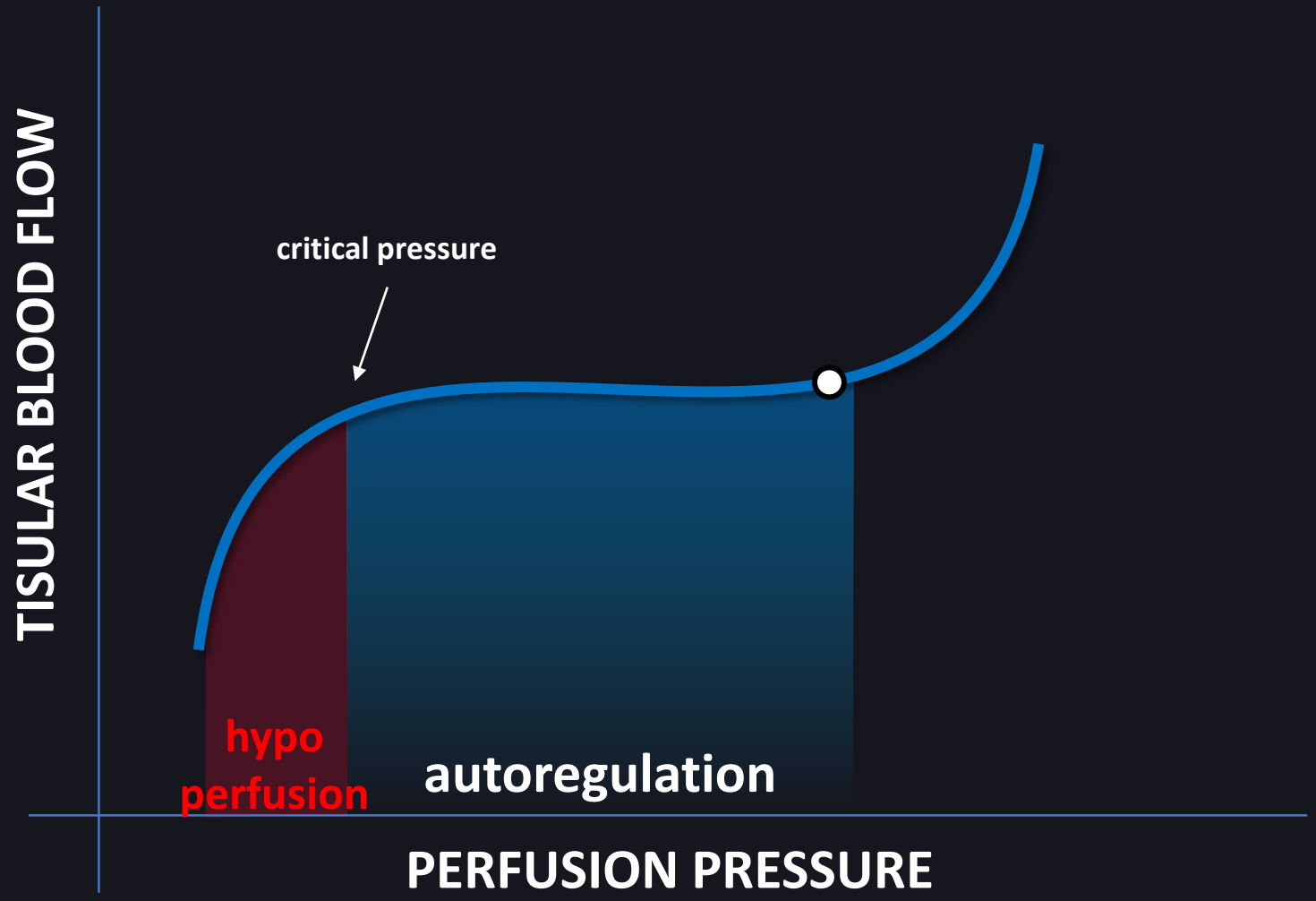
XXVVIII kongres ČSARIM,
Brno 2022

predicting hemodynamic instability

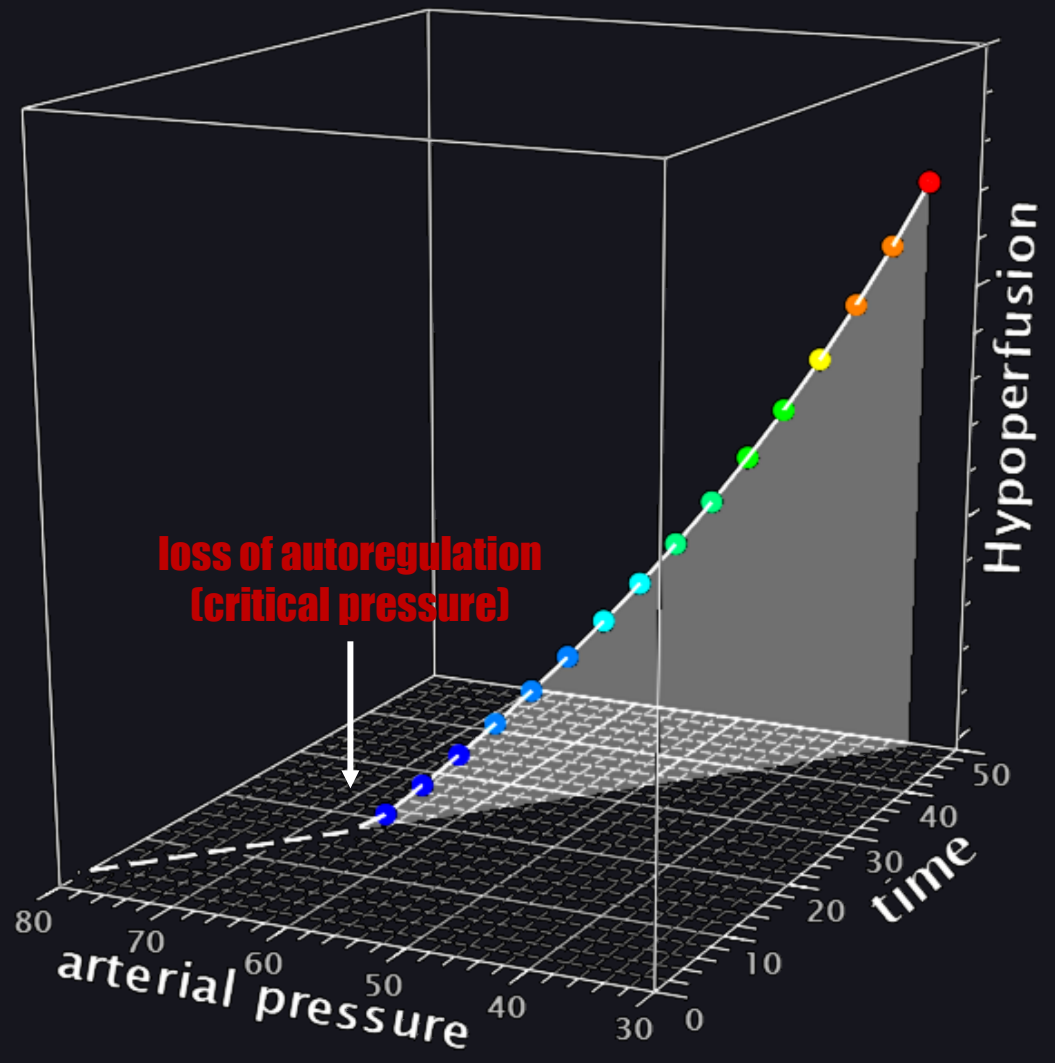
The Hypotension Prediction Index (HPI)

Dr. M. Ignacio Monge García
Hospital SAS Jerez, Spain

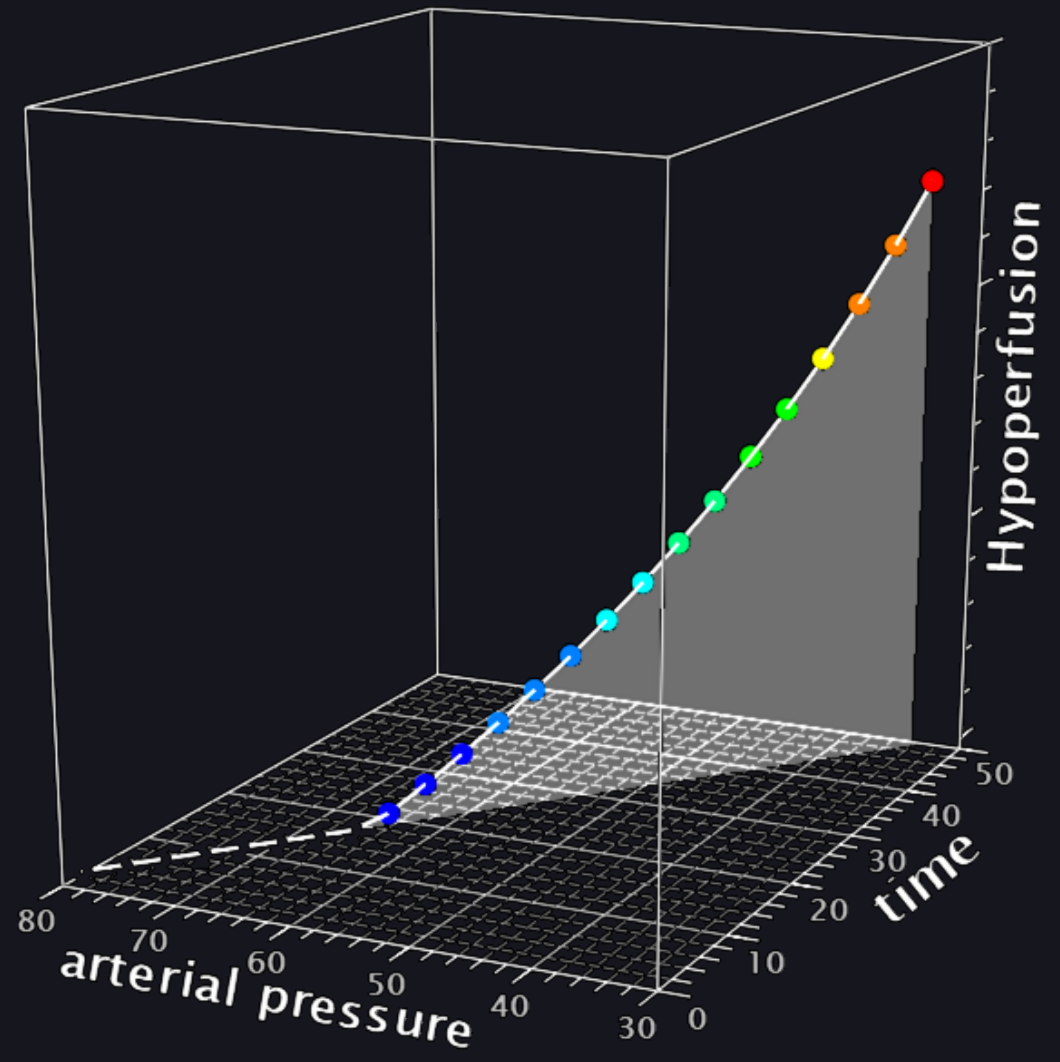
Arterial hypotension and organ hypoperfusion



