Original Article

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Effect of Masked Uncontrolled Hypertension on Perioperative Haemodynamic Response and Recurrent Adverse Cardiovascular Events among Patients Undergoing Major Noncardiac Surgery

Sirikarn Siripruekpong, M.D.[1,2], Alan F. Geater, Ph.D.[2], Sirichai Cheewatanakornkul, M.D.[3]

[1]Department of Anaesthesiology, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.

[2]Department of Epidemiology, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.

[3]Division of Cardiology, Department of Internal Medicine, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.

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Abstract:

Objective: To compare masked uncontrolled hypertension (MUCH) (n=16) and adequately controlled hypertension (ACH) (n=21) patients regarding their haemodynamic response to induction, incision and extubation, and evaluate the risk of perioperative recurrent adverse cardiovascular events in a prospective observational study.

Material and Methods: After home blood pressure (BP) monitoring, patients were classified as MUCH or ACH using objective criteria. Perioperative haemodynamic parameters were monitored. Recurrent adverse event risks were evaluated using total-time and gap-time recurrent-event analysis.

Results: BP responses to induction were qualitatively similar in the two groups, but with an exaggerated response following incision and extubation in the MUCH group. Risks of recurrent hypertensive events were higher in MUCH than in ACH patients during the intraoperative and emergence periods, with hazard ratios [95% confidence intervals] of 2.10 [1.21, 3.64] and 4.73 [1.12, 19.89] from total-time models, and 1.84 [1.20, 2.84] and 5.91 [1.45, 24.11] from gap-time models; the risk of recurrent bradycardia was higher during emergence, 4.08 [1.22, 13.59] from total-time and 4.88 [1.77, 13.45] from gap-time models. In contrast, the risk of recurrent hypotension was significantly lower in the MUCH patients during induction.

Conclusion: Compared to ACH, MUCH patients were at increased risk of recurrent hypertensive events during the intraoperative and emergence periods, and of recurrent bradycardia during emergence.

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Contact: Alan F. Geater, Ph.D.
Department of Epidemiology, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.
E-mail: alan.g@psu.ac.th

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Introduction

Preoperative hypertension is commonly encountered in surgical patients; at least 25% of patients undergoing major non-cardiac surgery have hypertension prior to their surgical procedure[1,2]. An association of preoperative hypertension with major adverse events has long been recognized. Hypertensive patients are known to have increased arterial BP lability during anaesthesia compared with normotensive patients[3] and are more likely to experience perioperative bradycardia, tachycardia, and hypertension-complications that require careful management[4].

A consequence of perioperative haemodynamic instability, both hypotension and hypertension, is an increased risk of adverse perioperative cardiovascular events. Various studies have reported that perioperative hypotension occurred frequently during non-cardiac surgery and was associated with myocardial injury, acute kidney injury, and death[5–11]. Also, perioperative hypertension has also been reported to be related to an increased risk of postsurgical delirium and intracranial haemorrhage[10]. The most important goal of BP management during anaesthesia is maintenance of adequate tissue perfusion that aims to protect organ function. The assessment of adequate tissue perfusion is not simple; in current practice, blood pressure and heart rate are used as the main haemodynamic targets[12].

The most common etiology of perioperative hypertension is poorly controlled hypertension[13], which is an independent predictive factor of cardiac adverse events in noncardiac surgery[12]. Controlling perioperative hypertension in relation to the patient's preoperative BP is currently recommended based on the assumption that the risk of complications will be reduced and outcomes improved. Home BP measurement (HBPM) has a better prognostic accuracy than office BP measurement and correlates better with left ventricular mass index[14], and an increase in systolic (SBP) and diastolic BP (DBP) from self-measurement at home was associated with an increased risk of a cardiovascular event and mortality[14,15].

