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REPORTS OF ORIGINAL INVESTIGATIONS

More hypotension in patients taking antihypertensives preoperatively during shoulder surgery in the beach chair position

L'incidence d'hypotension est plus élevée pendant une chirurgie de l'épaule en position chaise de plage chez les patients prenant des antihypertenseurs en période préopératoire

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Abstract

Purpose *Hypotension is common in patients undergoing surgery in the sitting position under general anesthesia, and the risk may be exacerbated by the use of antihypertensive drugs taken preoperatively. The purpose of this study was to compare hypotensive episodes in patients taking antihypertensive medications with normotensive patients during shoulder surgery in the beach chair position.*

Methods *Medical records of all patients undergoing shoulder arthroscopy during a 44-month period were reviewed retrospectively. The primary endpoint was the number of moderate hypotensive episodes (systolic blood pressure ≤ 85 mmHg) during the intraoperative period. Secondary endpoints included the frequency of vasopressor administration, total dose of vasopressors, and fluid administered. Values are expressed as mean (standard deviation).*

Results *Of 384 patients who underwent shoulder surgery, 185 patients were taking no antihypertensive medication, and 199 were on at least one antihypertensive drug. The antihypertensive medication group had more intraoperative hypotensive episodes [1.7 (2.2) vs 1.2 (1.8); P = 0.01] and vasopressor administrations. Total dose of vasopressors and volume of fluids administered were similar between groups. The timing of the administration of angiotensin-converting enzyme inhibitors and of angiotensin receptor antagonists (≤ 10 hr vs > 10 hr before surgery) had no impact on intraoperative hypotension.*

Conclusions *Preoperative use of antihypertensive medication was associated with an increased incidence of intraoperative hypotension. Compared with normotensive patients, patients taking antihypertensive drugs preoperatively are expected to require vasopressors more often to maintain normal blood pressure.*

Résumé

Objectif *L'hypotension est fréquente chez les patients subissant une chirurgie en position assise sous anesthésie générale, et le risque pourrait être exacerbé par l'utilisation préopératoire de médicaments antihypertenseurs. L'objectif de cette étude était de comparer les épisodes d'hypotension chez les patients prenant des médicaments antihypertenseurs à ceux survenant chez des patients normotendus pendant une chirurgie de l'épaule en position chaise de plage.*

Méthode *Les dossiers médicaux de tous les patients subissant une arthroscopie de l'épaule au cours d'une période de 44 mois ont été rétrospectivement passés en revue. Le critère d'évaluation principal était le nombre d'épisodes d'hypotension modérée (tension artérielle*

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systolique ≤ 85 mmHg) en période peropératoire. Les critères d'évaluation secondaires comprenaient la fréquence d'administration de vasopresseurs, la dose totale de vasopresseurs, et les liquides administrés. Les valeurs sont exprimées sous forme de moyenne (écart type).

Résultats *Parmi les 384 patients ayant subi une chirurgie de l'épaule, 185 patients ne prenaient pas de médicaments antihypertenseurs, et 199 patients prenaient au moins un médicament antihypertenseur. Le groupe prenant des antihypertenseurs a manifesté davantage d'épisodes d'hypotension peropératoire [1,7 (2,2) vs 1,2 (1,8); P = 0,01] et a eu plus souvent besoin de vasopresseurs. La dose totale de vasopresseurs et la quantité de liquide administré étaient semblables dans les deux groupes. Le moment de l'administration des inhibiteurs de l'enzyme de conversion de l'angiotensine et des antagonistes des récepteurs de l'angiotensine (≤ 10 hr vs > 10 hr avant la chirurgie) n'ont pas eu d'impact sur l'hypotension peropératoire.*

Conclusion *L'utilisation préopératoire de médicaments antihypertenseurs a été associée à une incidence accrue d'hypotension peropératoire. Par rapport aux patients normotendus, il faut prévoir que les patients prenant des médicaments antihypertenseurs en période préopératoire auront besoin de vasopresseurs plus souvent afin de maintenir une tension artérielle normale.*

A number of reports describe catastrophic cerebral and spinal ischemic events in patients undergoing surgical procedures in the beach chair position.[1,2] Patients in this position may experience hypotensive episodes and alterations in cerebral perfusion pressure (CPP). It has been shown that shoulder surgery patients in the beach chair position experience significant reductions in cerebral oxygen saturation as compared with patients in the lateral decubitus position.[3]

Antihypertensive medications, including angiotensin-converting enzyme inhibitors (ACEI) and angiotensin receptor antagonists (ARA), can contribute to perioperative hypotension, particularly after induction of general anesthesia.[4-6] Preoperative administration of antihypertensive therapy leads to a greater incidence of hypotension in patients who undergo surgery in the supine position.