Arterial hypotension and organ hypoperfusion



Arterial hypotension and organ hypoperfusion



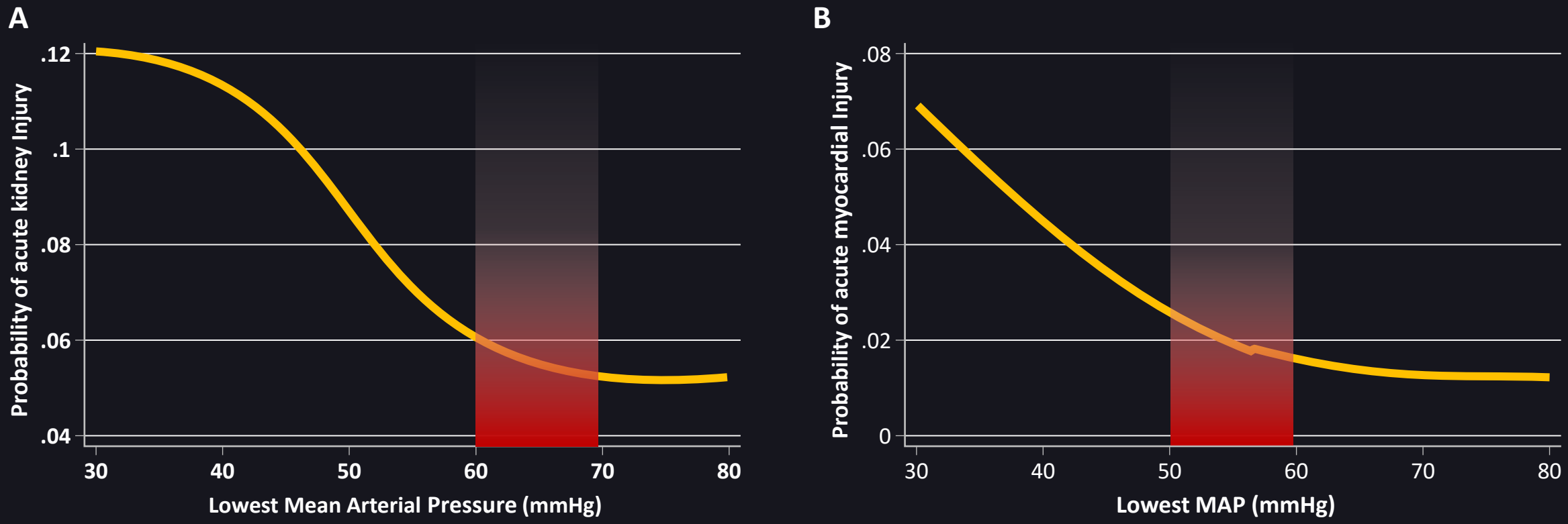
HYPOPERFUSION IS A FUNCTION OF TIME AND THE PERFUSION PRESSURE.

THE LONGER AND MORE SEVERE HYPOTENSION, THE MORE LIKELYHOOD ORGAN HYPOPERFUSION

Relationship between intraoperative arterial pressure and clinical outcomes after noncardiac surgery

Toward an empirical definition of Hypotension

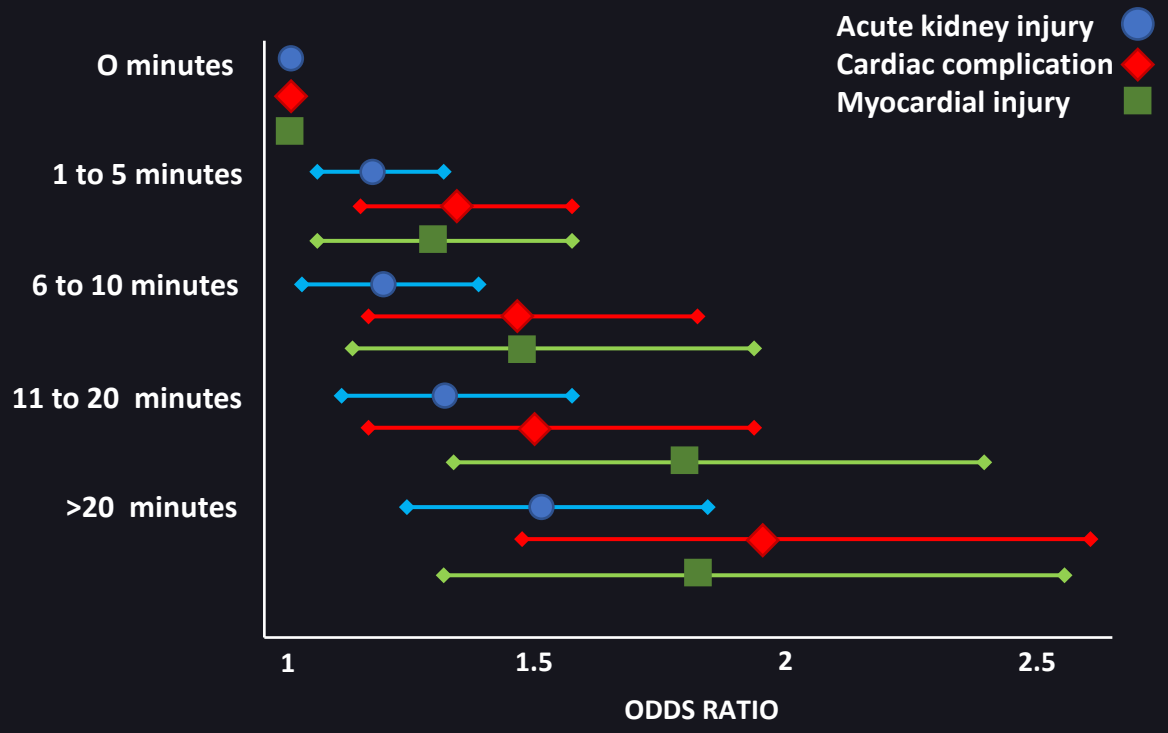
Predicted probability of (A) acute kidney injury and (B) myocardial injury by lowest mean arterial pressure (MAP) experiences during suregry



Walsh et al. Anesthesiology 2013

Relationship between intraoperative arterial pressure and clinical outcomes after noncardiac surgery

Toward an empirical definition of Hypotension



Adjusted odds ratio for acute kidney injury, cardiac complications, and myocardial injury by time spent with a mean arterial pressure < 65 mmHg

Walsh M et al. **Relationship between Intraoperative Mean Arterial Pressure and Clinical Outcomes after Noncardiac Surgery: *Toward an Empirical Definition of Hypotension*:**
ANESTHESIOLOGY, 119(3), 2013.
(33.330 noncardiac surgery patients)

Monk TG et al. **Association between intraoperative hypotension and hypertension and 30-day postoperative mortality in noncardiac surgery.**
ANESTHESIOLOGY 123(2); 2015
(18.756 noncardiac surgery patients, 6 hospitals)

Actual event

Standard clinical signs of event

Standard resuscitation start

Probability of event

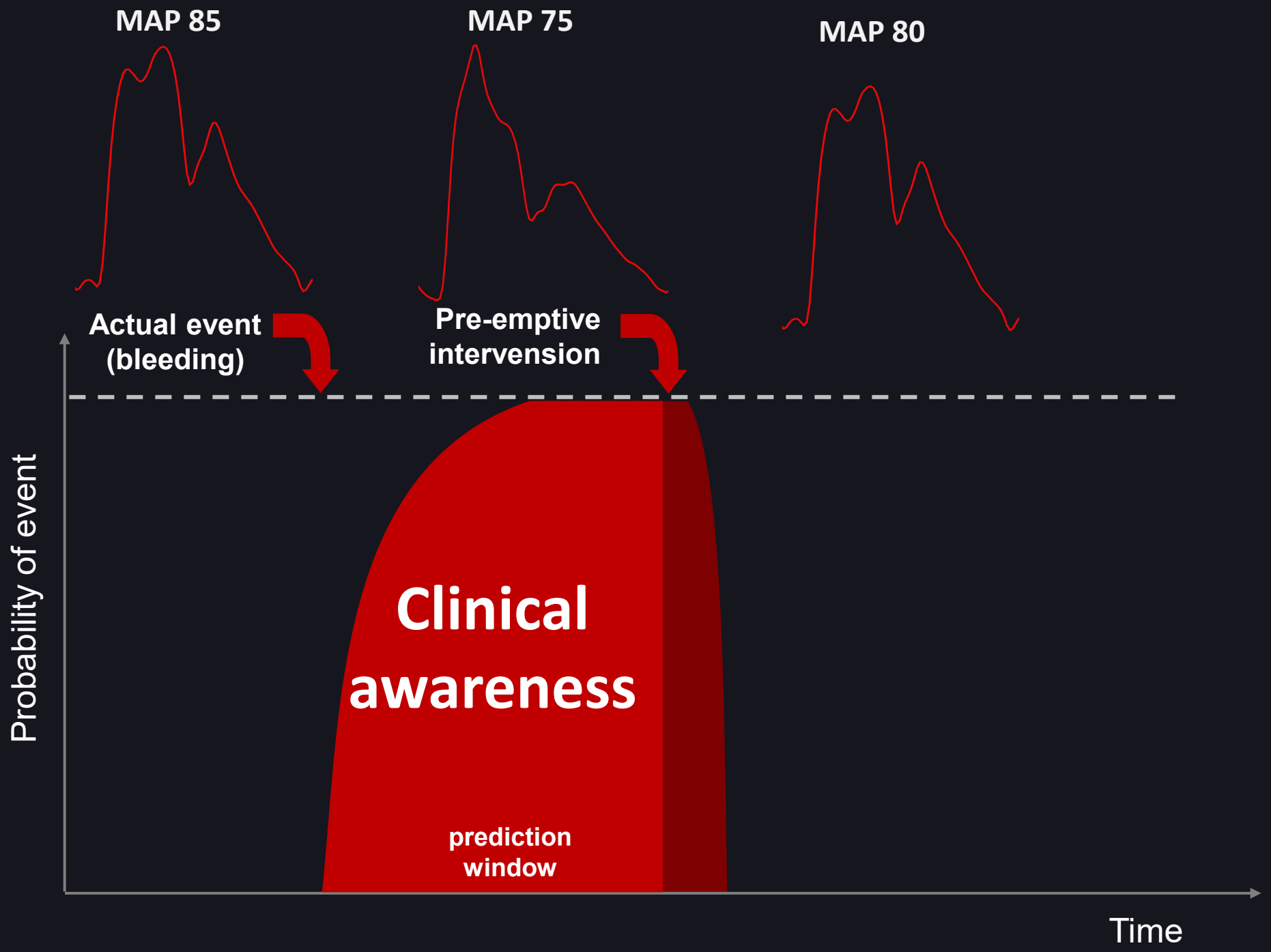
"If something can predict that event will happen, that will be a helpful tool. "

"Once the event has happened, there's not much you can do."