Masked uncontrolled hypertension (MUCH) occurs in approximately 30% of hypertensive patients on antihypertensive therapy, in whom BP appears to be well controlled based on office assessment[16] but whose BP at home remains high. These patients are often under-recognized but the risks of future cardiovascular events and end organ damage are 2-3 times higher than in normotension or white coat hypertension[14,17]. The effects of MUCH on the cardiovascular system have been reported to include autonomic nervous system dysfunction with increased sympathetic activity and decreased parasympathetic tone[18], decreased baroreflex sensitivity[19], and increased blood pressure variability[20]. These mechanisms can result in vigorous haemodynamic responses during anaesthesia.

Because of the apparently controlled hypertension at the clinic, MUCH patients are at high cardiovascular risk but there is a lack of information about the haemodynamic response during anaesthesia. The objective of this study was to compare the immediate haemodynamic responses, including blood pressure and heart rate, to anaesthetic induction, surgical incision and emergence from anaesthesia, and to compare the risk of perioperative recurrent adverse cardiovascular events between MUCH and adequately controlled hypertension (ACH) patients.

Material and Methods

1) Study design and setting. This was a prospective observational study conducted at Songklanagarind Hospital, Thailand, between August 2020 and January 2021.

2) Study participants. Patients who were currently being treated for hypertension, had apparently controlled BP (less than 140/90 mmHg) based on office measurements, and were scheduled for elective major non-cardiac surgery under general anaesthesia were invited to participate in this study. All patients received essential information on the study objectives and willingly gave their written informed consent. Patients who had a history of severe cardiac problems, e.g., severe valvular heart disease, heart failure, myocardial infarction with poor cardiac output, left ventricular ejection fraction <35.0% or functional class III-IV by the New York Heart Association classification, pheochromocytoma or a mass or a masses at the adrenal glands, increased intracranial pressure, end-stage renal failure receiving haemodialysis or peritoneal dialysis therapy, severe vascular diseases e.g. aortic aneurysm or arterial occlusion, or who were pregnant were not enrolled in the study. The required sample size was estimated to be 40, using the implementation in Stata version 14.1 (StataCorp LLC, Texas, USA) for detecting a hazard ratio of at least 2.5 (or less than 0.4) between the MUCH and ACH patients with a power of 80.0% and an alpha of 0.05 with a ratio of ACH to MUCH patients of 1.5.

3) Study variables. Baseline BP at the clinic, out-of-office BP and perioperative BP and HR measured every 1 minute during induction and every 5 minutes during intraoperative and post-anaesthtetic care periods.

4) Study instruments: For out-of-office BP measurements an automatic BP device (HEM-7121AP OMRON Healthcare, Japan) was used. Intraoperative and postoperative BP and HP were measured using real-time multipurpose monitoring: IntelliVue MX550/MP50 Patient Monitors, Philips, Germany.

5) Data collection procedures. The baseline BP in the office was the average of the last 2 out-patient visit BP measurements taken when the participant was sitting unstressed and pain-free. The baseline clinical profile of all patients was detailed at the out-patient clinic. For accurate measurements and recordings of BPs, every patient and caregiver performed BP self-monitoring after being trained to follow the protocol by a cardiac nurse specialist, requesting them to measure at least once in the morning and once in the evening over a period of 3-7 days[21,22] within 6 months prior to surgery at home or elsewhere outside the clinic setting.

This study selected HBPM to measure out-of-office BP. This was due to the expectation that HBPM over a period of days should be more reliable than 24-hour ambulatory BP monitoring (ABPM) on a single day, and HBPM being a more practical approach than ABPM in real clinical practice. All patients used the OMRON automatic BP device, which is clinically validated according to the standards of the Association for the Advancement of Medical Instrumentation (AAMI)/European Society of Hypertension International Protocol (ESH), as the HBPM device. Cuff size and procedures for the BP recording and the measurement validation followed the recommendation of the 2017 ACC/AHA High BP Clinical Practice Guideline[21].

