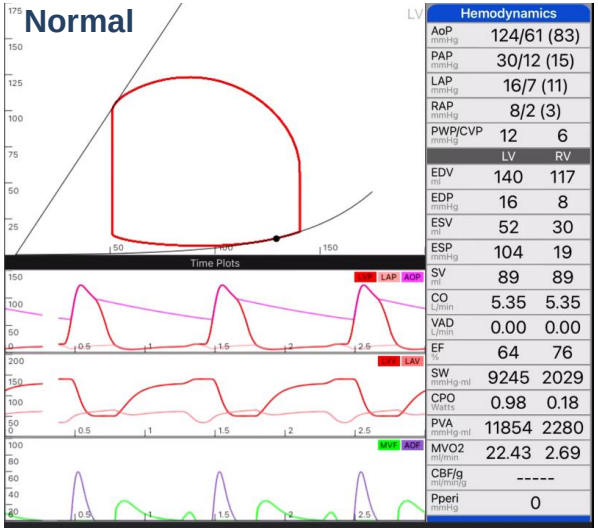
Impella



Hemodynamics		
AoP mmHg	92/83 (85)	
PAP mmHg	48/27 (33)	
LAP mmHg	23/18 (21)	
RAP mmHg	6/2 (4)	
PWP/CVP mmHg	22	5
	LV	RV
EDV ml	150	104
EDP mmHg	21	5
ESV ml	130	67
ESP mmHg	91	46
SV ml	30	40
CO L/min	0.90	4.39
VAD L/min	3.55	0.00
EF %	20	39
SW mmHg·ml	1410	1543
CPO Watts	0.84	0.32
PVA mmHg·ml	6348	2838
MVO2 ml/min	21.20	5.98
CBF/g ml/min/g	1.03	
Pperi mmHg	0	

PV Loop & LV support

Normal



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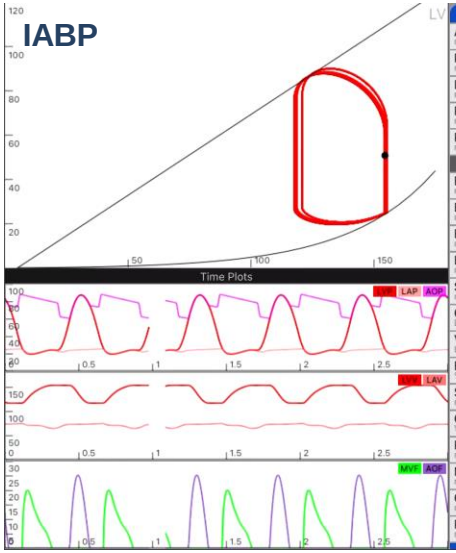
CBF/g ml/min/g	-----	
Pperi mmHg	0	

IABP



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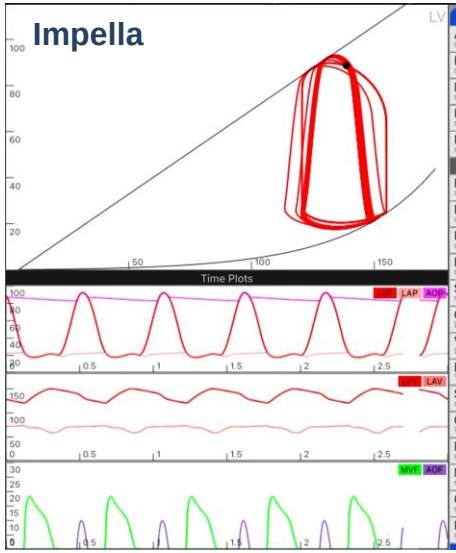
Pperi mmHg	0	

Impella



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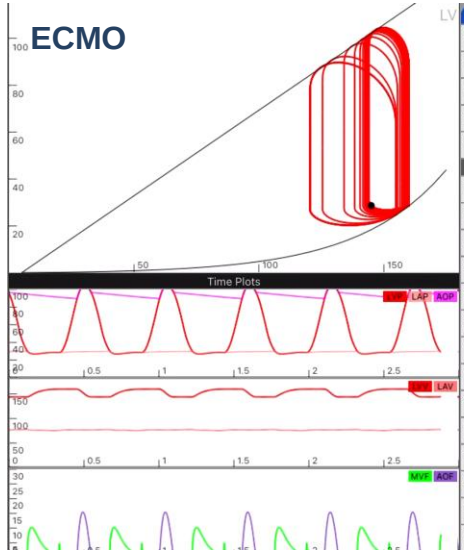
CBF/g ml/min/g	1.03	
Pperi mmHg	0	

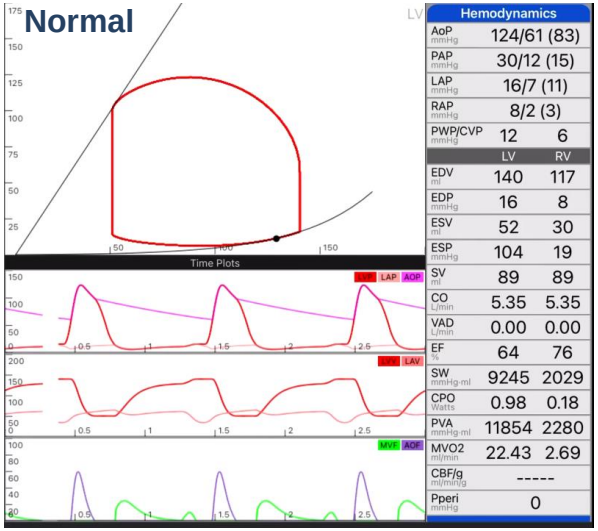
ECMO



Hemodynamics		
AoP mmHg	105/90 (94)	
PAP mmHg	41/31 (34)	
LAP mmHg	30/27 (29)	
RAP mmHg	3/1 (1)	
PWP/CVP mmHg	29	3
	LV	RV
EDV ml	160	75
EDP mmHg	29	2
ESV ml	147	60
ESP mmHg	103	41
SV ml	16	16
CO L/min	1.75	1.77
VAD L/min	3.28	0.00
EF %	10	22
SW mmHg·ml	1191	589
CPO Watts	1.05	0.13
PVA mmHg·ml	7738	1644
MVO2 ml/min	23.96	3.75
CBF/g ml/min/g	1.16	
Pperi mmHg	0	

