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Predictive hemodynamic monitoring: the use of artificial intelligence for the prevention of hypotension in major surgeries.

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Author: **Daniely Ribeiro**
Academic qualifications/education: medical student.
Institution: Faculty of Medical Sciences - Afya, Abaetetuba, PA.
ORCID: 0009-0006-6855-794
City/Country: Abadeetetuba - Pará, Brazil.
Email: Doutoraribeirodaniely@gmail.com

Author: **Anna Clara Costa Hiraide**
Title/Education: Medical Student
Institution: Faculty of Medical Sciences - Afya Abaetetuba, PA.
ORCID: 0009-0004-7066-0845
City/Country: Barcarena/Brazil
Email: Annahiraide12@icloud.com

Author: **Fernanda Pinheiro Chagas.**
Academic qualifications/education: medical student.
Institution: Faculty of Medical Sciences - Afya, Abaetetuba, PA.
ORCID: 0000-0001-6626-0508
City/Country: Abaetetuba, Brazil
Email: fernandachagasfp@gmail.com

Co-author: **Leandro Gabriel Costa Macedo.**
Academic qualifications/education: medical student.
Institution: Faculty of Medical Sciences - Afya, Abaetetuba, PA.
ORCID: 0009-0007-0483-4036
City/Country: Abaetetuba - Pará, Brazil.
Email: Leandrogabrielcostamacedo@gmail.com

Co-author: **Joselio Granja Rodrigues**
Title/Education: Medical Student
Institution: Faculty of Medical Sciences - Afya, Abaetetuba, PA.
ORCID: 0009-0002-1884-2583
City/Country: Abaetetuba - Pará, Brazil. Email: joseliogranja99@gmail.com

Co-author: **Marcus Raphael Maia Moura**
Academic qualifications/education: medical student.
Institution: Faculty of Medical Sciences - Afya, Abaetetuba, PA.
ORCID: 0009-0009-6472-0350
City/Country: Abaetetuba - Pará, Brazil.
Email: raphaelmarcus325@gmail.com

Co-author: **Bárbara Begot de Freitas Rodrigues**
Academic qualifications/education: medical student.
Institution: Faculty of Medical Sciences - Afya, Abaetetuba, PA.
ORCID: 0000-0002-0467-3451
City/Country: Belém - Pará, Brazil. Email: begotbarbara@gmail.com

Co-author: **Wesley Patrick Santos Bonfim.**
Academic qualifications/education: medical student.
Institution: Faculty of Medical Sciences - Afya, Abaetetuba, PA.
ORCID: 0000-0002-0067-7068
City/Country: Abaetetuba - Pará. Brazil.
Email: Wesleypatrick318@gmail.com

Co-author: **Ricardo Ferreira Silva**
Title/Education: Medical Student
Institution: Faculty of Medical Sciences - Afya, Abaetetuba, PA.
ORCID: 0009-0000-2689-8718
City/Country: Belém - Pará. Brazil.
Email: ricardosilvafr15@gmail.com

Co-author: **Luana Frazão da Silva**
Title/Education: Medical Student
Institution: Faculty of Medical Sciences - Afya, Abaetetuba, PA.
ORCID:0000-0002-8033-6860
City/Country: Abaetetuba - Pará, Brazil
Email: Frazaoluana6@gmail.com

Co-author: **Rikelme Costa Silva**
Academic Title/Education: Medical Student
Institution: Faculty of Medical Sciences – Afya Abaetetuba, PA.
ORCID: 0009-0009-6360-1800
City/Country: Abaetetuba - Pará, Brazil. Email: rikecsilva@icloud.com

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Summary

Objective: To analyze the applicability and impact of artificial intelligence, specifically the Hypotension Prediction Index (HPI), in the prevention of hypotensive events in major surgeries. **Method:** This is an integrative literature review conducted in the PubMed, Cochrane Library, and SciELO databases, with a time frame from 2021 to 2026. Studies addressing the proactive analysis of arterial pressure waveform morphology and outcomes were selected.
Post-operative clinical assessments. **Results:** The evidence demonstrates that the tool offers a window. Predictive monitoring within 5 to 15 minutes allows for early interventions guided by parameters such as inotropism and stroke volume variation. The use of these algorithms resulted in greater hemodynamic stability and a significant reduction in postoperative complications, such as acute kidney injury and myocardial injury. **Conclusion:** The integration of predictive systems based on operational artificial intelligence raises the standard of surgical safety, transforming reactive monitoring into a precision strategy that mitigates the risks of tissue hypoperfusion.
Keywords: Artificial Intelligence; Hemodynamic Monitoring; Hypotension; Patient Safety; Surgery.

