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CORRESPONDENCE

Hypotension Prediction Index software alarms during major noncardiac surgery: a *post hoc* secondary analysis of the EU-HYPROTECT registry

Karim Kouz[a,b], Thomas W. L. Scheeren[c,d], Tim van den Boom[e] and Bernd Saugel[a,b,*]

[a]Department of Anesthesiology, Center of Anesthesiology and Intensive Care Medicine, University Medical Center Hamburg–Eppendorf, Hamburg, Germany, [b]Outcomes Research Consortium, Cleveland, OH, USA, [c]Department of Anesthesiology, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands, [d]Edwards Lifesciences, Garching, Germany and [e]Edwards Lifesciences, Nyon, Switzerland

*Corresponding author. E-mail: bernd.saugel@gmx.de

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Editor—We recently reported the primary results[1] of the prospective observational EU-HYPROTECT registry[2] that includes 702 patients who were monitored using the Acumen Hypotension Prediction Index software (HPI-software) (Edwards Lifesciences, Irvine, CA, USA) during elective major noncardiac surgery in 12 medical centres in five European countries (France, Germany, Italy, Spain, and the United Kingdom).[1] The HPI-software was developed using machine learning to predict impending hypotension, defined as a MAP of less than 65 mm Hg for at least 1 min, by analysing features of the BP waveform.[3] The unitless HPI quantifies the likelihood that hypotension will occur on a scale between 0 and 100.[3] HPI values over 85 trigger acoustic and visual alarms.

Patients in the registry were monitored using the Acumen IQ sensor (Edwards Lifesciences) and the HemoSphere monitoring platform (Edwards Lifesciences), which calculates and continuously displays HPI.[1,2] In registry patients, the degree and duration of intraoperative hypotension was low, as indicated by a low median (25% percentile–75% percentile) time-weighted average MAP less than 65 mm Hg of 0.03 (0.00–0.20) mm Hg.[1] During surgery with a median duration of 209 (153–290) min, patients spent a median of 2 (0–9) min with a MAP below 65 mm Hg.[1] The observational nature of the registry makes it difficult to know to what extent the HPI-software monitoring contributed to limiting the degree and duration of hypotension. Nevertheless, data on HPI alarms that occurred in registry patients may help to understand the role that HPI-software monitoring may have played.

Therefore, we aimed to investigate how often, when, and at what MAP HPI alarms occurred during surgery in patients included in the EU-HYPROTECT registry. We performed a *post hoc* secondary analysis of HPI alarms that occurred in these patients. We performed descriptive analyses to characterise HPI alarms and reported continuous variables as medians (25%–75% percentiles) and categorical variables as absolute numbers (percentages).

In the EU-HYPROTECT registry patients, the total duration of HPI monitoring was 2606 h, and the median duration of HPI monitoring per patient was 199 (141–275) min. There were 5465 HPI alarms in total. In 625 of 702 patients (89%), there was at least one HPI alarm during surgery. The median number of HPI alarms per patient was 5 (2–11). The median duration of a single HPI alarm was 2 (1–4) min. The median cumulative duration of HPI alarms per patient was 18 (5–50) min, which translates into 10 (3–25)% of monitoring time. The occurrence of HPI alarms was evenly distributed throughout the course of surgery (Fig 1a). The median MAP at which HPI alarms occurred was 71 (70–73) mm Hg (Fig 1b).