PV Loop & LV support

Normal



Hemodynamics		
AoP mmHg	124/61 (83)	
PAP mmHg	30/12 (15)	
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VAD L/min	0.00	0.00
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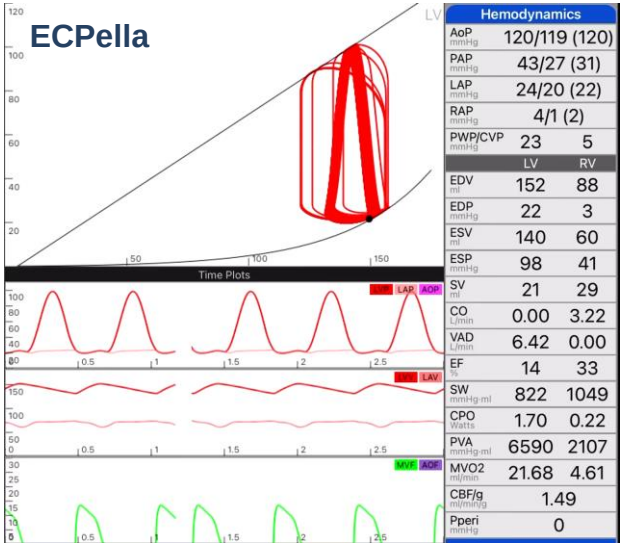
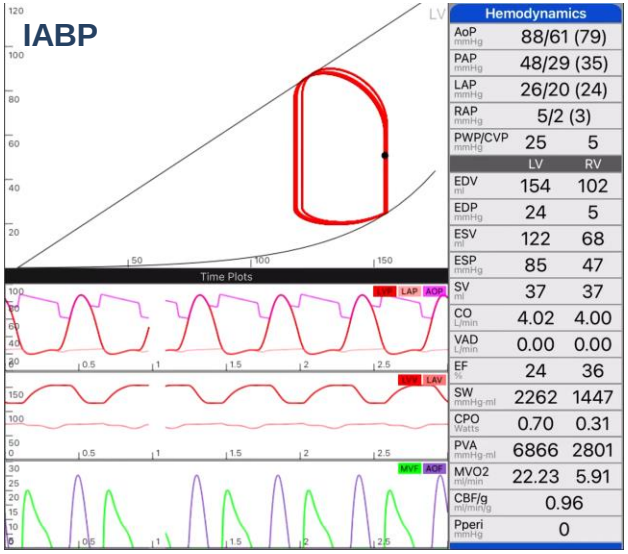
PVA mmHg·ml	11854	2280
MVO2 ml/min	22.43	2.69
CBF/g ml/min/g	-----	
Pperi mmHg	0	

ECPella



Hemodynamics		
AoP mmHg	120/119 (120)	
PAP mmHg	43/27 (31)	
LAP mmHg	24/20 (22)	
RAP mmHg	4/1 (2)	
PWP/CVP mmHg	23	5
	LV	RV
EDV ml	152	88
EDP mmHg	22	3
ESV ml	140	60
ESP mmHg	98	41
SV ml	21	29
CO L/min	0.00	3.22
VAD L/min	6.42	0.00
EF %	14	33
SW mmHg·ml	822	1049
CPO Watts	1.70	0.22
PVA mmHg·ml	6590	2107
MVO2 ml/min	21.68	4.61
CBF/g ml/min/g	1.49	
Pperi mmHg	0	

IABP



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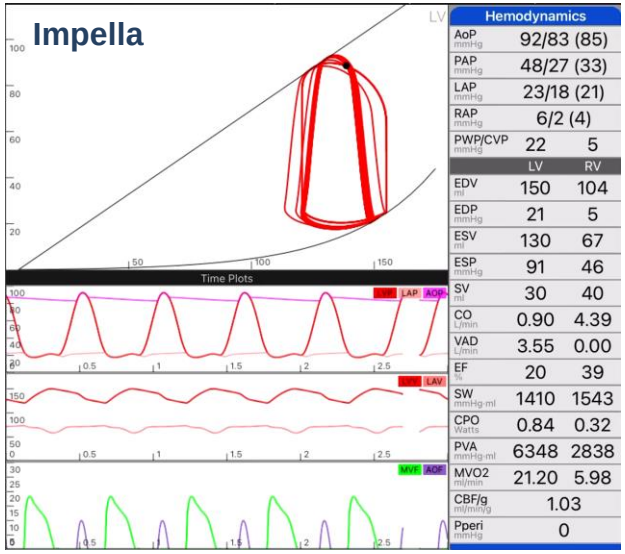
Pperi mmHg	0	

Impella



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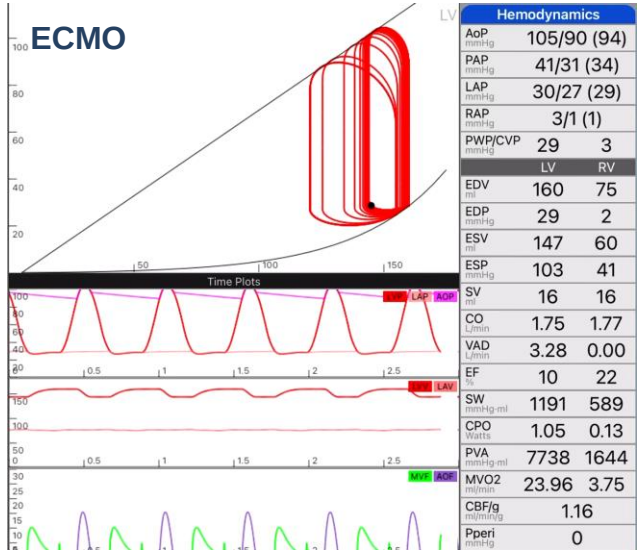
Pperi mmHg	0	

ECMO



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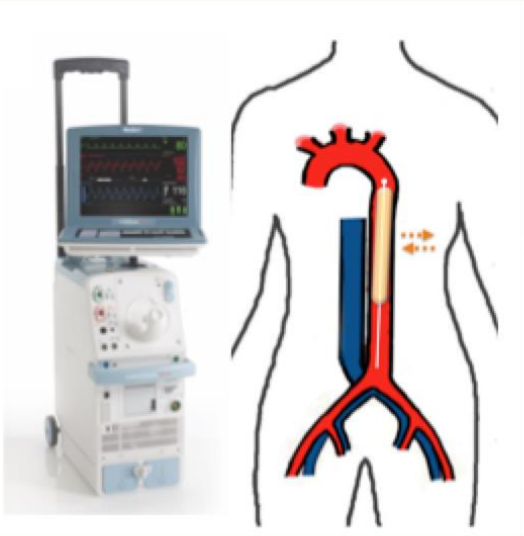
PVA mmHg·ml	7738	1644
MVO2 ml/min	23.96	3.75
CBF/g ml/min/g	1.16	
Pperi mmHg	0	