On the day of operation, the preinduction haemodynamic parameters, consisting of SBP, MAP, DBP and HR were measured after stabilizing the patient in the operating room for 5-10 minutes before inducing anaesthesia and then monitored throughout the procedure. The BP was monitored either oscillometrically from an upper-arm cuff at intervals or continuously from an arterial catheter, and heart rate was recorded as the actual data from a real time monitor. The real time parameters were recorded every minute during the first 10 minutes after anaesthetic induction and thereafter every 5 minutes until the end of the recovery phase in the Post-Anaesthetic Care

Unit (PACU). Decisions concerning anaesthesia were made by the attending anaesthetic team, who did not know the classification of hypertension of the patient.

6) Data management. All data were double-entered using EpiData 3.1 and analysed using Stata version 14.1 (StataCorp LLC, Texas, USA).

7) Data analysis. Masked hypertension was defined as having normal BP in the clinic (<140/90 mmHg) but high out-of-clinic BP, defined as an average daytime BP on multiple measurements with a HBPM of ≥135/85 mmHg[21,23]. Participants were then classified into the MUCH or ACH group, and the classification was confirmed by an experienced cardiologist.

Standard descriptive analysis was performed. Patient characteristics are reported as mean and standard deviation (S.D.) for normally distributed data and were compared using t-test. Categorical variables are presented as frequency with percentage and were compared across groups using Fisher's exact test. A p-value<0.05 was considered to indicate statistical significance.

The perioperative haemodynamic parameter responses in the critical periods following anaesthesia induction, surgical skin incision, and emergence from anaesthesia were compared between the MUCH and ACH groups. To evaluate the patients' responses to anaesthetic induction, the haemodynamic parameters were analysed starting from the time that the first anaesthetic agent was given and repeated each minute for 10 minutes. For the response to incision the parameters were evaluated starting at the moment of incision and continued at 5-minute intervals for the first 30 minutes, to cover the period when massive bleeding is unlikely. The response to extubation was evaluated at 5-minute intervals from 10 minutes before to 20 minutes after the time of tracheal extubation. Evaluation was started 10 minutes before extubation as this is the time that drugs to reverse neuromuscular blockade were administered – most commonly, the cholinesterase inhibitors were combined with anticholinergic agents to prevent fatal muscarinic effects.

Evaluation of the changes in SBP, MAP, DBP and HR in the MUCH and ACH patients was performed using mixed-effects random-intercept linear regression models to accommodate the repeated measures on each patient, and the results are presented as margin plots showing mean values with 95% confidence intervals (95%CIs). The values at each time point for each patient were compared with those at the start of the evaluation time window, and the magnitude of these changes and of the values themselves at each time point compared between the two groups.

The risks of recurrent minor haemodynamic adverse events – hypertension, hypotension, tachycardia and bradycardia – throughout the three perioperative periods, namely in the 10 minutes following anaesthesia induction, the whole duration from first incision to extubation, and from time of extubation to exiting the PACU, were compared between the two groups. The occurrence of any serious complications including abnormal ECG, acute coronary arterial disease/myocardial infarction, and death, were also recorded. A hypertension episode was defined as a BP monitoring value of SBP>160 mmHg or MAP>100 mmHg; a hypotensive episode as a BP value of SBP<90 or MAP<65 mmHg; a tachycardia episode as an HR value of >100 bpm, and a bradycardia episode as a HR value of <60 bpm. In the case that the same adverse event was recorded at contiguous monitoring time points, only the first occurrence in the series was considered as the event.

The risks of these adverse haemodynamic episodes were compared using the techniques of recurrent-event analysis applied to Cox proportional hazard models. Two techniques were applied, namely the Prentice, Williams and Peterson total-time (PWP-TT) and gap-time (PWP-GT) techiques[24], each of these assembling the risk group

of a recurrent event in different ways. In PWP-TT models the time to each event is counted from the onset of the corresponding perioperative period, whereas in PWP-GT models the time at risk of a recurrent event (if not the first event) is reset to zero at the end of the preceding event[25,26].

However, in each model in our study, within event type, the events were considered to be equivalent and to have the same risk. That is, the order of the event was considered to be non-distinguishing. Comparative risks for each type of adverse event in each of the three perioperative periods were expressed as hazard ratios with corresponding 95% CI.

