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Article

ARTICLE

Intraoperative arterial blood pressure lability is associated with improved 30 day survival

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Abstract

Background: Arterial blood pressure lability, defined as rapid changes in arterial blood pressure, occurs commonly during anaesthesia. It is believed that hypertensive patients exhibit more lability during surgery and that lability is associated with poorer outcomes. Neither association has been rigorously tested. We hypothesized that hypertensive patients have more blood pressure lability and that increased lability is associated with increased 30 day mortality.

Methods: This was a retrospective single-centre study of surgical patients from July 2008 to December 2012. Intraoperative data were extracted from the electronic anaesthesia record. Lability was calculated as the modulus of the percentage change in mean arterial pressure between consecutive 5 min intervals. The number of episodes of lability >10% was tabulated. Multivariate logistic regression was performed to determine the association between lability and 30 day mortality using derivation and validation cohorts.

Results: Inclusion criteria were met by 52 919 subjects. Of the derivation cohort, 53% of subjects were hypertensive and 42% used an antihypertensive medication. The median number of episodes of lability >10% was 9 (interquartile range 5–14) per patient. Hypertensive subjects demonstrated more lability than normotensive patients, 10 (5–15) compared with 8 (5–12), $P<0.0001$. In subjects taking no antihypertensive medication, lability >10% was associated with decreased 30 day mortality, odds ratio (OR) per episode 0.95 [95% confidence interval (CI) 0.92–0.97], $P<0.0001$. This result was confirmed in the validation cohort, OR 0.96 (95% CI 0.93–0.99), $P=0.01$, and in hypertensive patients taking no antihypertensive medication, OR 0.96 (95% CI 0.93–0.99), $P=0.002$. Use of any antihypertensive medication class reduced this effect.

Conclusions: Intraoperative arterial blood pressure lability occurs more often in hypertensive patients. Contrary to common belief, increased lability was associated with decreased 30 day mortality.

Key words: anaesthesia; anaesthesiology; blood pressure; haemodynamics; intraoperative period; perioperative period

Approximately 50 million surgical procedures are performed annually in the USA.[1] Despite tremendous advances that have occurred over the past 50 yr in perioperative medicine, 30 day mortality rates remain ~1.5%. Most perioperative care providers have been taught that arterial blood pressure (BP) lability, defined as rapid changes in arterial BP over a short period of time, contribes to cardiovascular complications and mortality.[2] It is also believed that hypertensive patients exhibit more lability during surgery.[3] While these opinions are well accepted amongst anaesthetists, neither association has been tested rigorously. To date, there is only evidence showing that changes from a baseline determined before surgery or the percentage of time spent above or below a defined BP threshold are associated with adverse outcomes.[2 4–7]

We previously validated a method for quantifying intraoperative haemodynamic lability based upon the percentage change in arterial BP between consecutive time intervals. That study,

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Editor's key points

- In a retrospective analysis of 52 919 subjects undergoing surgery with general anaesthesia, hypertensive subjects had more arterial pressure lability.
- In subjects not taking antihypertensive medication, arterial pressure lability was associated with reduced 30 day mortality.
- These data suggest that labile perioperative haemodynamic responses reflect a more adaptive and protective autonomic nervous system.

however, did not investigate associations of lability with outcome.[8] In the present study, we hypothesized that intraoperative haemodynamic lability is associated with an increase in 30 day mortality in patients undergoing non-cardiac surgery. As a secondary outcome, we looked at the incidence of non-fatal perioperative myocardial injury (PMI).

Methods

Institutional Review Board approval and waiver of informed consent were obtained for this study. We retrospectively reviewed all adult (aged 18–89 yr) inpatient and day-of-admission non-cardiac surgical procedures performed at our institution between July 1, 2008 and December 18, 2012. Patients who underwent more than one anaesthetic during their admission were excluded. Haemodynamic data were electronically recorded by our anaesthesia information management system (CompuRecord; Philips Medical, Andover, MA, USA). The frequency of data recording ranged from every 15 s for patients with invasive arterial BP monitoring, to every 1–5 min when non-invasive blood pressure monitoring was used. Patient characteristics, preoperative medication use and perioperative data (e.g. length of surgery, anaesthetic technique, use of blood products) were also obtained from the anaesthesia information management system. Additional data on patient co-morbidities (i.e. ICD-9 diagnosis codes) were retrieved from administrative data. Supplementary data Table S1 provides a detailed description of the definition and source of variables used in the analysis. The 30 day mortality was determined using either institutional administrative data or the Social Security Administration Death Master File (National Technical Information Service, Alexandria, VA, USA).