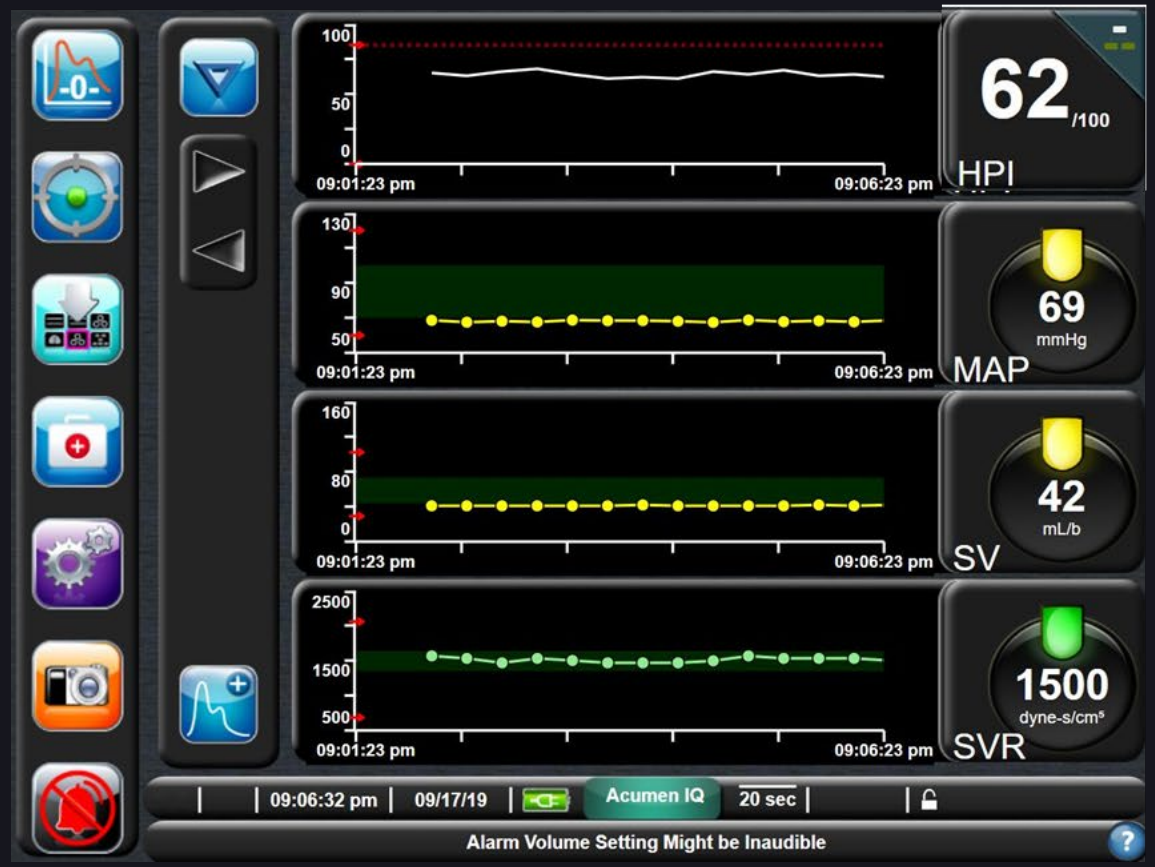
Prediction window

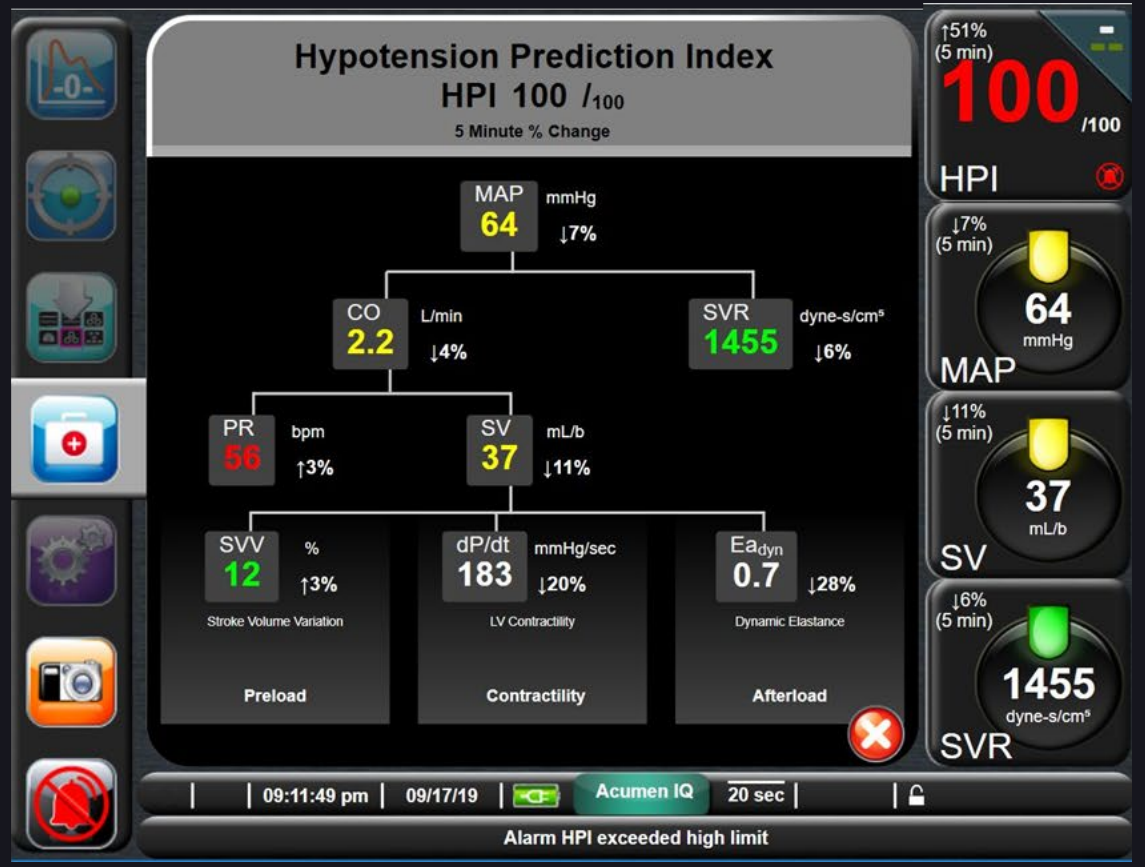
Reacting to a compication

Time


MAP 85
MAP 75
MAP 80
Actual event (bleeding)
Pre-emptive intervension
Probability of event
Clinical awareness
prediction window
Time

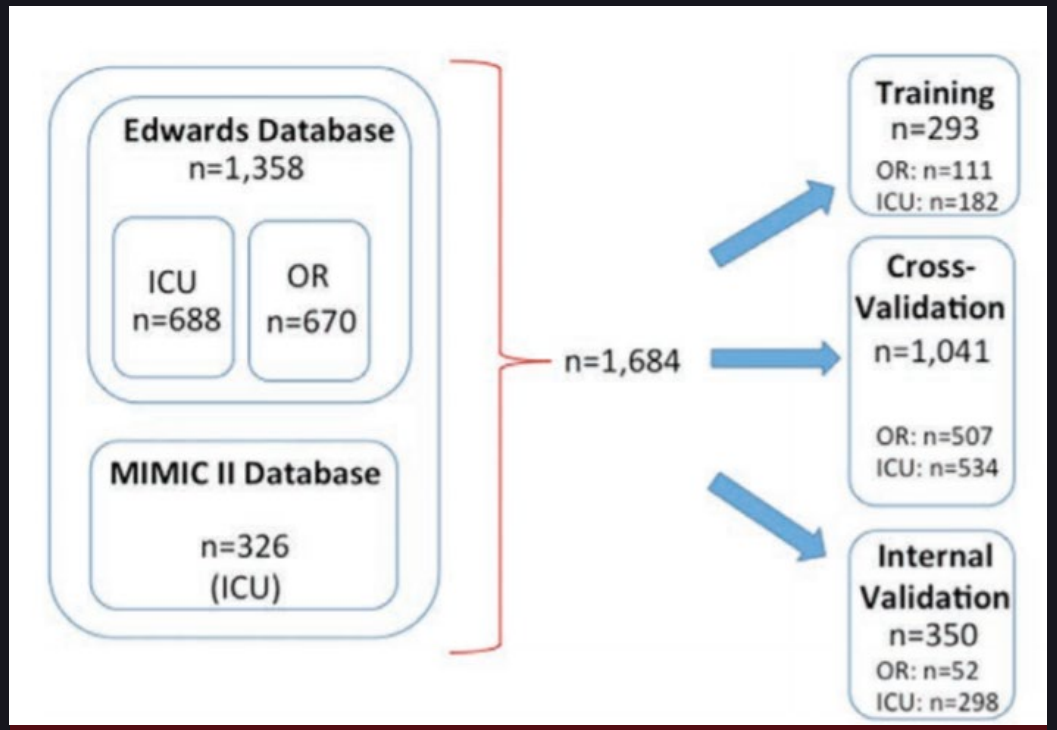
Hypotension Prediction Index (HPI) predicts the occurrence of arterial hypotension





HPI is not a physiological parameter but a number.
The higher the number greater the likelihood of hypotension occurring

HPI algorithm was developed using machine learning techniques on a large patient database

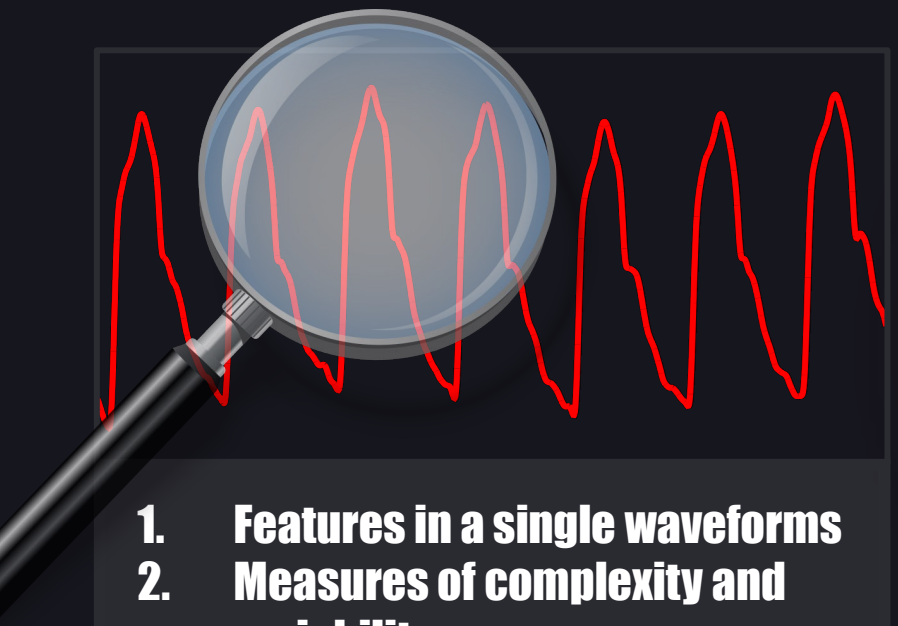


The database consists of blood pressure waveforms from patients in various clinical settings including the ICU and OR presenting with a broad set of clinical conditions.