8) Ethical considerations. Approval for this study was granted by the Office of the Human Research Ethics Committee (HREC) of the Faculty of Medicine, Prince of Songkla University, Thailand (REC.62-387-18-5), and the proposal submitted to the Thai Clinical Trial Registry (TCTR20210615001).

Results

In total, this study enrolled 43 consecutive eligible patients. Six patients were excluded from the study-one who could not complete HBPM recording according to the criteria and 5 who cancelled their operation. Thirty-seven patients underwent surgery as planned, 16 MUCH and 21 ACH patients.

The baseline characteristics of the MUCH and ACH groups were mostly similar (Table 1). However, the MUCH group had a shorter overall duration of anaesthesia and surgery, and the ACH group showed higher current use of angiotensin-converting enzyme inhibitors (ACEIs) as their antihypertensive medication.

Haemodynamic response in critical periods

The pre-anaesthetic induction haemodynamic parameters in each group are summarized in Table 2. The mean baseline SBP in the MUCH group, 163.3 mmHg (S.D. 23.03), was higher than the corresponding value in the ACH group, 145.6 mmHg (S.D. 19.48) (P=0.016). There were no significant differences in the MAP, DBP or HR between the groups.

The mean values of SBP, MAP, DBP and HR at all monitoring points within the three critical periods are displayed in Figure 1 based on the mixed-effects linear regression models, together with pre-induction values.

During the anaesthetic induction period, all BP parameters of patients in both groups underwent continuous decline from preanaesthetic baseline values during the first 4 minutes after the onset of anaesthetic induction, after which the BP values increased at the 5th minute, corresponding to the normal time of intubation, and thereafter remained relatively stable from 5 to 9 minutes but dropped again at 10 minutes, reflecting the end of the induction period. Throughout the induction period (up to 9 minutes) the SBP was consistently higher in the MUCH group than in the ACH group, although this difference was not statistically significant in the mixed effects model. The HR responses following induction were similar in the two groups, with only a slightly and not statistically significant lower value in the MUCH group.

Following skin incision, the BP parameters of the patients in the MUCH group underwent a significant and marked continuous rise during the first 10 minutes in contrast to BP parameters in the ACH group, which showed a much less marked change, so that by 10 minutes after incision, both SBP and MAP were significantly higher in the MUCH group. By 15 minutes, however, SBP and MAP in the MUCH group showed a significant drop to levels close to those in the ACH patients. This drop occurred at the usual time of maximum depth of anaesthesia and the administration of additional analgesic medication to blunt the effects of the skin incision and surgical manipulation.

Table 1 Characteristics and perioperative factors by type of hypertension

Characteristic	MUCH group n=16 (43.20%)	ACH group n=21 (56.80%)	p-value
Sex*			0.715
Male	3 (18.75)	3 (14.29)	
Female	13 (81.25)	18 (85.71)	
Age, years**	62.1 (13.80)	58.0 (13.30)	0.366
BMI, kg/m^2 **	26.1 (4.35)	27.8 (6.97)	0.393
<18.5	0 (0.00)	2 (9.52)	0.313
18.5–29.9	14 (87.50)	13 (61.90)	
30–34.9	1 (6.25)	2 (9.52)	
>35	1 (6.25)	4 (19.05)	
Current antihypertensive drug*			
Diuretic	0 (0.00)	2 (9.52)	0.495
ACEI	1 (6.25)	10 (47.62)	0.010
ARB	6 (37.50)	4 (19.05)	0.274
Beta blocker	5 (31.25)	6 (28.57)	1.000
Calcium channel blocker	9 (56.25)	10 (47.61)	0.743
Alpha blocker	4 (25.00)	3 (14.29)	0.437
Other underlying diseases*			
Coronary heart disease/MI	2 (12.50)	1 (4.76)	0.393
Cerebrovascular event/stroke	1 (6.25)	1 (4.76)	0.843
Diabetes mellitus	6 (37.50)	8 (38.10)	0.970
Dyslipidemia	11 (68.75)	16 (76.19)	0.614
Chronic kidney disease	2 (12.50)	1 (4.76)	0.393
Other: risk aspiration morbid obesity, thyroid disease, asthma, cirrhosis, AF, SLE	9 (6.25)	13 (61.90)	0.729
ASA PS classification*			0.565
Class 2	10 (62.50)	15 (71.43)	
Class 3	6 (37.50)	6 (28.57)	
Site of surgery*			0.517
Intraabdomen	7 (43.75)	7 (33.33)	
Intrapelvis	9 (56.25)	14 (66.67)	
Choice of anaesthesia*			0.957
General anaesthesia	9 (56.25)	12 (57.14)	
Combined regional and general anaesthesia	7 (43.75)	9 (42.86)	
Induction agent*			0.354
Propofol	15 (93.75)	20 (95.24)	
Thiopental	1 (6.25)	0 (0.00)	
Etomidate	0 (0.00)	1 (4.76)	
Analgesic agent*			0.718
Fentanyl	15 (93.75)	19 (90.48)	