The high number of HPI alarms in EU-HYPROTECT registry patients suggests that they were prone to intraoperative hypotension. Considering that the HPI-software predicts impending hypotension defined as a MAP of less than 65 mm Hg for at least 1 min[3] and that the median time-weighted average MAP of less than 65 mm Hg was very low in registry patients, one may speculate that clinicians reacted to HPI alarms and intervened to treat impending hypotension. However, we cannot match HPI alarms with therapeutic interventions, as we did not systematically record interventions. Thus, there may have been other reasons for the low occurrence of hypotension in the registry

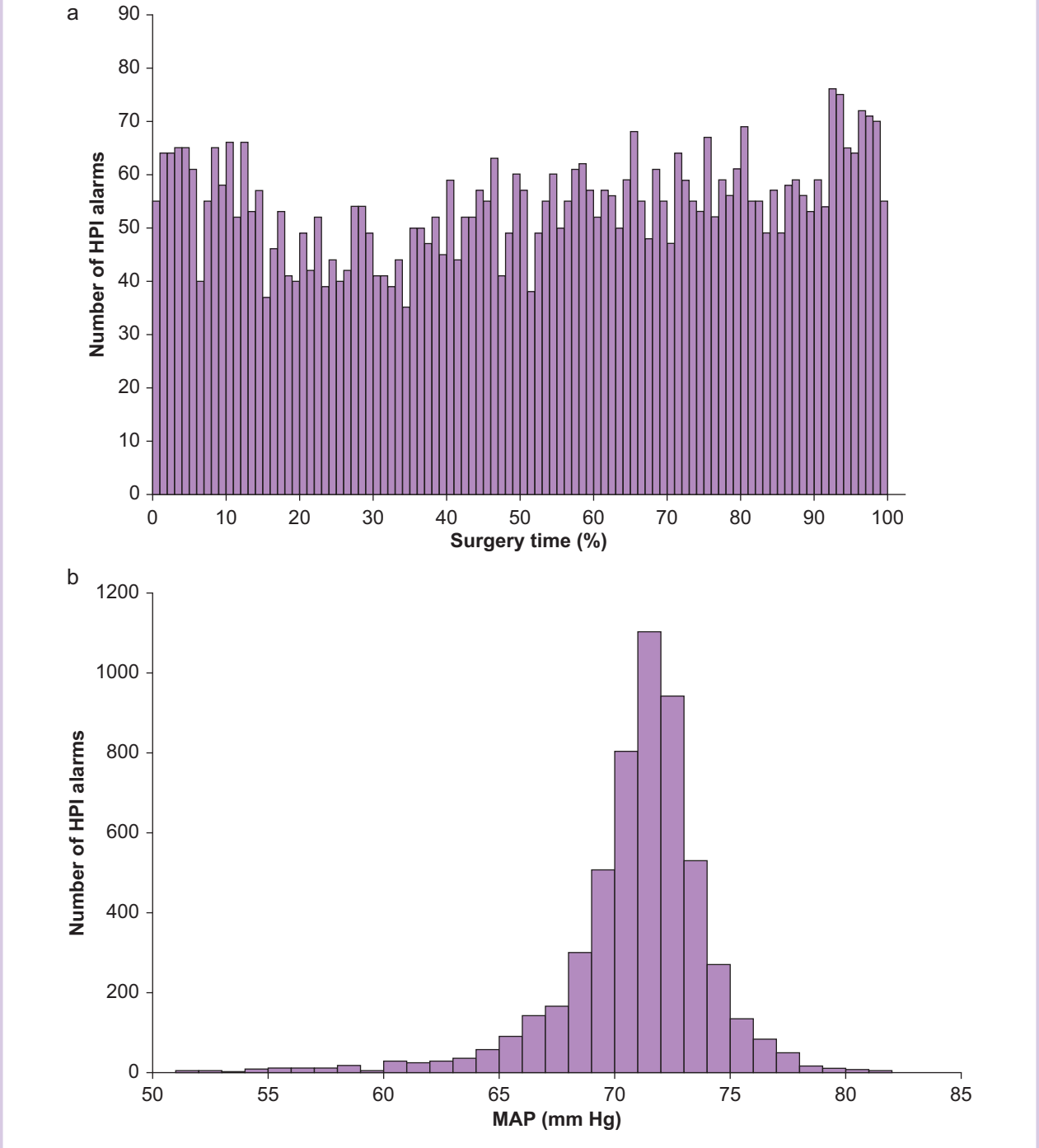

Fig 1. Histograms illustrating (a) when during surgery HPI alarms occurred and (b) the MAP values at which HPI alarms occurred. HPI, Hypotension Prediction Index.

patients, including a tendency for clinicians to avoid hypotension because they knew that the patients were in the study.