Number of events: 59,376
Total event time: 367,550 min
Cardiac cycles: 31.45M

Number of non-events: 144,045
Total non-event time: 1,126,573 min
Cardiac cycles: 101.9M

Machine learning techniques to build HPI algorithm



1. Features in a single waveforms
2. Measures of complexity and variability
3. Compensatory mechanisms such as baroreflex and cardiopulmonary reflex
4. Interactions between features

2,600,000
Features

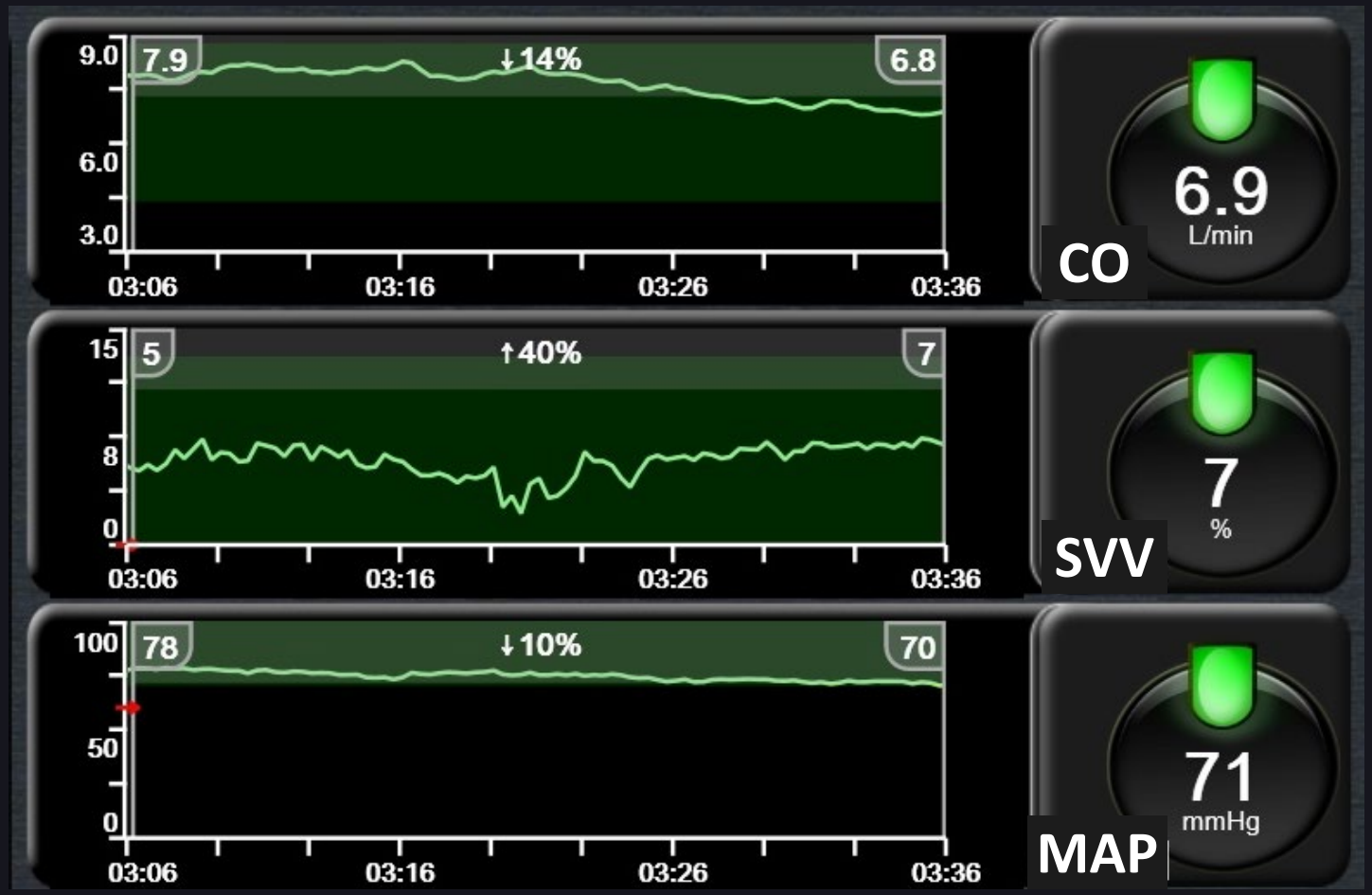
Individual feature performance analysis

62

Sequential feature selection

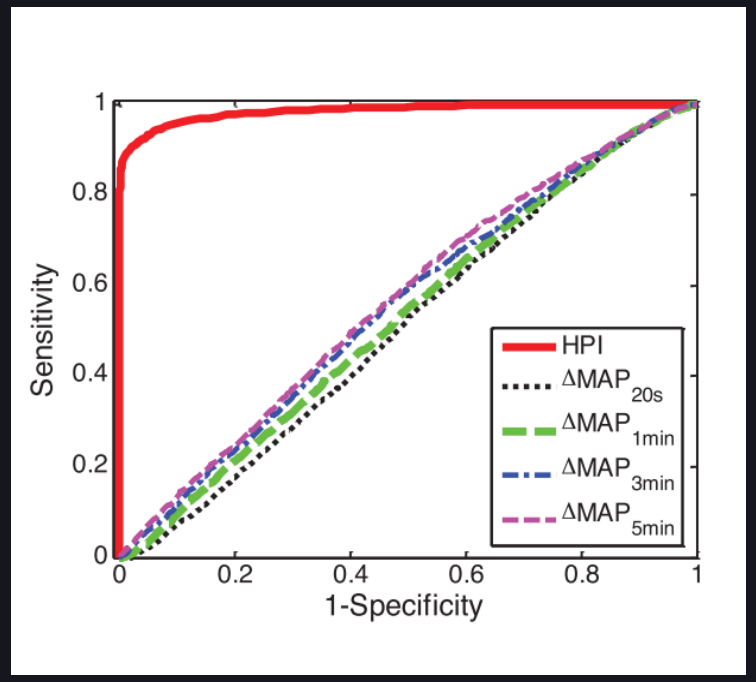
23

Most predictive features


9.0
7.9
↓14%
6.8
6.0
3.0
03:06
03:16
03:26
03:36
6.9
L/min
CO
15
5
↑40%
7
8
0
03:06
03:16
03:26
03:36
7
%
SVV
100
78
↓10%
70
50
0
03:06
03:16
03:26
03:36
71
mmHg
MAP

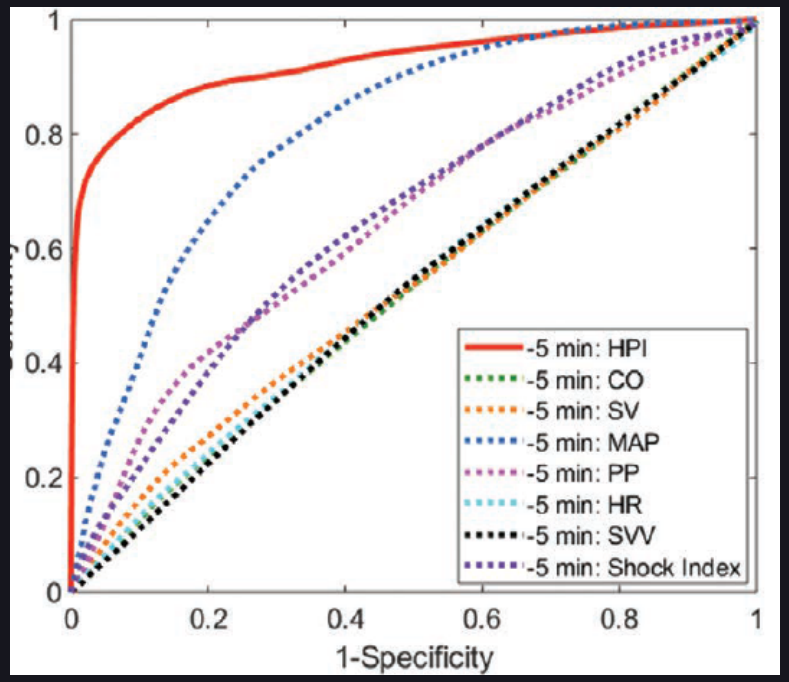
Hypotension Prediction Index

Performance of the Hypotension Predictor Index (HPI) for predicting arterial hypotension



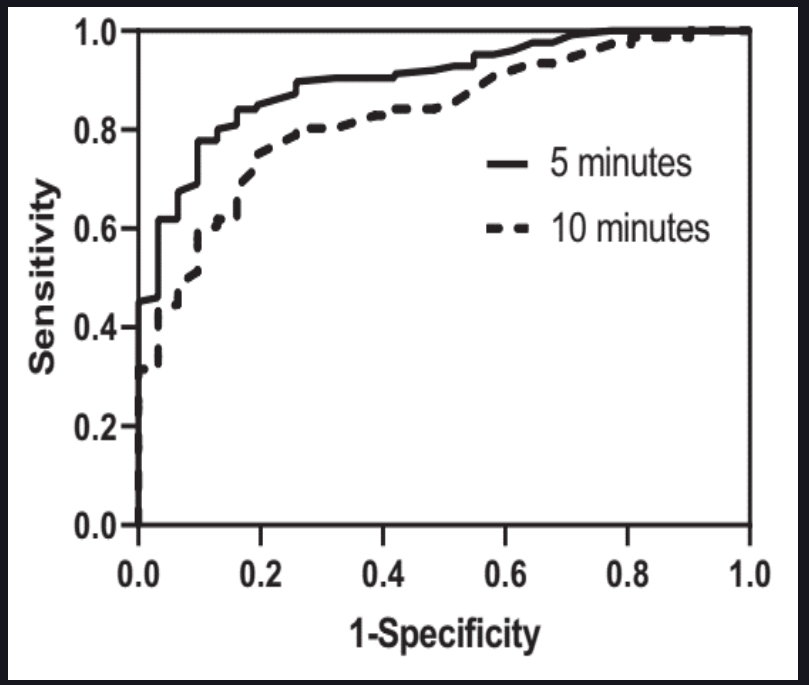
Hatib F *et al*. **Anesthesiology** 2018.