The purpose of this study was to quantify hypotensive episodes in patients taking antihypertensive medications who were undergoing surgery in the beach chair position and to compare the results with those of untreated normotensive patients. The primary endpoint was the frequency of moderate hypotensive episodes (systolic blood pressure ≤ 85 mmHg) occurring intraoperatively. We hypothesized that patients receiving antihypertensive therapy would have significantly more hypotensive episodes compared with those patients not on antihypertensives.

Methods

The Institutional Review Board (Rochester, MN, USA) approved the study and waived the requirement for informed consent. The medical records of all patients undergoing elective shoulder arthroscopy during a 44-month period (January 1, 2007-August 31, 2010) were reviewed. In an effort to minimize confounding factors, our study population included only patients who had surgery 1) in the beach chair position, 2) under general anesthesia with tracheal intubation, 3) with propofol-induced anesthesia, and 4) with either an interscalene or supraclavicular block. Patients were excluded if the surgeon requested hypotension or if antihypertensive drugs (including dexmedetomidine) were administered during the induction or maintenance of anesthesia.

Patients who undergo shoulder arthroscopy in our practice are routinely placed in a 45-90° upright (beach chair) position. The blood pressure cuff or arterial catheter is placed on the arm of the nonoperative side along with the intravenous access, and the nonoperative arm is placed on the patient's lap. The patient's head is secured to a head frame in the neutral position. Blood pressure management is left to the discretion of the anesthesia team, which consists of an anesthesiologist and either a Certified Registered Nurse Anesthetist (CRNA) or an anesthesiology resident. Typically, anesthesia is maintained primarily with volatile anesthetics, which are titrated to effect based on the hemodynamic response of the patient and the judgement of the anesthesia team.

Demographic, anesthetic management, and hemodynamic variables were gathered by two CRNA reviewers (S.F., M.L.) and placed in a database for analysis. The electronic medical records reviewed included electronically scanned anesthesia records, postanesthesia care unit records, preoperative medical evaluation clinic assessments, clinic or hospital progress notes, operative reports, and relevant incidental reports (e.g., emergency room reports). Information regarding the patients' usual medication regime and drugs taken the evening before or the morning of surgery was obtained from the preoperative nursing assessment. Data were gathered on preoperative use of ACEI/ARA, diuretics, beta blockers, vasodilators, alpha blockers, calcium channel blockers, and central alpha-2 adrenergic agonists. If ACEI/ARA were taken preoperatively, the time of administration was noted; specifically, if the drug was taken < 10 hr or ≥ 10 hr prior to the time the patient entered the operating room.

The primary endpoint was the total number of hypotensive episodes occurring during the intraoperative period. Hypotension was defined as a single systolic blood pressure reading $\leq$ 85 mmHg, according to the definition of Comfere *et al.*[7] Blood pressure was measured with an oscillometric device or an arterial catheter and was recorded manually at least every five minutes. Arterial catheter transducers were placed at the level of the patient's heart. Each hypotensive episode was included in the total number of hypotensive episodes used for data analysis.

Secondary endpoints for hypotension included the number of vasopressor administrations, total dose of vasopressors, and fluid volume administered. Vasopressors included ephedrine and phenylephrine. In subgroup analyses, we compared 1) patients taking ACEI/ARA based on the timing of their last dose of medication ($\leq$ 10 hr *vs* $>$ 10 hr preoperatively) and 2) patients having surgery in the beach chair position taking ACEI/ARA plus diuretic *vs* patients on no antihypertensive medication.

Statistical methods

The number of hypotensive episodes between patients not receiving antihypertensive therapy *vs* those on antihypertensive therapy was compared using a two-sample Student's *t* test. Continuous secondary endpoints were analyzed in a similar fashion. Categorical secondary endpoints were assessed using a Chi square test. All subgroup analyses were conducted in a similar manner. Adjusted comparisons were evaluated by using a general linear model with terms for age and body mass index (BMI). Statistical significance was considered to be present if *P* values $\leq$ 0.05. Due to the exploratory nature of this study, the only planned comparisons were the primary outcomes; any other comparisons were purely observational, and no adjustments were made for multiplicity. All computations were performed using SAS® software version 9 (SAS Institute, Inc, Cary, NC, USA).

Results

Four-hundred ninety two procedures were performed by any one of three surgeons during this time period, and 108 patients were excluded (Table 1). Thus, 384 cases were used for analysis. There were 185 patients taking no antihypertensive medication *vs* 199 patients who were taking at least one antihypertensive. In terms of ACEI/ARA use, 119/384 (31%) were taking one or both. There were 33 patients who were taking an ACEI/ARA only (no additional antihypertensives), and only one patient was taking both an ACEI and an ARA. Thirteen patients were treated with an intraoperative phenylephrine infusion, 11 of whom were receiving preoperative antihypertensive medications. Blood pressure was measured with an arterial catheter in four patients; the remaining patients had noninvasive blood pressure taken in the nonoperative arm.