Table 1 (continuted)

Characteristic	MUCH group n=16 (43.20%)	ACH group n=21 (56.80%)	p-value
Morphine	1 (6.25)	2 (9.52)	
Neuromuscular blocking agent*			0.875
Cisatracurium	14 (87.50)	18 (85.71)	
Rocuronium	2 (12.50)	3 (14.29)	
Maintenance anaesthetic agent*			0.957
Sevoflurane	9 (56.25)	12 (57.14)	
Desflurane	7 (43.75)	9 (42.86)	
Duration of anaesthesia, minutes **	204.7 (56.60)	262.4 (84.80)	0.025
Duration of surgery, minutes**	156.6 (48.30)	214.7 (84.20)	0.019

Values reported as number (%)* or mean (S.D.)**. p-value from Fisher's exact test or t-test as appropriate, BMI=body mass index, ACEI=angiotensin-converting enzyme inhibitor, ARB=angiotensin II receptor blocker, MI=myocardial infraction, AF=atrial fibrillation, SLE=systemic lupus erythematosus, ASA PS=American society of anaesthesiologists physical status

Table 2 Comparison of preanaesthetic induction baseline haemodynamic parameters by type of hypertension

Parameter	MUCH group n=16 (43.20%)	ACH group n=21 (56.80%)	p-value
Systolic blood pressure	163.3 (23.00)	145.6 (19.50)	0.016
Mean arterial pressure	108.0 (18.90)	101.4 (11.50)	0.199
Diastolic blood pressure	82.4 (17.10)	81.6 (11.90)	0.867
Heart rate	77.4 (11.90)	78.2 (16.90)	0.870