Intraoperative hypotension can have multiple causes, including vasodilation, myocardial depression, bradycardia, and hypovolaemia,[4] and is probably best treated causally considering the presumed underlying causes. To better understand the effects of using HPI-software monitoring on hypotension, future studies need to focus on investigating whether and how clinicians react to HPI alarms.

In summary, there were HPI alarms in 9 of 10 EU-HYPROTECT registry patients. The median number of HPI alarms per patient was 5. The HPI alarms occurred throughout surgery at a median MAP of 71 mm Hg. Future research needs to determine how clinicians react to HPI alarms and how to best treat impending hypotension.

Declarations of interest

KK is a consultant for and has received honoraria for giving lectures from Edwards Lifesciences (Irvine, CA, USA). KK is a consultant for Vygon (Aachen, Germany). TWLS received research grants and honoraria from Edwards Lifesciences (Irvine, CA, USA) and Masimo (Irvine, CA, USA) for consulting and lecturing (all payments made to institution). TWLS is currently working at Edwards Lifesciences (Irvine, CA, USA) as a medical affairs director. TvdB is a employee of Edwards Lifesciences (Irvine, CA, USA). BS is a consultant for and has received institutional restricted research grants and honoraria for giving lectures from Edwards Lifesciences (Irvine, CA, USA). BS is a consultant for Philips North America (Cambridge, MA, USA) and has received honoraria for giving lectures from Philips Medizin Systeme Böblingen (Böblingen, Germany). BS has received institutional restricted research grants and honoraria for giving lectures from Baxter (Deerfield, IL, USA). BS is a consultant for and has received institutional restricted research grants and honoraria for giving lectures from GE Healthcare (Chicago, IL, USA). BS has received institutional restricted research grants and honoraria for giving lectures from CNSystems Medizintechnik (Graz, Austria). BS is a consultant for Maquet Critical Care (Solna, Sweden). BS has received honoraria for giving lectures from Getinge (Gothenburg, Sweden). BS is a consultant for and has received institutional restricted research grants and honoraria for giving lectures from Pulsion Medical Systems (Feldkirchen, Germany). BS is a consultant for and has received institutional restricted research grants and honoraria for giving lectures from Vygon (Aachen, Germany). BS is a consultant for and has received institutional restricted research grants from Retia Medical (Valhalla, NY, USA). BS has received institutional restricted research grants from Osypka Medical (Berlin, Germany). BS was a consultant for and has received institutional restricted research grants from Tensys Medical (San Diego, CA, USA). BS is an Editor of the *British Journal of Anaesthesia*.

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References

1. Kouz K, Monge Garcia MI, Cerutti E, et al. Intraoperative hypotension when using hypotension prediction index software during major noncardiac surgery: a European multicentre prospective observational registry (EU HYPROTECT). *BJA Open* 2023; **6**, 100140
2. Monge García MI, García-López D, É Gayat, et al. Hypotension Prediction Index software to prevent intraoperative hypotension during major non-cardiac surgery: protocol for a European Multicenter Prospective Observational Registry (EU-HYPROTECT). *J Clin Med* 2022; **11**: 5585
3. Hatib F, Jian Z, Buddi S, et al. Machine-learning algorithm to predict hypotension based on high-fidelity arterial pressure waveform analysis. *Anesthesiology* 2018; **129**: 663–74
4. Kouz K, Brockmann L, Timmermann LM, et al. Endotypes of intraoperative hypotension during major abdominal surgery: a retrospective machine learning analysis of an observational cohort study. *Br J Anaesth* 2023; **130**: 253–61

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