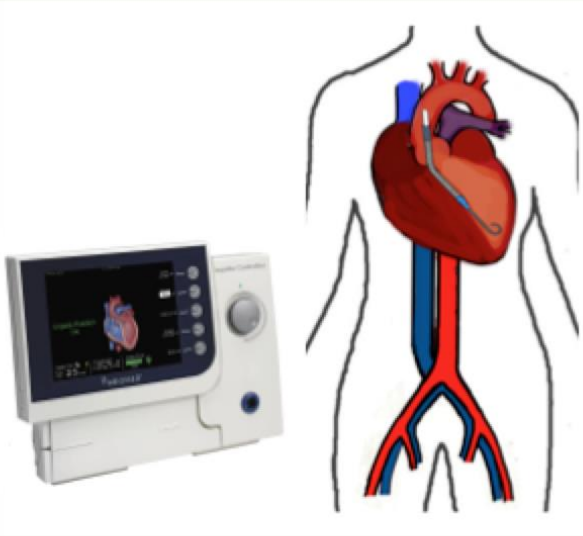
AI & Left ventricle support

IABP



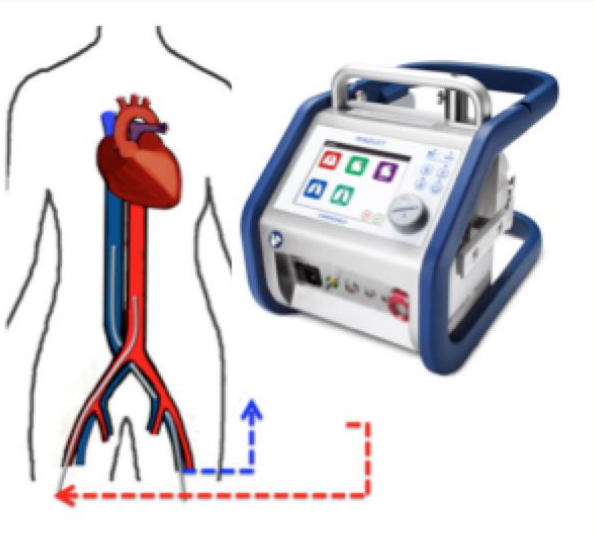
French	8-9
Cardiac Work	–
Mean AP	↑
Cardiac Output	↑
Coronary Blood Flow	↑
LV Unloading	↑

Impella



French	13 (2.5) – 14 (CP)
Cardiac Work	↓
Mean AP	↑
Cardiac Output	↑↑
Coronary Blood Flow	↑↑
LV Unloading	↑↑

ECMO

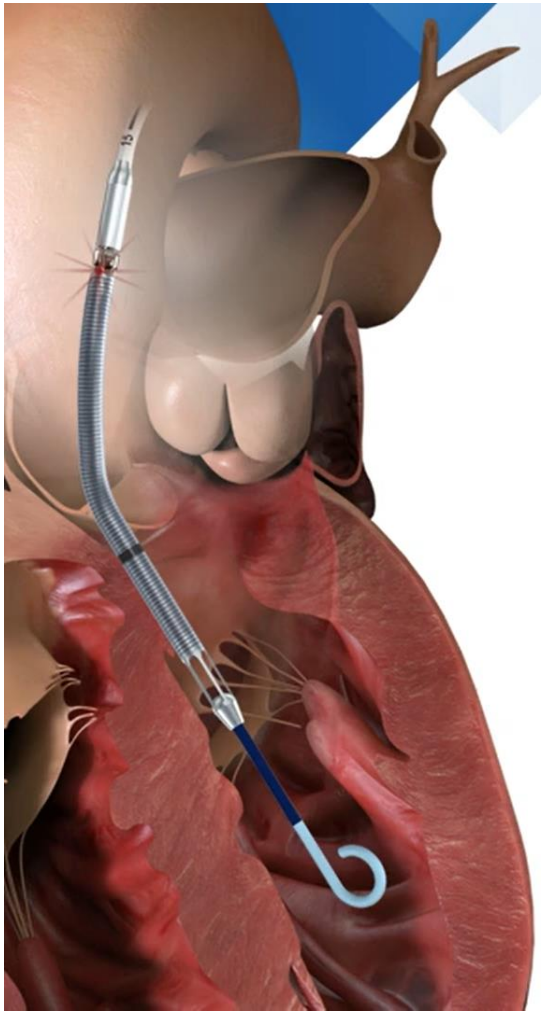


French	15/17 A 21/23 V
Cardiac Work	↑
Mean AP	↑
Cardiac Output	↑↑↑
Coronary Blood Flow	↑↑↑
LV Unloading	–/↓

Advanced technologies such as wireless devices and remote monitoring are quite promising in that regard. Advanced artificial intelligence algorithms might help to improve patient selection, ameliorate early detection of complications, and offer further guidance to manage those complications.

AI & Impella Smart Assist

The latest innovation on Smart Assist Platform



- ✓ New sensor technology allows for repositioning in the ICU without the need for imaging
- ✓ Intelligently position, manage and wean
- ✓ Cloud-based, remote viewing for collaborative patient management

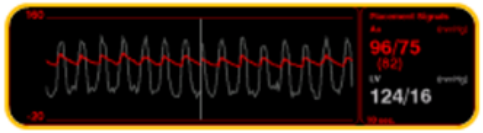
Smart Assist: Intelligent Pump Metrics

Display of LV Waveform

LVP = AoP − Pressure Gradient (dP)

LVP

LV Waveform

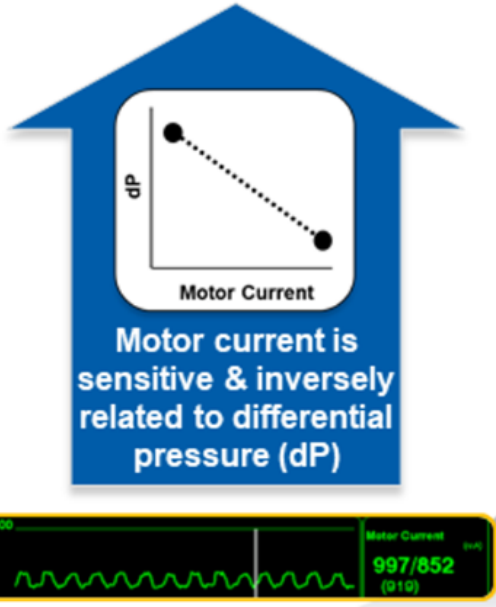


AoP

Pressure Sensor

Pressure Gradient (dP)