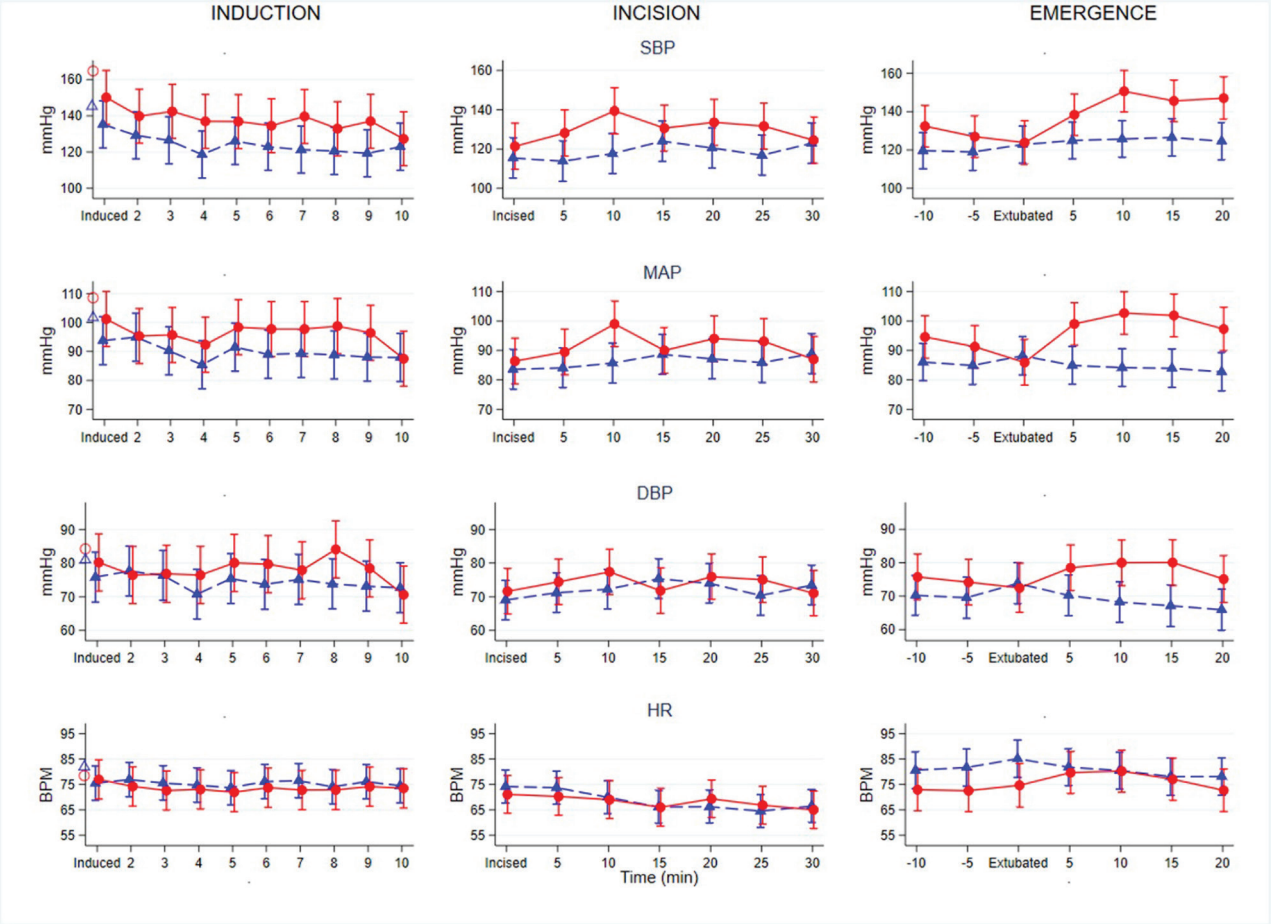
Values reported as mean (S.D.), p-value from t-test.

The HR dropped slightly during these first 15 minutes in both groups, significantly so in the ACH group.

During the emergence period, the BP of the ACH patients showed a slight increase up to the time of extubation and then began to decline (DBP and MAP) or remained steady (SBP). By contrast, the BP parameters of the patients in the MUCH group showed a decline durng preparation for extubation followed by a marked and significant rise over the following 10 to 15 minutes.

Risk of recurrent adverse haemodynamic events

Comparative risks of recurrent cardiovascular adverse events are presented as hazard ratio [95% CI] (Table 3). Compared with the ACH patients, the risk of recurrent hypertensive events was higher in the MUCH patients during the intraoperative period with the following hazard ratios: PWP-TT 2.10 [1.21, 3.64], and PWP-GT 1.84 [1.20, 2.84]. The difference between the groups was even greater during the immediate postoperative periods with hazard ratios of 4.73 [1.12, 19.89] (PWP-TT) and



Red open circles and blue open triangles on the left vertical axes of the induction period are the baseline SBP, MAP, DBP and HR values in the masked uncontrolled hypertensive and adequately controlled hypertensive groups, respectively. The red dots and blue triangles and red lines and blue dashed lines are the SBP, MAP, DBP and HR values in the masked uncontrolled hypertensive and adequately controlled hypertensive groups, respectively, at each measurement time point.

SBP=systolic blood pressure, MAP=mean arterial pressure, DBP=diastolic blood pressure (each in mmHg), HR=heart rate, BPM=beats per minute

Figure 1 Margin plots with 95% CIs of real-time measurement of haemodynamic parameters at each time point during the corresponding events by type of hypertension.