Table 1 Patient flow

Total number of procedures		492
Exclusions:		108
Not in beach chair position	1	
General anesthesia not used	1	
Propofol not used for induction	7	
Interscalene block not performed	53	
Surgeon requested hypotension	9	
More than one shoulder surgery (only first anesthetic considered)	11	
Patient request not to use records for research	2	
Anesthesia record not located	2	
Antihypertensive medications given during anesthesia	22	
Cases retained for analysis		384

Table 2 summarizes demographics and the comparison of patients taking no antihypertensive medication *vs* patients taking at least one medication. The patients taking at least one antihypertensive were significantly older and more likely to be classified as American Society of Anesthesiologists (ASA) status $>$ II compared with those taking no antihypertensive medication. They also had a significantly higher BMI.

In the group of patients receiving preoperative antihypertensive medications, there were significantly more hypotensive episodes and vasopressor administrations. When adjusting for age and BMI on the incidence of hypotensive events, the group of patients receiving antihypertensive medications still had significantly more hypotensive episodes ($P = 0.01$). There were no significant differences between the groups in terms of total dose of phenylephrine and ephedrine and volume of fluids administered.

There were 15 patients (average age 66 yr) who had at least one recorded blood pressure $\leq$ 65 mmHg. Eleven of these 15 patients were being treated with at least one antihypertensive medication, including nine patients who were receiving an ACEI/ARA. Eight of the nine ACEI/ARA patients had taken their medication the morning of surgery.

Table 3 shows the impact of the timing of ACEI/ARA administration on intraoperative blood pressure $\leq$ 10 hr *vs* $>$ 10 hr before surgery. There were no significant differences between the groups including the number of episodes of hypotension.

In Table 4, patients taking an ACEI and/or an ARA (ACEI/ARA) plus a diuretic were compared with those on

Table 2 Demographic and intraoperative data

	No antihypertensive medication ($n = 185$)	At least one antihypertensive medication ($n = 199$)	P
Age, yr			< 0.001
Mean (SD)	59.5 (11.5)	66.5 (8.7)	
Range	(20-85)	(33-84)	
Sex, *n* (%)			0.69
Male	106 (57%)	118 (59%)	
Female	79 (43%)	81 (41%)	
ASA status *n* (%)			< 0.001
I	132 (72%)	103 (54%)	
> II	50 (28%)	88 (46%)	
n	182	191	
Body mass index, $kg \cdot m^{-2}$			< 0.001
Mean (SD)	26.9 (4.5)	29.6 (5.1)	
Range	(18.4-40.4)	(17.1-47.6)	
Hypotension, *n* (%)			
No	104 (56%)	76 (38%)	< 0.001
Yes	81 (44%)	123 (62%)	
Episodes per case, Mean (SD)	1.2 (1.8)	1.7 (2.2)	0.01
Range	(0-9)	(0-11)	
Vasopressor administrations, *n* (%)			
No	85 (46%)	50 (25%)	< 0.001
Yes	100 (54%)	149 (75%)	
Number per case, Mean (SD)	2.1 (2.55)	3.0 (3.64)	0.003
Range	(0.0-11.0)	(0.0-18.0)	
Phenylephrine administered, *n* (%)			
No	131 (71%)	119 (60%)	0.03
Yes	54 (29%)	79 (40%)	
Total dose (μg), Mean (SD)	101 (232)	179 (350)	0.01
Range	(0-2,000)	(0-2,300)	
Ephedrine administered, *n* (%)			
No	103 (56%)	76 (38%)	< 0.001
Yes	82 (44%)	123 (62%)	
Total dose (mg), Mean (SD	7.6 (11.3)	10.2 (11.6)	0.03
Range	(0-75)	(0-75)	
Crystalloid volume (mL)			0.99
Mean (SD)	1,307 (1,536)	1,199 (379)	
Range	(300-2,600)	(300-2,600)	
Colloid volume (mL)			0.92
Mean (SD)	481 (69)	485 (131)	
Range	(250-500)	(250-1,000)	

ASA = American Society of Anesthesiologists status; SD = standard deviation. Data on ASA status and body mass index not recorded in all patients

Table 3 Comparison of patients having surgery in the beach chair position taking ACEI/ARA based on timing of last dose of medication