Derived from Motor Current



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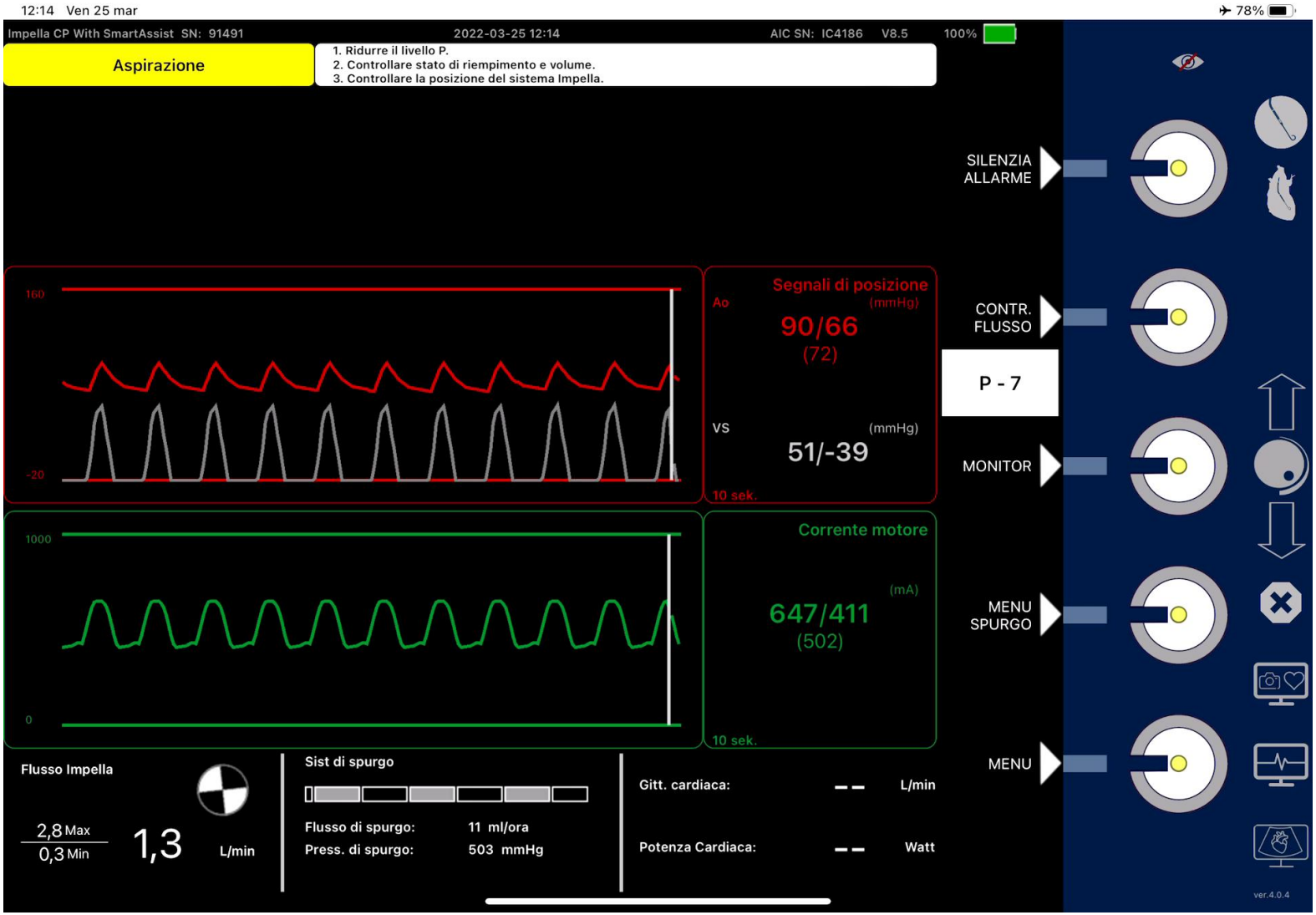

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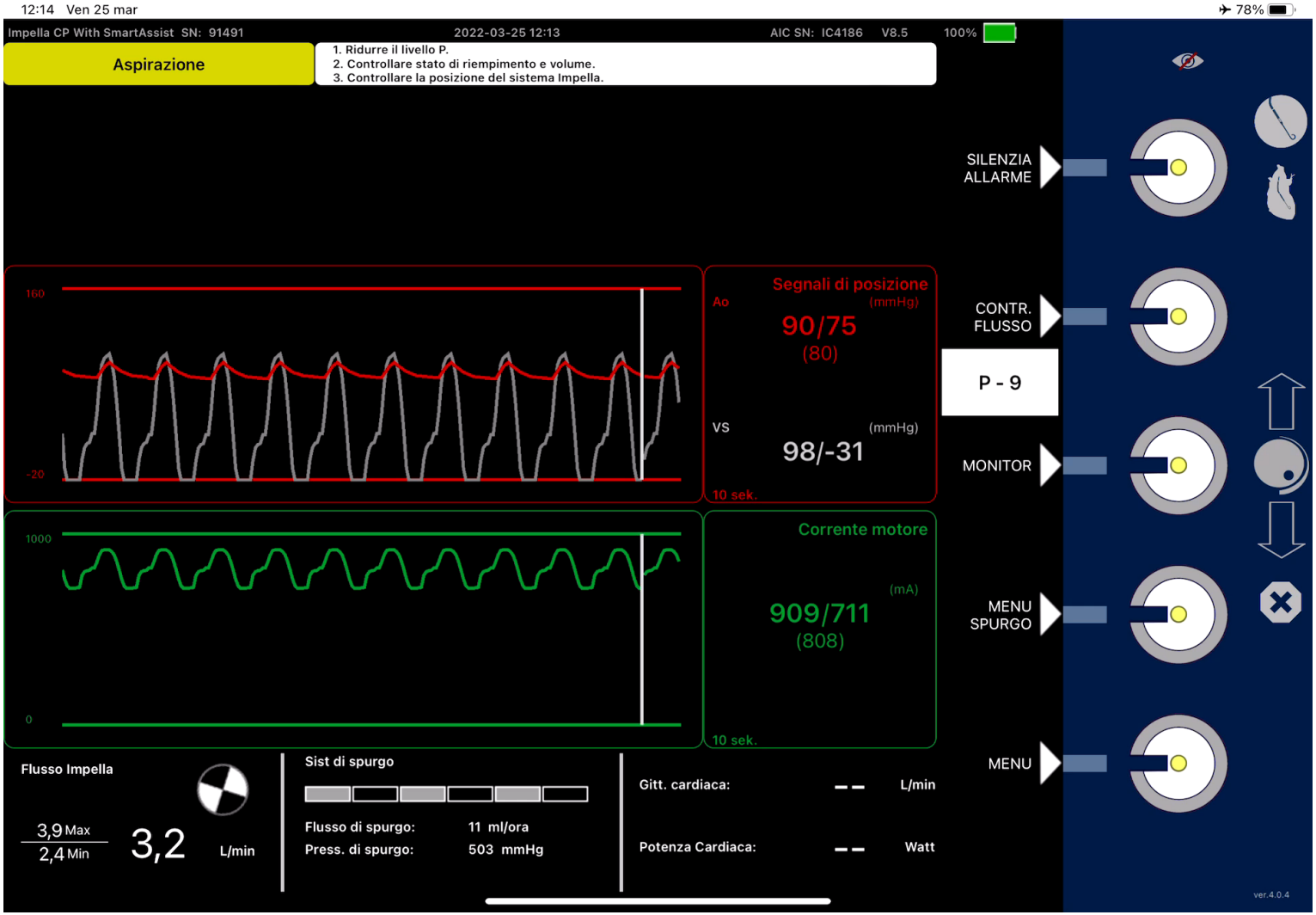