Table 3 Results of recurrent event analysis of perioperative adverse cardiovascular events in masked uncontrolled hypertension compared with adequately controlled hypertension using Prentice–Williams–Peterson total–time and gap–time models.

Adverse cardiovascular event	PWP–Total–time model Hazard ratio [95% CI]	PWP–Gap–time model Hazard ratio [95% CI]
Induction period		
Hypertension	1.05 [0.61, 1.82]	0.98 [0.58, 1.65]
Hypotension	**0.30 [0.09, 0.95]**	**0.30 [0.09, 0.99]**
Tachycardia	0.88 [0.21, 3.60]	0.86 [0.22, 3.33]
Bradycardia	0.88 [0.29, 2.68]	0.96 [0.33, 2.78]
Intraoperative period		
Hypertension	**2.10 [1.21, 3.64]**	**1.84 [1.20, 2.84]**
Hypotension	0.71 [0.27, 1.88]	0.67 [0.30, 1.49]
Tachycardia	2.46 [0.71, 8.54]	1.38 [0.39, 4.83]
Bradycardia	1.03 [0.54, 1.96]	0.98 [0.63, 1.54]
Postoperative period		
Hypertension	**4.73 [1.12, 19.89]**	**5.91 [1.45, 24.11]**
Hypotension	0.48 [0.06, 3.79]	0.58 [0.06, 6.04]
Tachycardia	0.18 [0.02, 1.32]	0.29 [0.03, 3.16]
Bradycardia	**4.08 [1.22, 13.59]**	**4.88 [1.77, 13.45]**

5.91 [1.45, 24.11] (PWP–GT). By contrast, the risk of recurrent hypotensive events was significantly lower during anaesthetic induction with hazard ratios of 0.30 [0.09, 0.95] (PWP–TT) and 0.30 [0.09, 0.99] (PWP–GT).

The risk of recurrent bradycardia events was significantly higher in the MUCH patients during the immediate postoperative period, with HRs of 4.08 [1.22, 13.59] (PWP–TT) and 4.88 [1.77, 13.45] (PWP–GT). There was no evidence for any difference in the risks of tachycardia or of hypotension in the intraoperative or immediate postoperative periods.

Two major cardiovascular events occurred with MUCH patients during the study period. One patient developed ST elevation with hypotension during the intraoperative period. This was a critical cardiovascular complication indicating haemodynamic instability leading to a life–threatening condition; immediate cardiac resuscitation and work up to confirm diagnosis of acute coronary disease were performed to correct the situation, and the patient survived. Another patient developed an acute coronary arterial event with cardiac arrest at 16 hours following surgery; despite immediate cardiopulmonary resuscitation by the hospital rescue team, they were unable to resuscitate this patient, and he died.

Discussion

While the immediate haemodynamic reponses to anaesthesia induction and to incision were qualitatively similar in the two groups, the SBP and MAP of the MUCH group showed an exaggerated rise over the first 10 minutes following incision. Furthermore, upon extubation all BP parameters rose rapidly to significantly higher levels than those in the ACH group. Overall, compared with adequately controlled hypertensive patients, those

with masked uncontrolled hypertension experienced more recurrent events of hypertension in the intraoperative and postoperative periods and more bradycardia events in the postoperative period but fewer hypotension events in the induction period. These differences in haemodynamic response and occurrence of minor adverse haemodynamic events are consistent with the reported reduced capacity for haemodynamic control in hypertensive and poorly controlled hypertensive patients[12,13,27,28] and with our previous findings of increased BP lability during anaesthesia of MUCH compared with ACH patients.