Internal validation (1334 patients)
External validation (204 patients)



Davies SJ *et al*. **Anesthesia & Analgesia** 2020.

Retrospective analysis of 255 patients undergoing major non-cardiac surgery.



Shin B *et al*. **J Cardiothorac Vasc Anesth** 2020 .

- Single-center prospective Study.
- 37 patients undergoing cardiac surgery (CBP, valve repair, aneurism repair…)

Performance of the non-invasive HPI (ClearSight) for predicting arterial hypotension

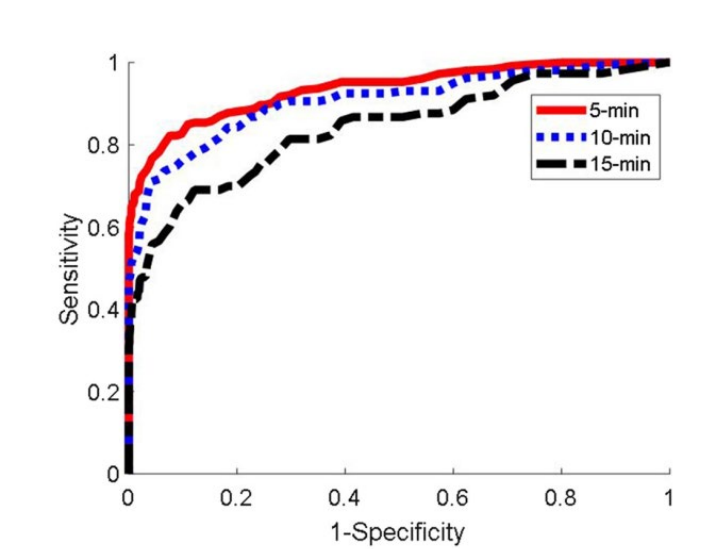
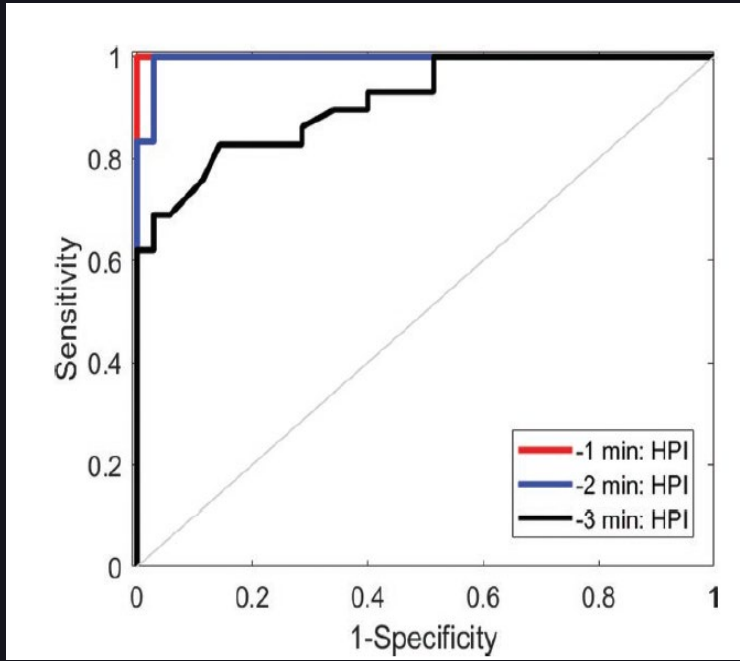


Fig. 2 ROC plot at 5, 10, and 15-min for the entire cohort of 305 patients

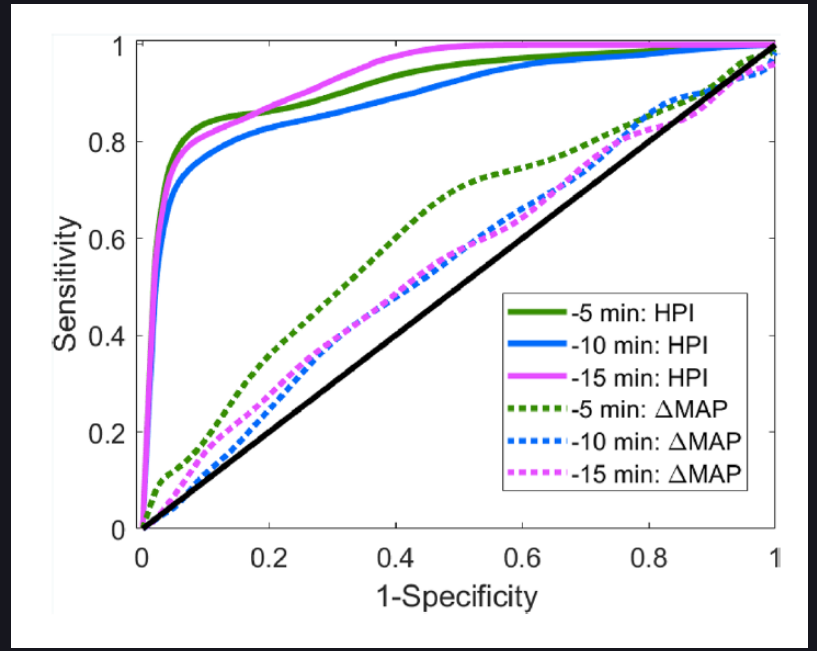
Maheshwarit K *al*. **J Clin Monit Comput** 2020 .

- Retrospective analysis of 305 adults patients undergoing to moderate-to-high risk non cardiac sugery.



Frassanito L et al. **Anesthesia & Analgesia**, 2021

Retrospective analysis of 48 pregnant patients scheduled for elective cesarean under spinal anesthesia.



Frassanito L et al. **J Clinical Monitor and Comput**, 2021

Retrospective analysis of 31 patients scheduled for Gynaecologic Oncologic Surgery.

HPI in ICU patients with COVID-19

Journal of Clinical Monitoring and Computing
https://doi.org/10.1007/s10877-021-00778-x

ORIGINAL RESEARCH

Performance of a machine-learning algorithm to predict hypotension in mechanically ventilated patients with COVID-19 admitted to the intensive care unit: a cohort study

Ward H. van der Ven[1] · Lotte E. Terwindt[1] · Nurseda Risvanoglu[1] · Evy L. K. Ie[1] · Marije Wijnberge[1] · Denise P. Veelo[1] · Bart F. Geerts[2] · Alexander P. J. Vlaar[3,4] · Björn J. P. van der Ster[1]

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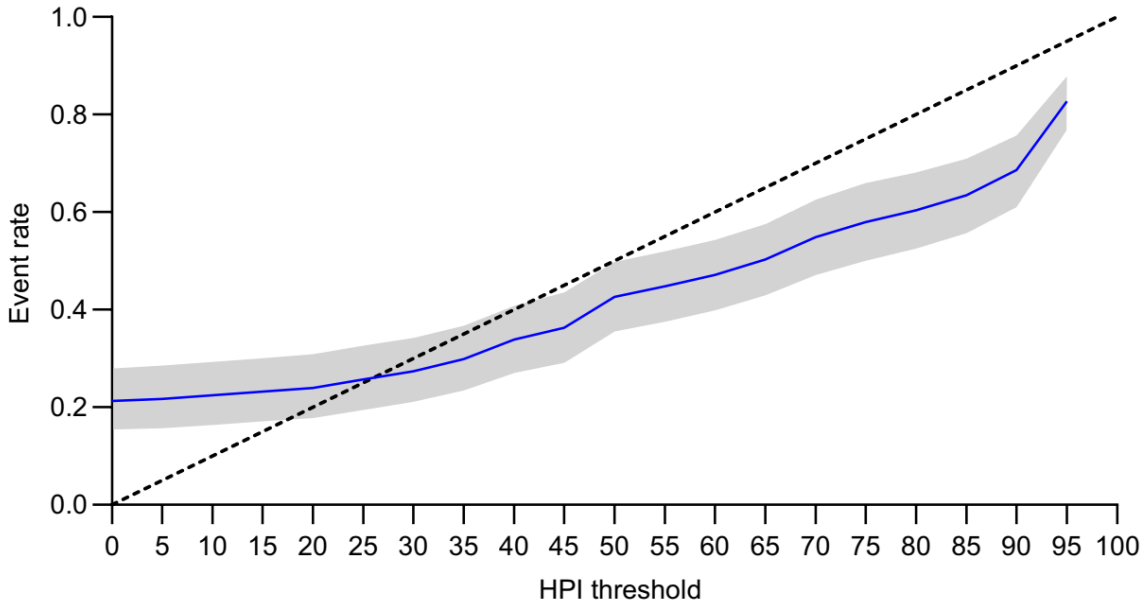
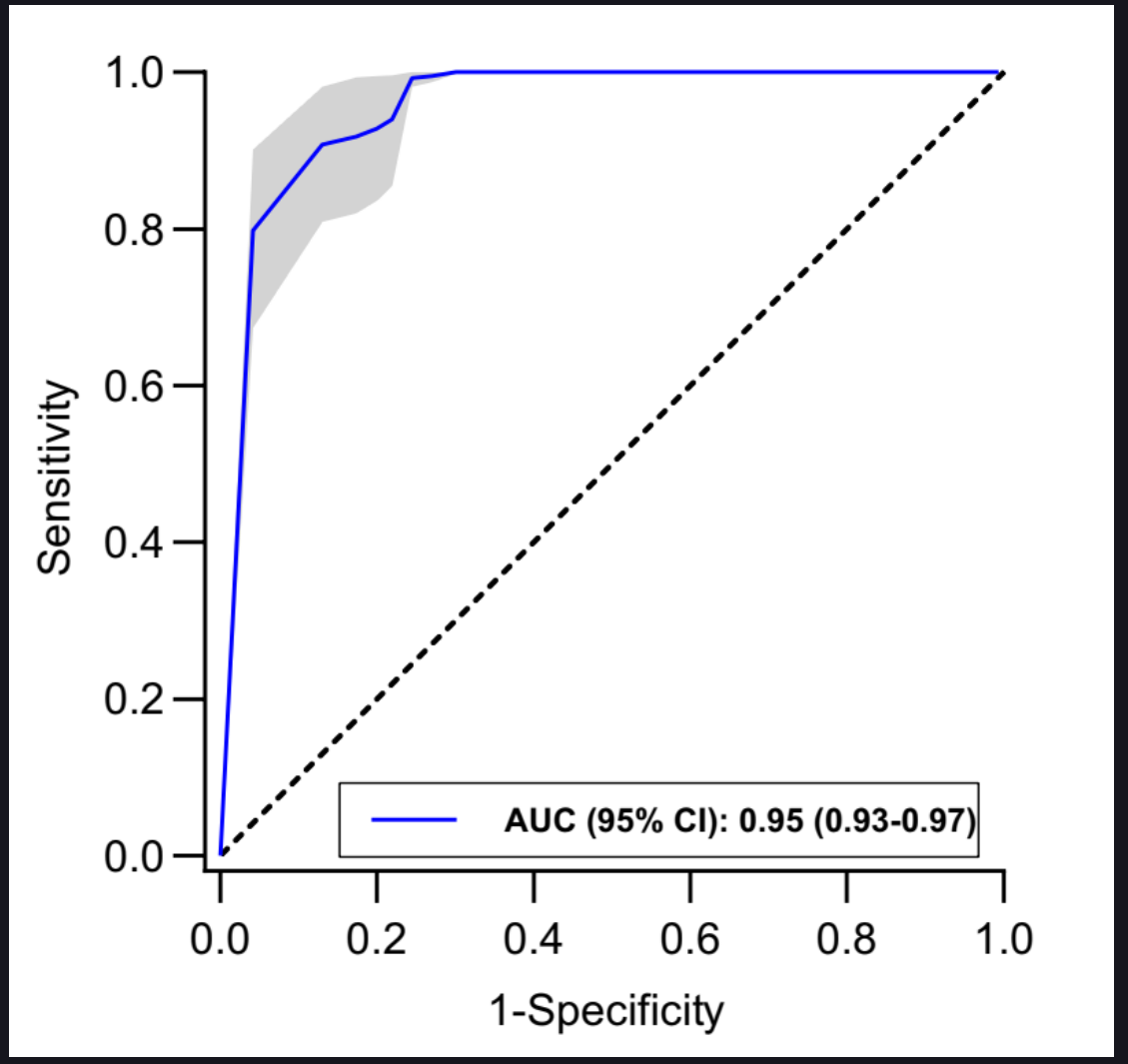