Abstract

Objective: To analyze the applicability and impact of artificial intelligence, specifically the Hypotension Prediction Index (HPI), in preventing hypotensive events during major surgeries.
Method: This is an integrative literature review conducted in the PubMed, Cochrane Library, and SciELO databases, covering the period between 2021 and 2026. Studies that addressed proactive analysis of arterial pressure waveform morphology and perioperative clinical outcomes were selected. **Results:** The evidence shows that the tool provides a predictive window of 5 to 15 minutes, allowing early interventions guided by parameters such as inotropism and stroke volume variation. The use of these algorithms resulted in greater hemodynamic stability and a significant reduction in postoperative complications, such as acute kidney injury and myocardial injury. **Conclusion:** The integration of artificial intelligence-based predictive systems into operations raises the standard of surgical safety, transforming reactive monitoring into a precision strategy that mitigates the risks of tissue hypoperfusion.
Keywords: Artificial Intelligence; Hemodynamic Monitoring; Hypotension; Patient Safety; Surgery.

Introduction

In the contemporary landscape of precision medicine, hemodynamic monitoring has evolved from a...

A purely reactive approach to a predictive model based on Artificial Intelligence (AI). The core of this

transformation is the Hypotension Prediction Index (HPI).

Index), a clinical decision support tool that uses machine learning algorithms.

(Machine learning) to analyze the morphology of the arterial pressure wave 1. Unlike

Conventional monitors, which only trigger alarms after a drop in pressure, are processed by HPI.

More than 2,600 characteristics of each cardiac cycle, identifying patterns of instability beforehand.

that hypotension manifests clinically 2.

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The tool operates using a numerical index that ranges from 0 to 100. High values indicate a high probability of the patient having a Mean Arterial Pressure (MAP) lower than 65 mmHg in the following minutes, offering a window of opportunity for intervention that varies from 5 15 minutes 3. In major surgeries, such as cardiac, vascular and other procedures For complex abdominal exercises, this anticipation is vital. Robust evidence published in recent years They consolidated the understanding that even brief periods of intraoperative hypotension can... being associated with serious complications, such as acute kidney injury and postoperative myocardial injury. 4, 5.

Currently, HPI is no longer considered an experimental technology. The tool has It has received regulatory approval from ANVISA and is already integrated into the routine of high-tech surgical centers. Complexity around the world 6. Clinical application allows the anesthesiologist to use data complementary contractility and stroke volume measurements, provided by the software, to treat the The specific cause of the instability before the event occurs on the 7th. Thus, the main objective The aim of this study was to clarify what HPI represents and how such technological utility can transform Hemodynamic management as part of a proactive strategy that prioritizes the safety of the surgical patient. 8.

Theoretical Framework

The basis of predictive monitoring lies in the advanced analysis of wave morphology. Systolic blood pressure. Unlike conventional monitoring, which is limited to extracting Instead of static values, the software processes complex elements, such as the area under the systolic curve and the... The slope of the systolic rise, technically represented by the formula dP/dtmax (pressure). diastolic/maximum positive pressure)9. This variable reflects the maximum variation in pressure over time. of the time during the ventricular ejection phase, serving as a reliable indicator of performance of the heart pump. This data is integrated by machine learning algorithms that recognize the hemodynamic signature of impending instability, allowing for the early detection of states of hypoperfusion 10.

A central pillar of this context is the ability of artificial intelligence to differentiate the The components of the hemodynamic triad are: preload, contractility, and afterload. The system utilizes the... Analysis of the systolic rise to identify if the drop in pressure is due to a failure in blood pressure monitoring. of heart contraction, cardiac compliance, or other vascular factors. Through

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real-time dynamic variables, such as Stroke Volume Variation (SVV) and Elastance
Arterial Dynamics , The doctor can determine if the patient is responsive to fluids or if...
requires vasopressor support 11. This differentiation is crucial in major surgeries to avoid both volume
overload and unnecessary use of catecholamines 12.
Recent literature also emphasizes the concept of "management by predictive goals," in which the objective
The therapeutic approach ceases to be about correcting established hypotension and becomes about maintaining it.
stability of the numerical index provided by the tool. Clinical studies demonstrate that
Maintaining the prediction index below critical limits correlates with a significant reduction.
in the variability of mean arterial pressure
13. This stability is the determining factor for preserving the self-regulation of organs.
vital organs, whose vascular beds are extremely sensitive to sudden pressure fluctuations during the
surgical procedure. 14.
Finally, integrating AI into the operating room reduces the cognitive load on the anesthesiologist.
by offering a "decision tree" based on statistical and physiological data. Furthermore, the
This tool can optimize diagnostic response time in cases of acute bleeding or failure.
of heart pump 15. Therefore, HPI is an assisted artificial intelligence tool that
promises to raise the standard of perioperative safety through accurate interpretation of the dynamics
cardiovascular 16.