MUCH patients share common characteristics with poorly controlled hypertensive patients in exhibiting overactivity of the sympathetic nervous system, which may lead to large reductions in BP during the administration of anaesthesia[1], as well as more pronounced responses than in normotensive patients to noxious stimuli such as surgical incision and surgical manipulation, which can initiate tachycardia, arrhythmias and hypertension[29–31]. These responses are mediated through activation of the sympathetic nervous system and elevated catecholamine release[28–31]. Thus, the exaggerated haemodynamic responses to surgical incision in MUCH compared to ACH patients in our study were not unexpected. However, unexpectedly, the drop in BP at induction of anaesthesia in the MUCH patients was of approximately the same magnitude as that in the ACH patients, and SBP was maintained at a higher level than in the ACH patients throughout most of the induction period. Following tracheal extubation, the sharp rise in BP in the MUCH patients presumably reflects the wearing off of the anaesthetic agent's suppression of sympathetic activity[13], the regaining of consciousness and a return to the former pre-induction levels of sympathetic overactivity.

It is well-documented that patients with preexisting hypertension are more likely to experience intraoperative blood pressure lability, either hypotension or hypertension[3,12]. The increased risks of hypertension events during the intraoperative and postoperative periods and of bradycardia during the postoperative period were clearly evident whether the duration at risk was counted from the onset of the respective period (PWP-TT model) or the risk duration was counted from the end of the preceding event of the same type (PWP-GT model). Hypotension was less likely in MUCH patients during anaesthesia induction under both risk duration models. These different levels of risk of recurrent hyper- and hypotension were not unexpected as the overall levels of BP, especially during the induction and postoperative periods, were higher in the MUCH patients than in the ACH patients. The poor haemodynamic control appears to be a characteristic of MUCH patients, similar to that reported in patients who had poor control of hypertension pre-operatively[13].

A hypertensive event is a critical condition during anaesthesia, and inadequate BP control may lead to hypertensive emergencies complicated by evidence of impending or progressive target organ dysfunction and related to an increased risk for bleeding, stroke, and/or myocardial infarction[27]. Hypertension events can be promoted by many factors, such as pain, anxiety, hypoxemia, hypercarbia, hypothermia, shivering, urinary retention, hypervolaemia and/or discontinuation of antihypertensive medications[12,13,28]. Since MUCH patients appear to be at greater risk of recurring hypertension, these patients may require more meticulous monitoring and immediate BP reduction to prevent or limit end organ damage not only in the intraoperative period but also while recovering in the PACU.

The risk of bradycardia events during the postoperative period was also considerably greater among the MUCH patients. It has been established that the baroreflex sensitivity in MUCH patients is significantly lower than that in normotensive patients[19]. Recent evidence

suggests an incomplete resetting and sustained responses in sympathetic activity and arterial pressure[32]. Bradycardia events may be explained by carotid baroreflex activation in response to blood pressure changes as well as by the effect of anticholinesterases, which are mainly used for reversal of non-depolarizing neuromuscular blocking agents and may initiate bradycardia as a muscarinic side effect. Neostigmine is most commonly given in combination with muscarinic antagonists such as atropine or glycopyrronium[33] to protect against severe bradycardia side effect.

This study was limited to some extent by the small sample size, possibly limiting the power to detect finer differences between MUCH and ACH patients in haemodynamic response and perioperative risks of recurrent adverse BP and HR events. Furthermore, although the study aimed to explore the magnitude of BP and HR responses throughout the perioperative period from induction until the end of postoperative care in the PACU, major fluctuations in haemodynamic variables would have been monitored, detected and managed by the attending anaesthesiologist to avoid extremely high or low levels as it was not acceptable to ignore critical values. Recording BP and HR at intervals also precluded identification of more transient adverse events between recordings, which could only have been obtained through continuous electronic recording. Nevertheless, the study had the strength of monitoring patients under real perioperative conditions, throughout the entire perioperative period.

Conclusion

Preoperative hypertensive patients diagnosed with masked uncontrolled hypertension are significantly at increased risk of recurrent hypertensive events during the intraoperative and emergence periods, and at increased risk of recurrent bradycardia during the emergence period; by contrast, the risk of recurrent hypotensive events is significantly reduced during induction period when compared to patients with adequately controlled hypertension.

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Conflict of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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