Acumen Hypotension Prediction Index Software (validation studies)

Study, year	N patients	Population	AUC (95% confidence interval)
Hatib, 2018	Internal: 350 External: 204	OR and ICU	$MAP<65_{5min}$: 0.95 (0.93 – 0.96) $MAP<65_{10min}$: 0.92 (0.90 – 0.94) $MAP<65_{15min}$: 0.91 (0.88 – 0.94)
Davies, 2020	255 patients	Non-cardiac surgery	$MAP<65_{5min}$: 0.93 (0.92 – 0.93) $MAP<65_{10min}$: 0.89 (0.89 – 0.89) $MAP<65_{15min}$: 0.88 (0.88 – 0.88)
Shin, 2020	37 patients	Cardiac surgery	$MAP<65_{5min}$: 0.90 (0.85 – 0.95) $MAP<65_{10min}$: 0.83 (0.75 – 0.90) $MAP<65_{15min}$: 0.83 (0.75 – 0.91)
Maheshwarit, 2021	305 patients (ClearSight)	Moderate-to-high-risk non-cardiac surgery	$MAP<65_{5min}$: 0.93 (0.91 – 0.95) $MAP<65_{10min}$: 0.90 (0.87 – 0.93) $MAP<65_{15min}$: 0.84 (0.79 – 0.88)
Frasanito, 2021	50 patients (ClearSight)	Awake elective cesarean under spinal anesthesia	$MAP<65_{5min}$: 0.95 (0.89 – 0.99) $MAP<65_{10min}$: 0.90 (0.83 – 0.97) $MAP<65_{15min}$: 0.84 (0.79 – 0.88)
Frasanito, 2021	28 patients (ClearSight)	Gynaecologic Oncologic Surgery	$MAP<65_{1min}$: 1 (1 – 1) $MAP<65_{2min}$: 0.99 (0.98 – 1) $MAP<65_{3min}$: 0.91 (0.84 – 0.99)
Wijnberge, 2021	507 patients (ClearSight)	Non-cardiac surgery	$MAP<65_{5min}$: 0.93 (0.92 – 0.94) $MAP<65_{10min}$: 0.91 (0.90 – 0.92) $MAP<65_{15min}$: 0.90 (0.89 – 0.91)
Van der Ven 2021	41 patients	COVID 19 ICU patients	MAP<65: 0.95 (0.93 – 0.97)

JAMA | Preliminary Communication | CARING FOR THE CRITICALLY ILL PATIENT

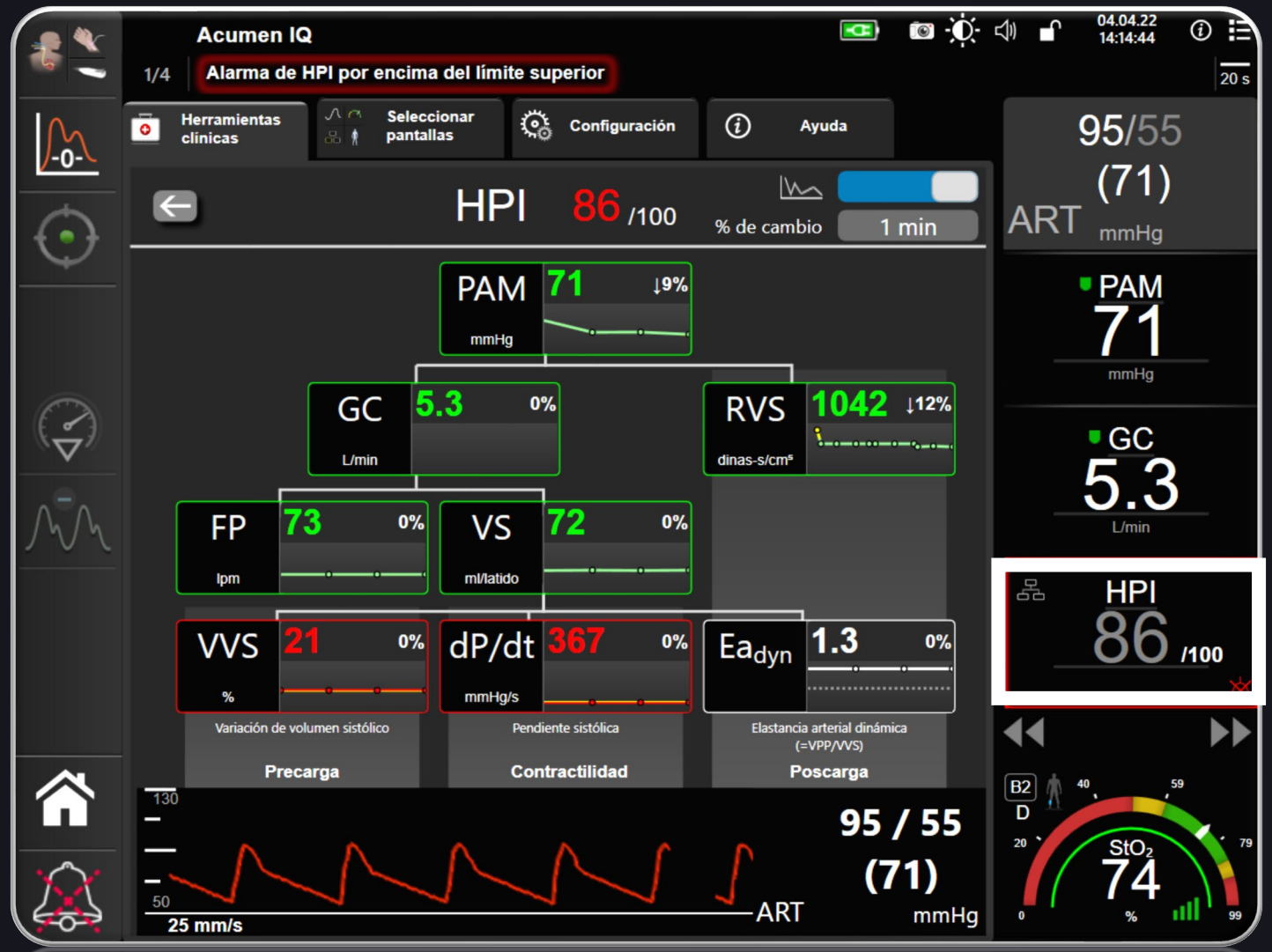
Effect of a Machine Learning–Derived Early Warning System for Intraoperative Hypotension vs Standard Care on Depth and Duration of Intraoperative Hypotension During Elective Noncardiac Surgery
The HYPE Randomized Clinical Trial

JAMA. 2020;323(11):1052-1060. doi:10.1001/jama.2020.0592
Published online February 17, 2020.

Marije Wijnberge, MD; Bart F. Geerts, MD, PhD, MSc, MBA; Liselotte Hol, MD; Nikki Lemmers, MD; Marijn P. Mulder, BSc; Patrick Berge, MD; Jimmy Schenk, MSc; Lotte E. Terwindt, MD; Markus W. Hollmann, MD, PhD; Alexander P. Vlaar, MD, PhD, MBA; Denise P. Veelo, MD, PhD