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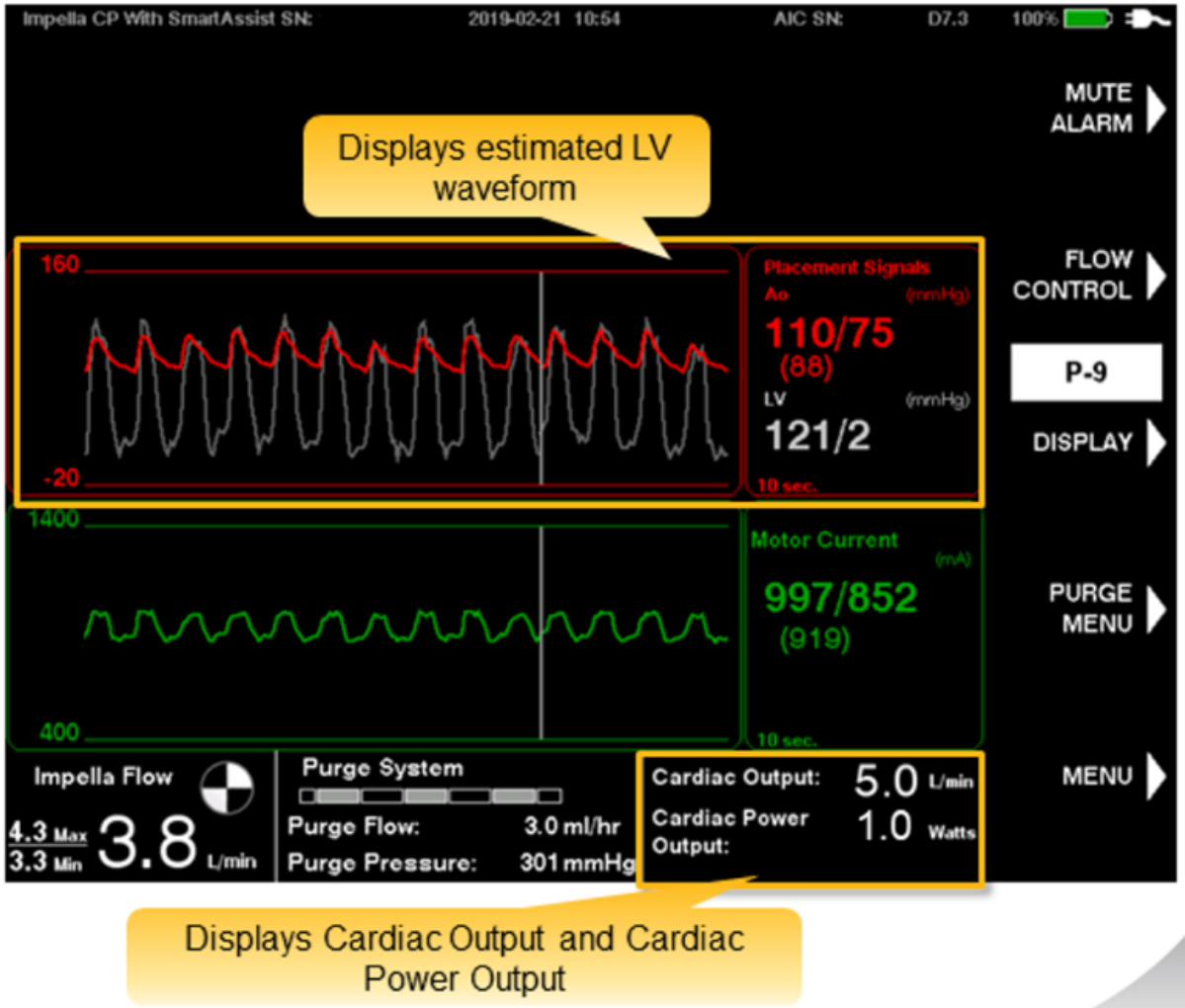
Smart Assist: Intelligent Pump Metrics



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Smart Assist: Intelligent Pump Metrics

Cardiac Output Metrics

Fundamental Relationship

$$\text{Cardiac Output} = \text{Pulse Pressure}^{*} \times \text{Vascular State (SVR, Compliance)}$$

Vascular State Calibration

Measurement of **CO** with PA-catheter or Fick CO Estimate

and

Concurrent **pulse pressure** measurement from Impella

$$VS_0 = \frac{\text{Cardiac Output}^{(\text{PA-C or Fick})}}{\text{Pulse Pressure}_0}$$

Cardiac Output Metrics

1. $CO_{Native} = PP \times VS$
2. $CO_{Total} = CO_{Native} + \text{Impella Flow}$
3. $CPO = \frac{CO \times MAP}{451}$

*Vascular State calibration requires a measurable pulse pressure. Calibrations are not recommended when arterial waveform is flat. VS is assumed to be constant for up to 8 hours or until a new reference Cardiac Output is entered.

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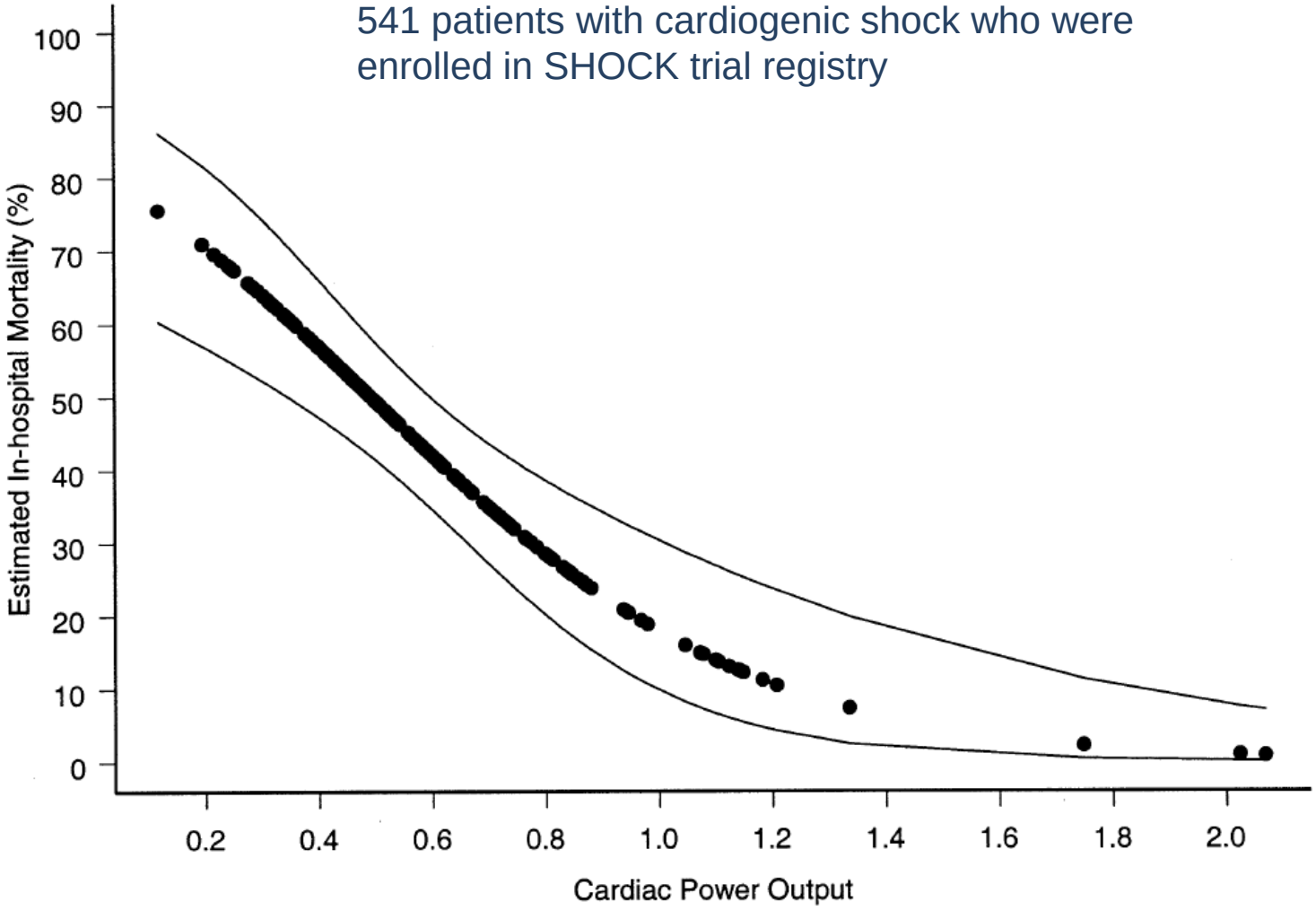
541 patients with cardiogenic shock who were enrolled in SHOCK trial registry