Assessment of preoperative risk

Preoperative risk was assessed using the ASA physical status score and the Charlson co-morbidity index, which was calculated using ICD-9-CM diagnosis codes, using the methods of Quan and colleagues[9] to map ICD-9-CM codes to co-morbidities and the revised weights of Schneeweiss and colleagues[10] to compute the index (see Supplementary data Table S1). The presence of preoperative hypertension was determined using a combination of anaesthesia information management system data (documented hypertension or documentation of antihypertensive medication use) and ICD-9-CM diagnosis codes (see Supplementary data for the definition of ICD-9-CM hypertension codes and full list of antihypertensive medications analysed).

Classification of antihypertensive medication was based upon the major classes of antihypertensive medications recommended by the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 for the treatment of hypertension (see Supplementary data Table S2).[11] Our goal was to include all medications used to treat hypertension. Preliminary analysis revealed a complex relationship among class of antihypertensive therapy, BP lability, and mortality, with each medication class associated with a distinct level of lability and 30 day mortality (see Supplementary data Table S3 and Fig. S1A). Antihypertensive medication use was therefore classified as follows: use of no antihypertensive medications, use of angiotensin-converting enzyme (ACE) inhibitors or angiotensin receptor blockers (ARBs) only, use of β-blockers (BB) with or without any other class of antihypertensive medications [ACE/ARBs, calcium channel blockers, diuretics, α_2-agonists, or directly acting vasodilators], and use of other antihypertensive medications without BB or ACE/ARB (see Supplementary data Fig. S1B).

To assess the risk of PMI, the revised cardiac risk index (RCRI) was calculated.[12] Perioperative myocardial injury was defined as an abnormal cardiac troponin I within 72 h after surgery. The laboratory cut-off value for an abnormal cardiac troponin I used at our institution during the study period was 0.5 ng ml^{-1}.

Calculation of intraoperative arterial blood pressure lability

Baseline mean arterial pressure (MAP) was determined by calculating the median of all recorded pre-anaesthesia induction MAP readings. For regional or monitored anaesthesia care (MAC) procedures, block placement or procedure start time, respectively, was used in place of anaesthesia induction time. The degree of intraoperative arterial BP lability was quantified using a previously validated method.[8] Briefly, median MAP was first calculated throughout 5 min intervals throughout the procedure. Medians were used in order to remove monitoring artifacts, such as arterial line flushes, and to minimize the influence of transient changes.[13] Blood pressure lability was then quantified by determining the modulus (absolute value) of the percentage change in MAP between consecutive 5 min intervals. We deliberately did not distinguish between a positive *vs* a negative change because the parameter of interest was lability, which is a fluctuating value, not dependent on increasing or decreasing values *per se*. If no valid data were available for a given interval, the last valid MAP was carried forward. In the absence of gold standards for definition of lability, we counted the number of episodes where the lability was within the prespecified ranges 6–10, 11–15, 16–20, 21–20, and >25% for each patient. We also counted the number of 5 min intervals during which MAP was within prespecified blood pressure ranges (<50, 50–59, 60–69, 70–79, 80–110, 111–120, 121–130, and >130 mm Hg).

Statistical analysis

Descriptive data are reported as *n* (percentage), mean (standard deviation) or median (interquartile range, IQR). For group comparisons, χ^2 tests were used for categorical variables, Student's *t*-tests or ANOVA were used for normally distributed continuous variables, and Wilcoxon rank-sum tests or Kruskal–Wallis tests for skewed continuous variables, as appropriate. Pearson or Spearman correlation coefficients were used to describe bivariate associations between two continuous variables.

Selection of lability and mean arterial pressure thresholds

In order to determine the most relevant lability thresholds to include in the final model, an initial stepwise logistic regression,