Materials and methods

Integrative literature review, focused on gathering evidence on the use of intelligence.
artificial intelligence applied to predictive hemodynamic monitoring in the surgical setting. The search was
conducted using highly relevant scientific databases, specifically PubMed and Cochrane.
Library and SciELO, using the health descriptors (DeCS/MeSH): "Artificial Intelligence",
"Hemodynamic Monitoring", "Hypotension" and "Predictive Analytics". The time frame
The established period covered the time from January 2021 to April 2026, aiming to capture from the
From pioneering studies validating the algorithm to the most recent evidence of clinical impact in
centers of excellence.
The inclusion criteria selected original articles, randomized clinical trials, and reviews.
systematic studies that specifically addressed the use of HPI and hemodynamic variables.
related to major surgeries. Studies that discussed the accuracy of were prioritized.

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algorithm in the prevention of adverse outcomes, such as acute kidney injury and myocardial injury perioperative. Studies that addressed non-invasive basic monitoring without support for predictive algorithms, as well as studies published before 2021, ensuring that the The discussion should reflect the evolution of software versions approved by ANVISA and the FDA.

Results

The outcomes analyzed demonstrate that the implementation of artificial intelligence in the environment Surgical monitoring promotes a paradigm shift: the transition from reactive monitoring to management. Proactive hemodynamics. The data reveals that the prediction algorithm identifies changes. early signs in vascular compliance and blood flow dynamics that precede the drop in Mean arterial pressure 2. In practice, this technological advancement gives the anesthesiologist a an intervention window of up to 15 minutes before the onset of clinical hypotension, allowing for maintaining a state of continuous and stable tissue perfusion 3, 8.

Another relevant result relates to the precision in fluid and vasopressor therapy, guided by Advanced hemodynamic parameters. Through the tool's visual interface, the clinician It can accurately distinguish whether the impending instability stems from a reduction in volume. systolic or a failure in myocardial contractility 11. The use of these dynamic variables It allows for personalized volume optimization, avoiding excessive fluid administration. a factor associated with tissue edema and organ dysfunction — and ensuring that the support Pharmacological treatment should be directed to the patient's exact physiological need 13.

Finally, the results indicate that the reduction in the accumulated time of intraoperative hypotension... This correlates directly with improved postoperative outcomes. A... a significant decrease in the incidence of myocardial injury and acute kidney injury, since the The tool mitigates periods of hypoperfusion that damage target organs 5, 14. It is concluded that the The use of predictive indexes acts as a decision support system that increases safety. perioperative recovery reduces hemodynamic variability and promotes a faster clinical recovery. favorable in highly complex procedures 16.

Discussion

Analysis of the evidence demonstrates that the main contribution of artificial intelligence in Perioperative medicine is about eliminating diagnostic latency. Traditionally, the management

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The hemodynamic approach is based on a reactive model, in which therapeutic intervention is initiated only after exceeding critical pressure thresholds. However, current literature emphasizes that to demonstrate that cellular and organ damage is cumulative and occurs even during episodes of hypotension. Subclinical 4, 5. The use of HPI allows the clinician to act in the "zone of protection," converting the monitoring as part of a primary prevention strategy for organ dysfunction, which redefines the standard of care in highly complex surgeries 9, 10.

Another key point for discussion is the mitigation of cognitive load and human error by through multiparametric analysis. In surgical stress scenarios, the isolated interpretation of Variables can lead to inaccurate decisions; however, the algorithm's ability to integrate data... Cardiovascular dynamics analysis offers an immediate differential diagnosis of the cause of instability. 11, 15. This precision in choosing between fluid replacement and inotropic support is what differentiates Modern management of conventional practice, avoiding iatrogenic interventions such as overload. water loss, which is known to compromise tissue healing and renal function 7, 13.

Finally, it is argued that the adoption of this technology represents the consolidation of precision medicine. in the operating room. Although the anesthesiologist's clinical judgment remains the central pillar. In the context of healthcare, the integration of predictive systems acts as a real-time digital biomarker. 1, 16. Thus, the discussion converges on the need to incorporate these tools as a standard. Gold standard for perioperative safety, ensuring that medical intervention is as early as possible. the physiological change itself 8, 12.

Conclusion

The implementation of the Hypotension Prediction Index (HPI) represents a disruptive advance in Patient safety during major surgery. By replacing the model of By shifting from a proactive and personalized approach to reactive monitoring, the tool allows you to maintain the hemodynamic stability and preserving organ perfusion, significantly reducing the incidence of serious postoperative complications, such as renal and myocardial injuries 5, 14.

In short, artificial intelligence is establishing itself as an indispensable decision support system. to contemporary precision medicine. The use of predictive algorithms not only optimizes the Fluid and vasopressor therapy, but it also raises the standard of perioperative care by mitigating risks inherent to hemodynamic variability, ensuring more favorable clinical outcomes and a Safer surgical recovery 8, 16.

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