Fincke R et al J Am Coll Cardiol 2004

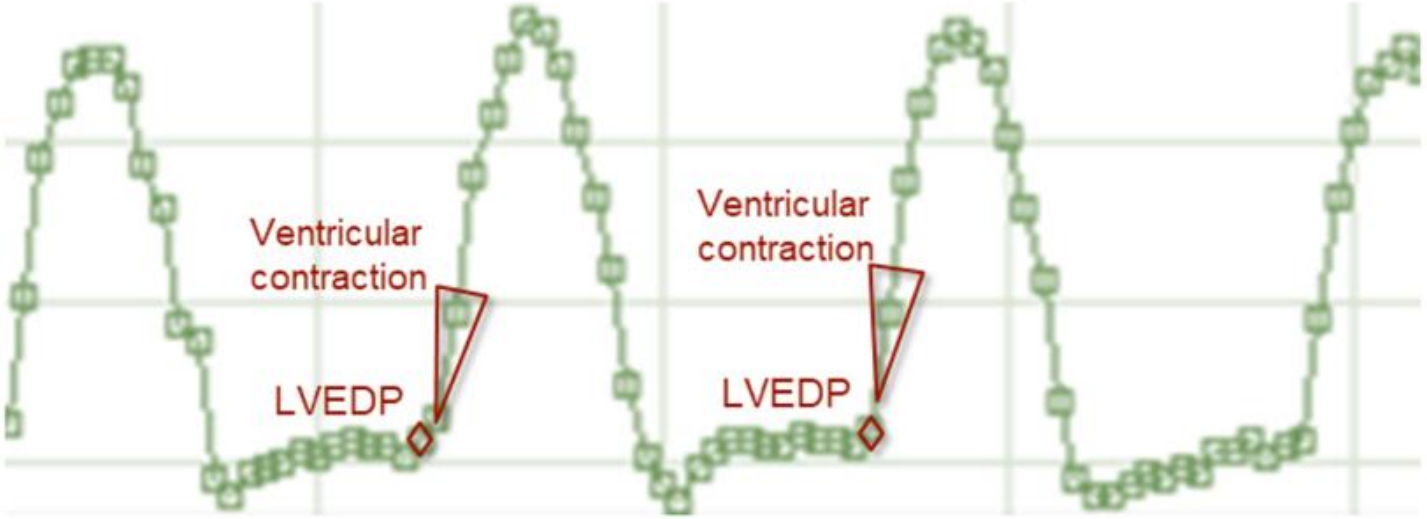
Smart Assist: Intelligent Pump Metrics

Calculating the LVEDP from the LV placement signal

The algorithm detects ventricular contraction based off the derived LV Placement Signal and calculates the pressure prior to the identified point of contraction

Ventricular contraction is detected by the rapid change in the LV placement signal

LVEDP is an average of the detected end-diastolic points on the LV placement signal over the last 10 seconds



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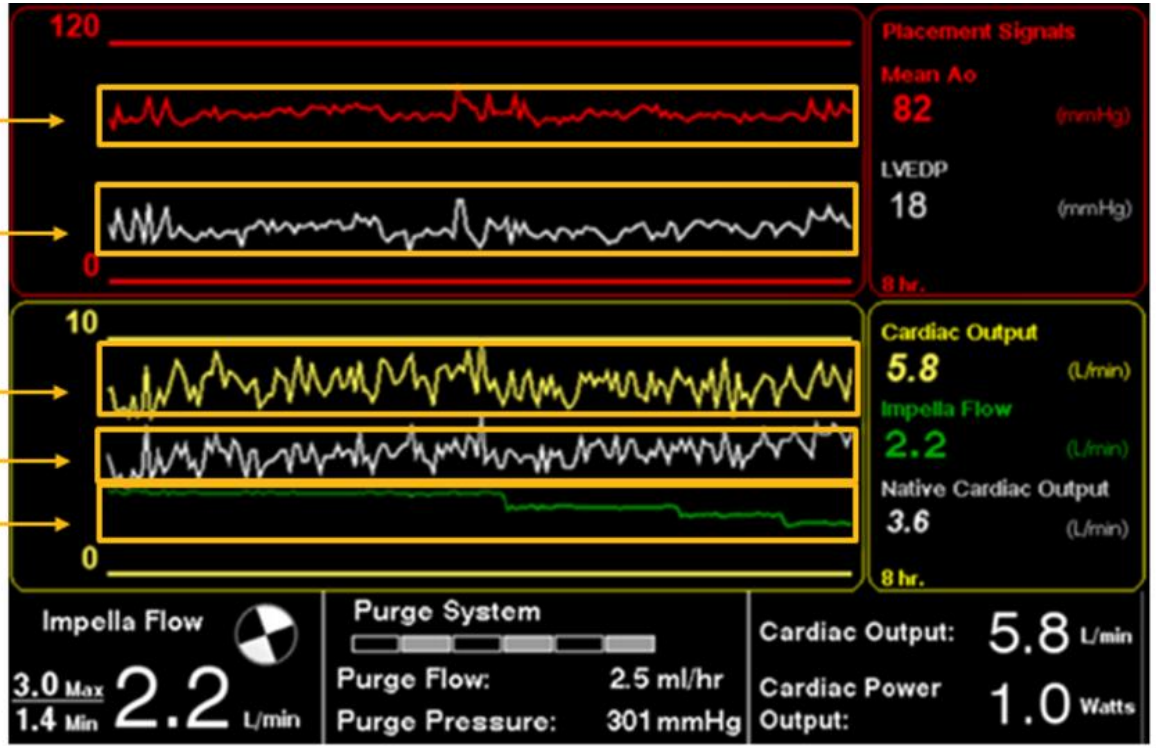
Trend Screen

