

Acumen Hypotension Prediction Index (HPI) Software

Clinical Evidence Bibliography

Algorithm Performance

#	Title, author, year, publication	Study design	n	Patient population	Main finding(s)
1	Machine Learning algorithm to predict hypotension based on high-fidelity arterial pressure waveform analysis. Hatib, Cannesson et al. 2018 Anesthesiology	Retrospective analysis	1334	Cardiac and noncardiac surgical and non surgical patients	The results demonstrate that a machine-learning algorithm can be trained, with large data sets of high-fidelity arterial waveforms, to predict hypotension* in surgical patients' record
2	Ability of an arterial waveform analysis- derived hypotension prediction Index to predict future hypotensive events in surgical patients. Davies, Scheeren, et al. 2019 Anesthesia & Analgesia	Retrospective analysis	255	Abdominal, vascular, and off-pump CABG	Acumen Hypotension Prediction Index (HPI) software provides an accurate real time and continuous prediction of impending intraoperative hypotension* before its occurrence and has superior predictive ability than the commonly measured perioperative hemodynamic variables
3	Use of hypotension prediction index during cardiac surgery. Shin et al. 2020 Journal of Cardiothoracic and Vascular Anesthesia	Prospective cohort feasibility study	37	Cardiac surgery	Acumen HPI software predicted hypotensive episodes* during cardiac surgeries with a high degree of sensitivity and specificity
4	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. Van der Ven et al. 2021 Journal of Clinical Monitoring	Prospective observational study	41	Noncardiac surgery in COVID-19 patients in the ICU	Acumen HPI software correctly predicts hypotension* in mechanically ventilated COVID-19 patients in the ICU, and provides a basis for future studies to assess whether hypotension can be reduced in ICU patients using this algorithm

Clinical Studies

#	Title, author, year, publication	Study design	n	Patient population	Main finding(s)
5	Hypotension Prediction Index based protocolized hemodynamic management reduces the incidence and duration of intraoperative hypotension in primary total hip arthroplasty: a single center feasibility randomized blinded prospective interventional trial. Schneck et al. 2019 Journal of Clinical Monitoring and Computing	RCT-single center	49 (RCT), 50 (historical control)	Noncardiac surgery (Ortho)	The Acumen HPI algorithm combined with a protocolized treatment was able to reduce the incidence and duration of hypotensive events* in patients undergoing primary hip arthroplasty
6	Hypotension Prediction Index RCT for prevention of hypotension during moderate-to-high-risk noncardiac surgery. Maheshwari et al. 2020 Anesthesiology	RCT	214	Moderate to high-risk noncardiac surgery	In this pilot trial, Acumen HPI software protocol did not reduce the amount of intraoperative hypotension*: half of the alerts were not followed by treatment, presumably due to short warning time, complex treatment algorithm, or clinicians ignoring the alert
7	Effect of machine learning derived early warning system for intraoperative hypotension vs standard care on depth and duration. The HYPE randomized clinical trial. Wijnberge, Geerts et al. 2020 JAMA	RCT-single center	60	Noncardiac surgery (oncology GI)	The use of a machine learning-derived early warning system for pending hypotension integrated into a treatment protocol, compared with standard care, resulted in less intraoperative hypotension*
8	Hemodynamic monitoring with Hypotension Prediction Index versus arterial waveform analysis alone and incidence of perioperative hypotension. Grundmann et al. 2021, Acta Anesthesiologica Scandinavica	Retrospective observational RCT-single center	100	Noncardiac surgery	Application of the Acumen HPI software combined with a personalized treatment protocol can reduce incidence and duration of hypotension* when compared to arterial waveform analysis alone.
9	The use of Hypotension Prediction Index integrated in an algorithm of goal directed hemodynamic treatment during moderate and high-risk surgery. Tsoumpa et al. 2021 Journal of Clinical Medicine	RCT-single center	99	Noncardiac surgery	In this single-center prospective study of patients undergoing elective noncardiac surgery, the use of the Acumen HPI software with a treatment protocol resulted in less intraoperative hypotension* compared with standard of care. An increase in time spent in hypertension in the treatment group was also observed, probably as a result of overtreatment.
10	Proactive management of Intraoperative hypotension reduces biomarkers of organ Injury and oxidative stress during non-cardiac surgery: A pilot randomized controlled trial. Murabito et al. 2021 Journal of Clinical Medicine	RCT-single center	40	Noncardiac surgery	The use of the Acumen HPI early warning system coupled with a hemodynamic algorithm resulted in reduced intraoperative hypotension*, reduced Neuronal specific enolase (NSE) and oxidative stress.