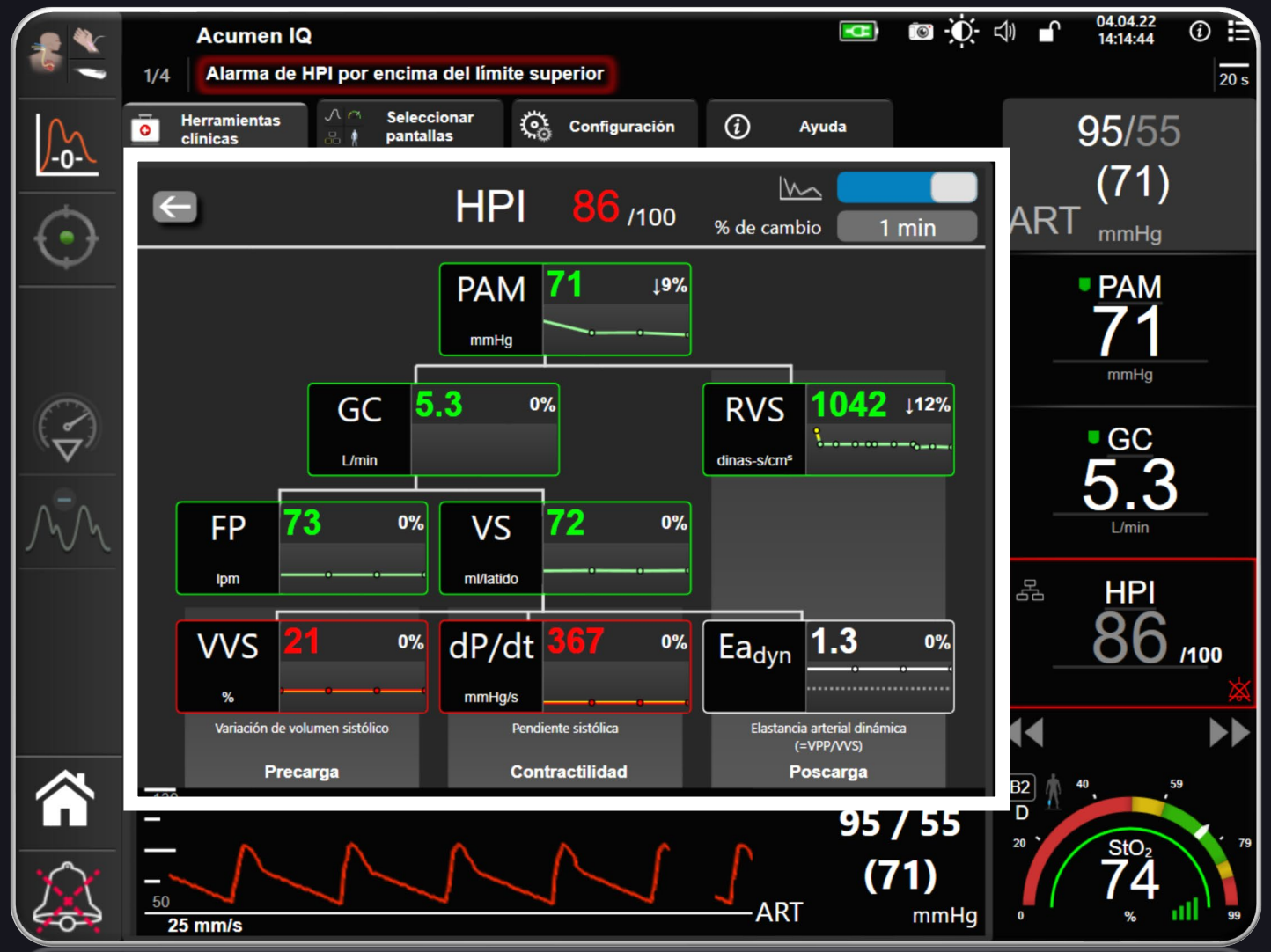
Table 2. Primary and Secondary End Points

	Median (Interquartile Range)[a]			
	Intervention (n = 31)	Control (n = 29)	Median Difference (95% CI)[b]	*P* Value[c]
Primary End Point				
Time-weighted average of hypotension, mm Hg	0.10 (0.01-0.43)	0.44 (0.23-0.72)	0.38 (0.14 to 0.43)	.001
Secondary End Points				
Hypotension				
Area under the threshold, mm Hg/min[d]	20.0 (2.2-148.3)	142.2 (64.67-258.92)	74.0 (33.0 to 137.7)	.002
Incidence	3.0 (1.0-8.0)	8.0 (3.5-12.0)	4.0 (1.0 to 7.0)	.004
Total time, min	8.0 (1.3-26.0)	32.7 (11.5-59.7)	16.7 (7.7 to 31.0)	.001
Surgery time, %	2.8 (0.8-6.6)	10.3 (4.6-15.6)	5.6 (3.0 to 9.4)	<.001
Hypertension				
Time-weighted average, mm Hg	0.09 (0.00-0.21)	0.05 (0.00-0.13)	0.00 (−0.85 to 0.17)	.47
Area above the threshold, mm Hg/min[d]	33.3 (0.0-88.0)	13.3 (0.0-44.3)	−3.5 (−29.0 to 5.5)	.40
Incidence	2.0 (0.0-3.0)	1.0 (0.0-2.0)	0.0 (−1.0 to 0.0)	.23
Total time, min	4.0 (0.0-10.7)	3.0 (0.0-6.8)	−0.7 (−4.3 to 0.7)	.40
Surgery time, %	1.5 (0.0-3.3)	0.9 (0.0-1.9)	−0.2 (−1.4 to 0.3)	.40
Treatment behavior				
Reaction time, s[e]	53.0 (24.0-99.0)	87.3 (53.0-172.5)	34.3 (22.8 to 47.3)	<.001



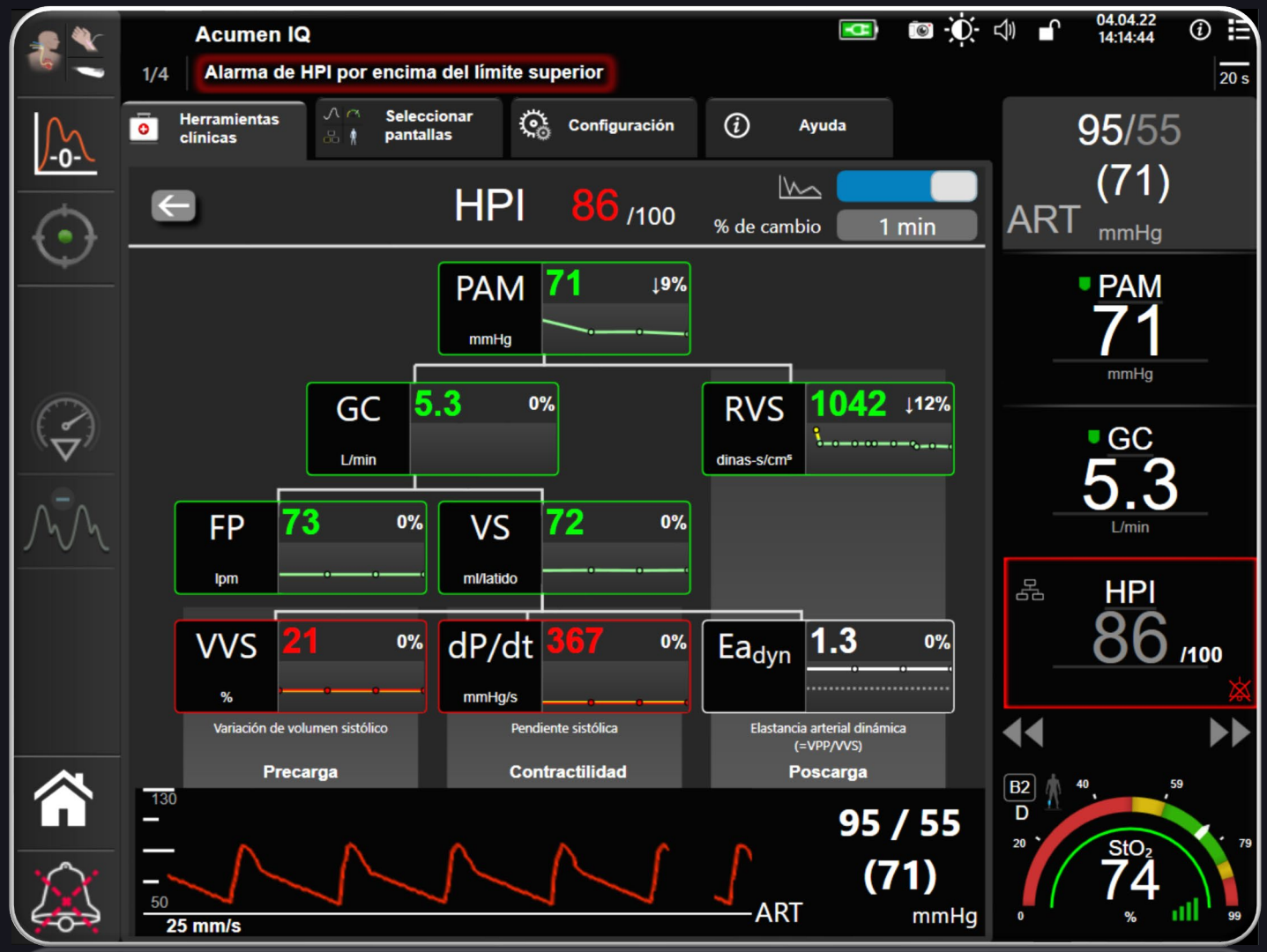
Hypotension Prediction Index (HPI)

- Early predictor of arterial hypotension
- Hemodynamic instability index



Secondary Screen

- Underlying mechanism of the increasing hemodynamic instability
- Optimal therapeutic decision for preventing arterial hypotension



Physiological management of arterial hypotension

- **SVV**: dynamic index of preload (preload-responsiveness)
- **Arterial dP/dtmax**: LV contractility
- **Eadyn**: dynamic index of afterload (pressure responsiveness)

physiological management of
arterial hypotension

SVV

$dPdt_{max}$

Ea_{dyn}

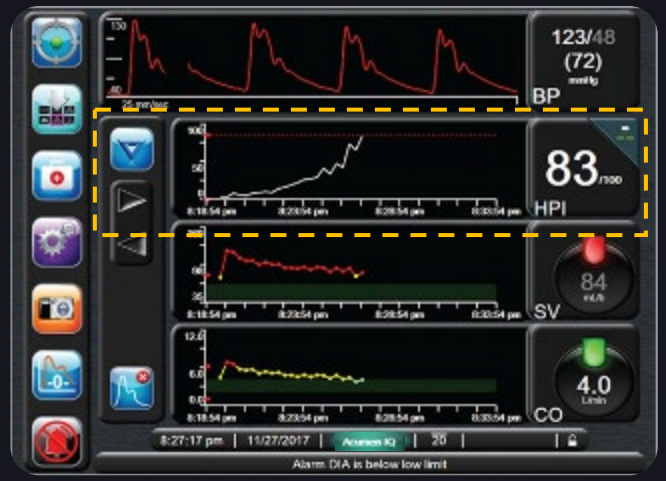
Acumen Hypotension Prediction Index Software

1

HPI parameter

Index value ranging from 0 to 100

Indicates likelihood a patient may be trending toward a hypotensive event



2

HPI high alert popup

Alerts clinician at preset threshold values

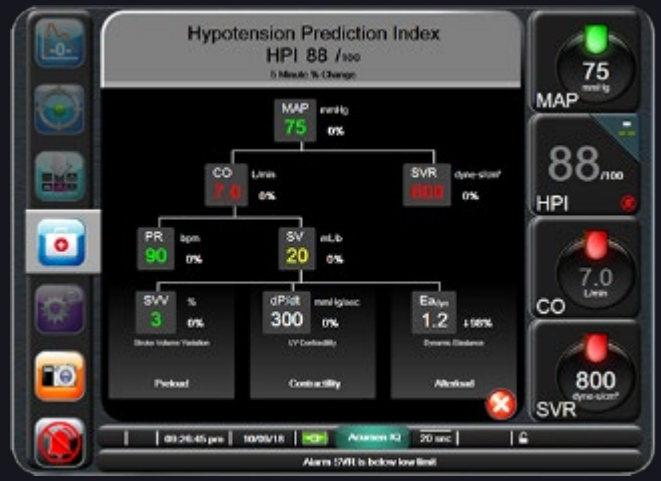
Alerts when patient is trending toward or experiencing a hypotensive event (90+% probability)