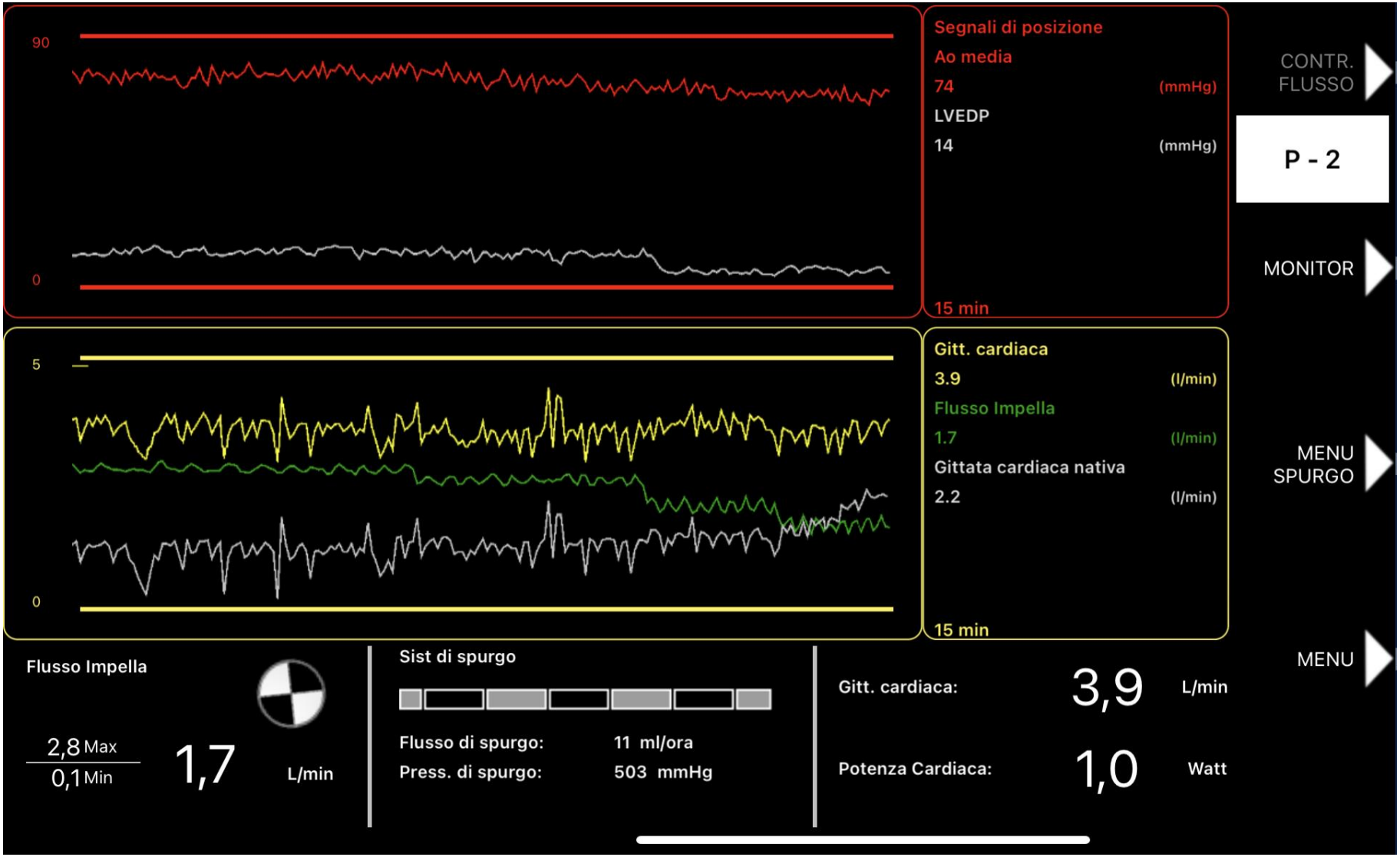
Hemodynamic trends over selectable time-scales assist clinical decision-making