Clinical Studies (continued)

#	Title, author, year, publication	Study design	n	Patient population	Main finding(s)
11	Real-world outcomes of the hypotension prediction index in the management of intraoperative hypotension during non-cardiac surgery: a retrospective clinical study. Solares et al. 2022 Journal of Clinical Monitoring and Computing	Single-center retrospective study	104 (GDFT, n=52; GDFT + HPI, n=52)	Noncardiac surgery	Personalized institutional GDFT protocol supported by HPI software may reduce the depth and duration ($TWA_{MAP<65}$) of IOH during noncardiac surgery along with a lower prevalence of postoperative complications and shorter LOS

Clinical evidence on systolic slope (dP/dt)

#	Title, author, year, publication	Study design	n	Patient population	Main finding(s)
12	Non-invasive radial pulse wave assessment for the evaluation of left ventricular systolic performance in heart failure. Tartiere et al. 2007 The European Journal of Heart Failure	Prospective observational study (Sub-studies: Validation and feasibility)	50 (Validation Cohort), 310 (Feasibility)	Cardiac failure	The maximal dP/dt of the radial pulse is a valuable and reproducible peripheral criterion of LV systolic performance
13	Performance comparison of ventricular and arterial dP/dt _{max} for assessing left ventricular systolic function during different experimental loading and contractile conditions. Monge Garcia et al. 2018 Critical Care	Prospective observational study	10	Yorkshire cross breed pigs	Although arterial dP/dt _{max} is a complex function of central and peripheral arterial factors, dP/dt _{max} allowed reasonably good tracking of left ventricular (LV) contractility changes as loading and inotropic conditions varied
14	Continual measurement of arterial dP/dt _{max} enables minimally invasive monitoring of left ventricular contractility in patients with acute heart failure. Ostadal et al. 2019 Critical Care	Prospective observational study	48	Cardiac surgery	In patients with acute heart failure requiring intensive care with an arterial line, continuous calculation of arterial dP/dt _{max} may be used for monitoring LV contractility, especially in those with higher SVR, lower CO, and lower SV, such as in patients experiencing cardiogenic shock

Clinical evidence on dynamic arterial elastance (Ea_{dyn})

#	Title, author, year, publication	Study design	n	Patient population	Main finding(s)
15	The use of pulse pressure variation and stroke volume variation in spontaneously breathing patients to assess dynamic arterial elastance and to predict arterial pressure response to fluid administration. Cecconi et al. 2015 Anesthesia & Analgesia	Prospective observational study	26	Cardiac surgery (high-risk surgical patients)	Noninvasive Ea_{dyn} , defined as the PPV to SVV ratio, predicted the arterial blood pressure increase to fluid administration in spontaneously breathing, preload-dependent patients
16	Dynamic arterial elastance predicts mean arterial pressure decrease associated with decreasing norepinephrine dosage in septic shock. Guinot et al. 2015 Critical Care	Prospective observational study	35	Sepsis	In sepsis patients treated with norepinephrine (NE), Ea_{dyn} may predict the decrease in arterial pressure in response to NE dose reduction; Ea_{dyn} may constitute an easy-to-use functional approach to arterial-tone assessment, which may be helpful to identify patients likely to benefit from NE dose reduction
17	Monitoring dynamic arterial elastance as a means of decreasing the duration of norepinephrine treatment in vasoplegic syndrome following cardiac surgery: a prospective, randomized trial. Guinot et al. 2017 Intensive Care Med	RCT	118	Cardiac surgery	A hemodynamic treatment algorithm based on dynamic arterial elastance was associated with a shorter duration of norepinephrine treatment and a shorter length of stay (LOS) in the ICU; use of the algorithm did not alter perfusion parameters or increase the volume of fluid infused
18	Predictive performance of dynamic arterial elastance for arterial pressure response to fluid expansion in mechanically ventilated hypotensive adults: a systematic review and meta-analysis of observational studies. Zhou et al. 2021 Annals of Intensive Care	Meta analysis	323	Noncardiac patients (ICU patients on mechanical ventilation)	Ea_{dyn} exhibits good performance for predicting MAP increases in response to fluid expansion in mechanically ventilated hypotensive adults, especially in the ICU setting

MAP: Mean arterial pressure

SVR: Systemic vascular resistance

CABG: Coronary artery bypass graft

CO: Cardiac output

RCT: Randomized controlled trial

SV: Stroke volume

GI: Gastrointestinal

*Hypotension, intraoperative hypotension, hypotensive event and hypotensive episodes are defined as MAP < 65 mmHg for a duration of at least one minute.

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