3

HPI secondary screen

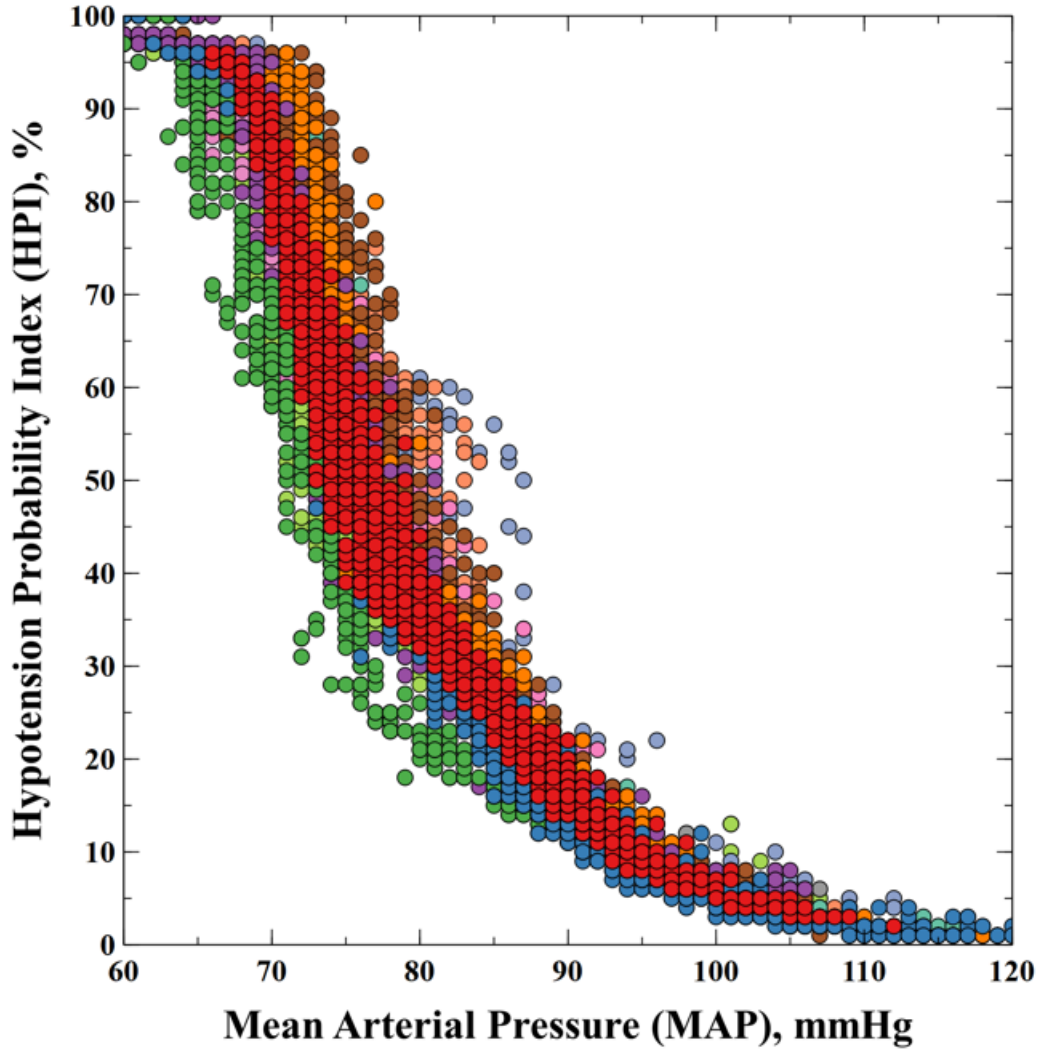
Visually links pressure and flow parameters

Allow opportunity to investigate and identify the root cause of potentially developing hypotensive events



ignaciomonge@gmail.com

HPI and MAP relationship



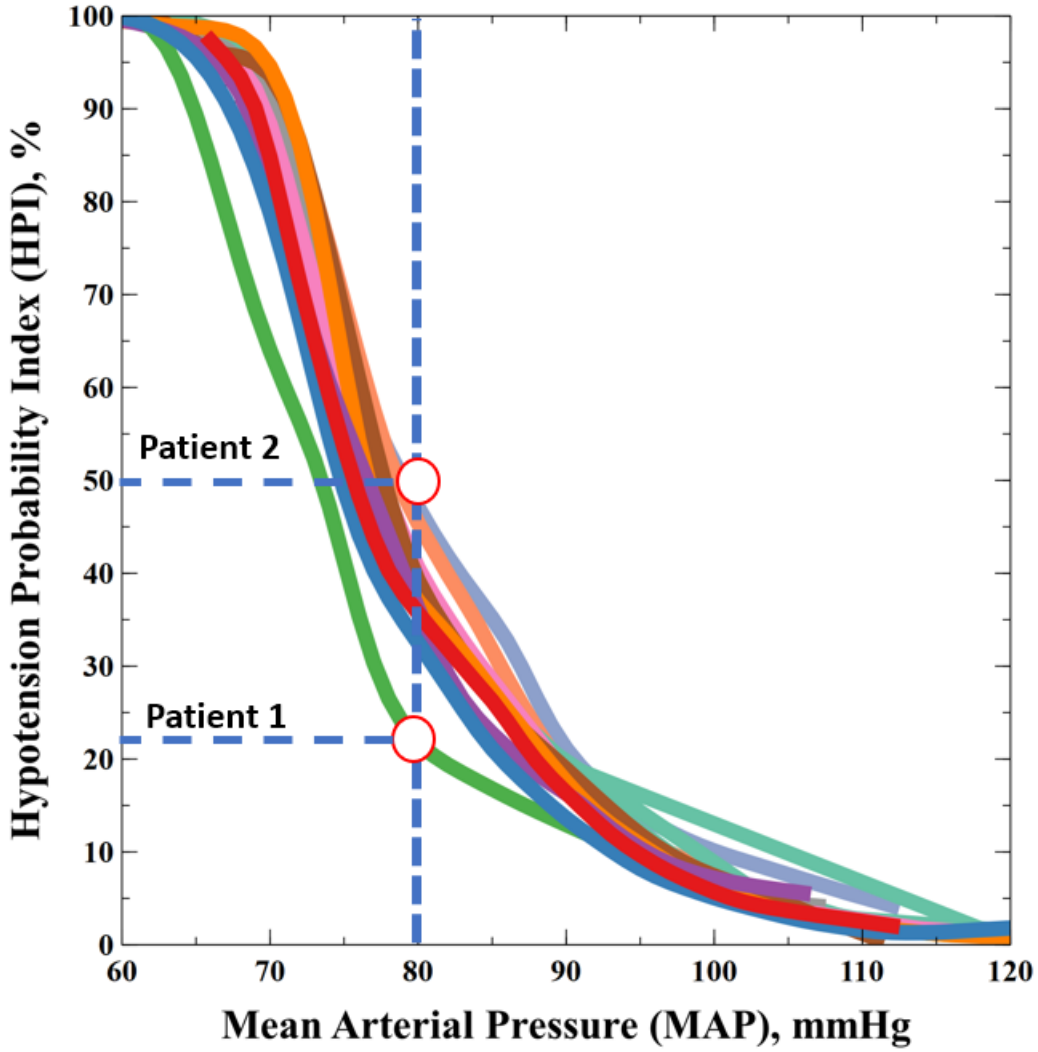
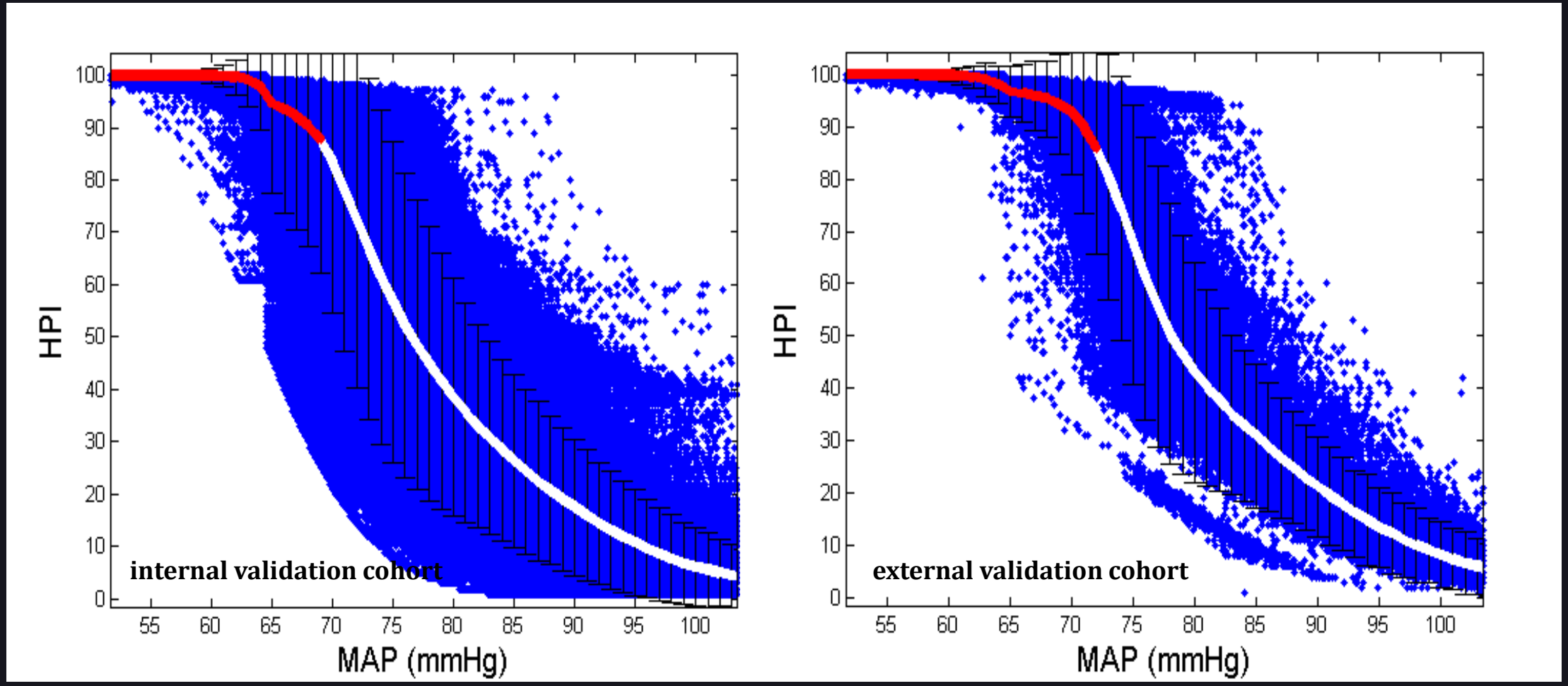


Figure 3 –Relationship between hypotension prediction index and mean arterial pressure for the internal validation cohort (left panel) and for the UCI external validation cohort (right panel).



Hatib F *et al*. **Anesthesiology** 2018.