1. Mean Ao Trend
2. LVEDP Trend
3. Total Cardiac Output
4. Native Cardiac Output
5. Impella Flow



AI & Impella Smart Assistance

Succefull Weaning



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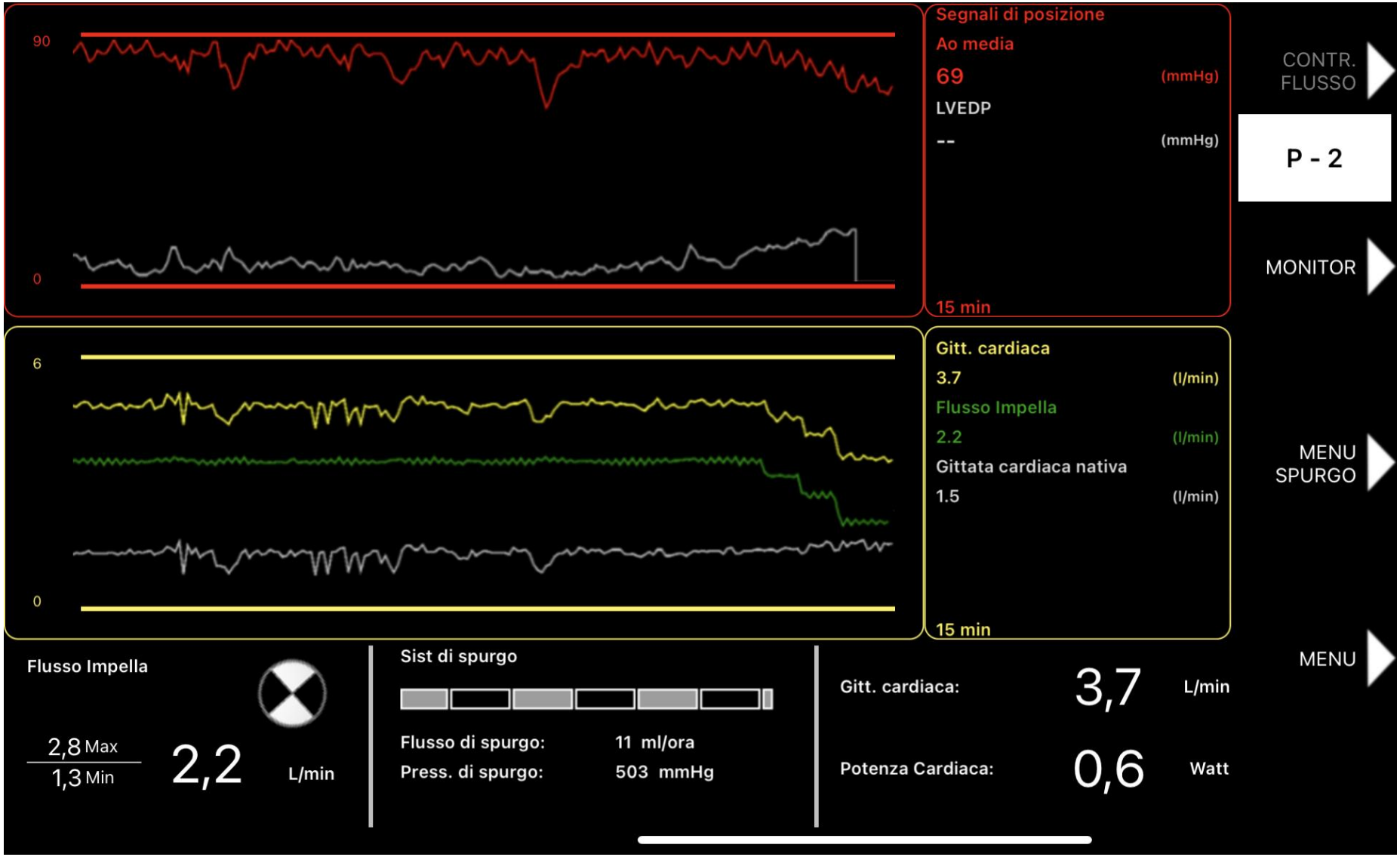
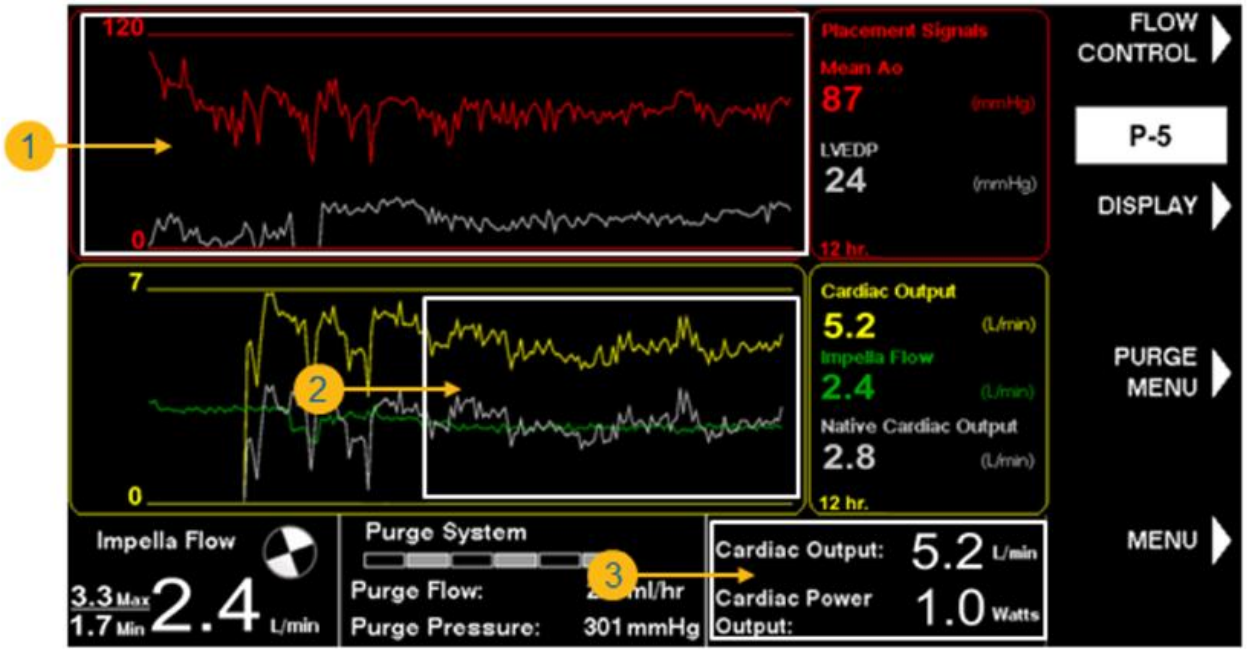
Unsuccefull Weaning



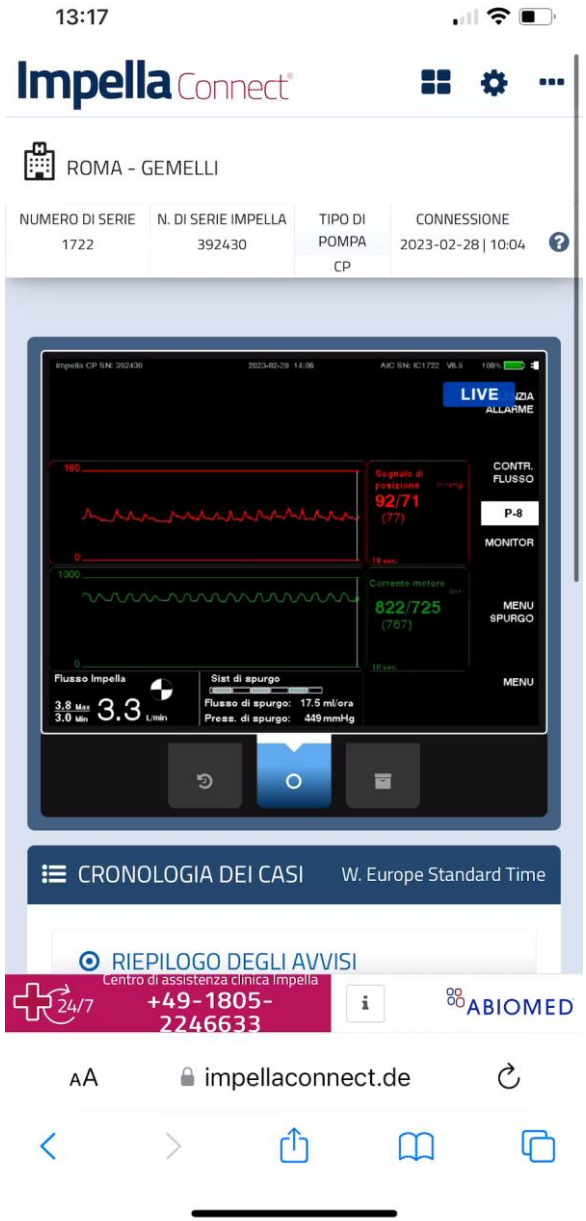
AI & Impella Smart Assistance

Unsuccefull Weaning

1. Look for stable MAP and LVEDP ✗
2. Assess native heart recovery ✓
3. Maintain stable Cardiac Output/Cardiac Power Output ✓



AI & Impella Smart Assistance



Conclusions

- ✓ AI is a new and rapidly evolving innovative field, it carries significant risks if underperforming and unregulated.
- ✓ Despite the landmark studies exhibiting the potential of AI in transforming medicine, the ethical dilemmas concerning its real-life implementation are still unaddressed
- ✓ Going forwards, education of scientists, physicians but also of the public regarding AI and the logic behind its applications is vital. This can lead to better understanding and improved engagement in commercialisation of AI applications.
- ✓ Cardiologists should educate themselves in the development of AI and take part in AI innovations and utilise them in their practice. However, they will need to take into consideration the ethical dilemmas generated in areas where AI is replacing human and aim to integrate their knowledge and AI-derived suggestions, for a mature and accurate decision making in every step in the decision process.