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Methodology to automatically detect abnormal values of vital parameters in anesthesia time-series: Proposal for an adaptable algorithm

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ABSTRACT

Abnormal values of vital parameters such as hypotension or tachycardia may occur during anesthesia and may be detected by analyzing time-series data collected during the procedure by the Anesthesia Information Management System. When crossed with other data from the Hospital Information System, abnormal values of vital parameters have been linked with postoperative morbidity and mortality. However, methods for the automatic detection of these events are poorly documented in the literature and differ between studies, making it difficult to reproduce results. In this paper, we propose a methodology for the automatic detection of abnormal values of vital parameters. This methodology uses an algorithm allowing the configuration of threshold values for any vital parameters as well as the management of missing data. Four examples illustrate the application of the algorithm, after which it is applied to three vital signs (heart rate, SpO2, and mean arterial pressure) to all 2014 anesthetic records at our institution.

1. Introduction

Abnormal values of vital parameters (AVVP) such as hypotension or tachycardia frequently occur during anesthesia procedures and may lead to organ dysfunction, resulting in increased hospital length of stay, increased morbidity and, in some cases, death [1]. These AVVP are related to side effects of anesthetic drugs such as vasoplegia or myocardial depression, procedure-related complications such as bleeding or fluid loss, and patient-related risk factors and comorbidities stratified by ASA status (patient health status assessed before surgery on a scale of 1 to 6, defined by the American Society of Anesthesiologists [2]). Occurrences of AVVP can be detected by analysis of time-series data collected during the anesthesia procedure by Anesthesia Information Management Systems (AIMS). AIMS are a specialized form of electronic health record (EHR) systems that allow the automatic and reliable collection, storage, and presentation of patient data during the perioperative period, from preoperative assessments through the intraoperative period to discharge from post-anesthesia care unit (PACU). These systems record patient

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history, surgery or procedure, drugs administered, surgical and anesthetic procedures, ventilation parameters (tidal volume, inhaled oxygen fraction, inhaled and exhaled anesthetic gas fractions. . .) and both vital and physiologic parameters among which: mean arterial pressure (MAP), heat rate (HR), respiratory rate (RR), end-tidal CO2 (EtCO2), bispectral index (BIS, an electroencephalogram-based index designed to assess depth of anesthesia). AVVP are characterized by clinically relevant thresholds/ranges defined for each parameter and time elapsed outside predefined thresholds/ranges. As an example, intraoperative time spent with a MAP lower than 55 mmHg is associated with increased likelihood of postoperative acute kidney injury and myocardial injury in patients undergoing noncardiac surgery [3].

Through the implementation of Health Information Systems (HIS) in hospitals, huge volumes of data related to patient care are currently recorded daily worldwide [4,5]. Some components of HIS, such as EHRs and AIMS, allow physicians to access patient information remotely and instantaneously for decision making during care delivery. HIS also offer opportunities for further post hoc use of recorded data for research, decision support, quality-control, and optimization or educational purposes [6,7]. To these ends, anesthesia time-series data collected with AIMS may be used post hoc to automatically detect AVVP retrospectively for analysis [8]. Automatic detection of these events has been reported to be of better quality than when manually recorded [8–10]. Moreover, AIMS data may be further analyzed in relation with information about hospital stay from other Hospital Information System (HIS) databases. Indeed, some studies highlighted a statistical relation between the occurrence of intraoperative AVVP and increased mortality or length of stay [1,3,11–15]. However, AVVP detection methods and management of missing data vary widely. Moreover, these issues are compounded by poor description of methods used in reported studies, so that reproducing results obtained by others remains challenging.

Concerning the issue of AVVP detection, various thresholds have been reported for vital parameters and for time elapsed outside of normal ranges. Reich *et al.* [12] measured hypotension using the median value of MAP measurements over a 5 min period in order to minimize the effect of measurement artifacts. Each median value was then classified as low, normal, or high according to the two predefined upper and lower thresholds of 55 and 100 mmHg, respectively. On the other hand, Sessler *et al.* [1] used the most recent values (measured at 1 min intervals from an arterial line or at 5 min intervals through oscillometry) within the past 20 min when available, and were otherwise considered to be missing. Neither study provided information on how missing data were handled. In order to detect the same AVVP, Kertai *et al.* [11] chose the linear interpolation between two successive measurements, with a MAP threshold of 75 mmHg defining hypotension. Records were excluded when there were missing data for more than 15 consecutive minutes for MAP, for more than 55% of the procedure time for BIS and/or more than 25% of missing data for the three studied parameters MAP, BIS, and Minimum Alveolar Concentration (MAC).

As these studies, crucial to defining safe intraoperative care, become increasingly frequent, proposing reliable and reproducible methods for automatic detection of AVVP in anesthesia time-series data is a priority. To this end, we propose detailed principles for AVVP detection on time-series data, the parameters that must be taken into account to configure an AVVP detection algorithm, an algorithm based upon these principles, the associated data model that can be implemented to compute the total duration of AVVP over the studied period, and a proposal for management of missing data. Additionally, the application of the algorithm is illustrated with sample runs covering various cases.

2. Computational method and theory

In order to be configurable in the way it deals with data and various missing data management methods, the algorithm must take into account the following constraints:

- manage the input data flow and discern the different interventions recorded;
- allow simultaneous screening for AVVP across several parameter/thresholds as different parameters may present abnormal values over the same or overlapping periods;
- detect episodes of abnormal values with a beginning and an end per event;

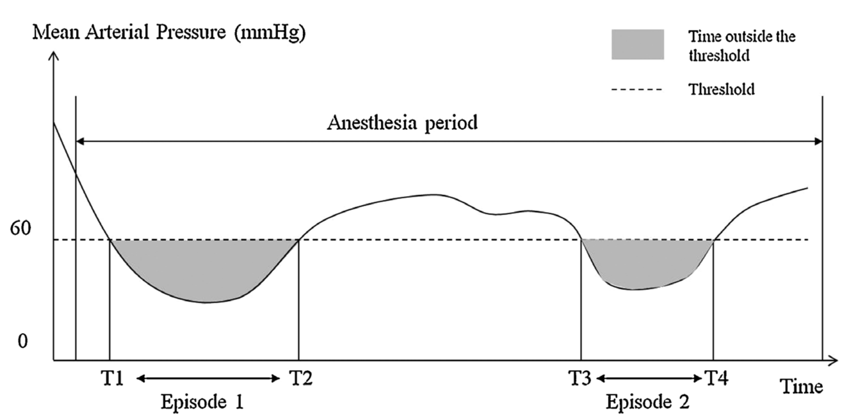

Fig. 1 – Graphical illustration of two instances of episodes of hypotension (Mean Arterial Pressure < 60 mmHg) during anesthesia. Episodes begin when the Mean Arterial Pressure decreases below the threshold (60 mmHg). Episodes end when this value returns above the threshold.

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