	≤ 10 hr preop ($n = 84$)	> 10 hr preop ($n = 35$)	P
Age, yr			0.46
Mean (SD)	66.3 (8.4)	65.9 (9.8)	
Range	(44-79)	(33-83)	
Sex, *n* (%)			0.74
Male	52 (62%)	24 (69%)	
Female	32 (38%)	11 (31%)	
ASA status > II, *n* (%)			0.26
No	48 (61%)	16 (46%)	
Yes	31 (39%)	19 (54%)	
Body mass index, $kg \cdot m^{-2}$			0.44
Mean (SD)	30.5 (5.6)	29.5 (4.9)	
Range	(21.8-47.6)	(21.1-44.6)	
Preoperative diuretic, *n* (%)			0.55
No	34 (41%)	18 (51%)	
Yes	50 (59%)	17 (49%)	
Hypotension, *n* (%)			
No	27 (32%)	13 (37%)	0.60
Yes	57 (68%)	22 (63%)	
Number per case, Mean (SD)	1.9 (2.2)	1.3 (1.9)	0.27
Range	(0-9)	(0-9)	
Vasopressor administration, *n* (%)			
No	21 (25%)	11 (31%)	0.47
Yes	63 (75%)	24 (69%)	
Number per case, Mean (SD)	3.4 (3.9)	2.5 (3.2)	0.42
Range	(0-17)	(0-12)	
Phenylephrine administered, *n* (%)			
No	49 (58%)	22 (65%)	0.68
Yes	35 (42%)	12 (35%)	
Total dose (μg), Mean (SD)	216 (379)	78 (136)	0.11
Range	(0-2,000)	(0-550)	
Ephedrine administered, *n* (%)			
No	31 (37%)	14 (40%)	0.84
Yes	53 (63%)	21 (60%)	
Total dose (mg), Mean (SD	11.0 (12.3)	10.7 (13.3)	0.98
Range	(0-75)	(0-50)	
Crystalloid volume (mL)			0.40
Mean (SD)	1,207 (404)	1,223 (325)	
Range	(300-2,600)	(700-2,200)	

ASA = American Society of Anesthesiologists status; ACEI = angiotensin-converting enzyme inhibitors; ARA = angiotensin receptor antagonists; ACEI/ARA signifies that patient could be taking a medication from either or both classes of antihypertensive; SD = standard deviation

no antihypertensive medication. The patients in the antihypertensive group were significantly older and had a higher BMI, and they were more likely to be classified as

Table 4 Comparison of patients taking ACEI/ARA plus diuretic *vs* patients on no antihypertensive medication

	ACEI/ ARA + diuretic ($n = 72$)	No antihypertensive medication ($n = 185$)	*P*
Age			< 0.0001
Mean (SD)	67.4 (8.8)	59.5 (11.5)	
Range	(44-83)	(20-85)	
Sex, *n* (%)			0.45
Male	45 (63%)	106 (57%)	
Female	27 (38%)	79 (43%)	
ASA status, *n* (%)			0.03
I	41 (59%)	132 (72%)	
> II	29 (41%)	50 (28%)	
Body mass index ($kg \cdot m^{-2}$)			< 0.001
Mean (SD)	29.7 (5.1)	26.9 (4.5)	
Range	(21.5-44.6)	(18.4-40.4)	
Hypotension, *n* (%)			
No	25 (35%)	104 (56%)	0.002
Yes	47 (65%)	81 (44%)	
Number of episodes, Mean (SD)	1.8 (2.1)	1.2 (1.8)	0.04
Range	(0-9)	(0-9)	
Vasopressor administration, *n* (%)			
No	21 (29%)	85 (46%)	0.01
Yes	51 (71%)	100 (54%)	
Number per case, Mean (SD)	3.2 (3.6)	2.1 (2.6)	0.006
Range	(0-17)	(0-11)	
Number of patients	72	185	
Phenylephrine administered, *n* (%)			
No	41 (58%)	131 (72%)	0.07
Yes	30 (42%)	54 (29%)	
Total dose (μg), Mean (SD)	175 (339)	101 (232)	0.05
Range	(0-2,000)	(0-2,000)	
Ephedrine administered, *n* (%)			
No	27 (38%)	103 (56%)	0.009
Yes	45 (63%)	82 (44%)	
Total dose (mg), Mean (SD	10.9 (11.7)	7.6 (11.3)	0.04
Range	(0-50)	(0-75)	
Crystalloid volume (mL)			0.59
Mean (SD)	1,208 (359)	1,307 (1536)	
Range	(300-2,200)	(300-2,600)	

ACEI = angiotensin-converting enzyme inhibitors; ARA = angiotensin receptor antagonists; ACEI/ARA signifies that patient could be taking a medication from either or both classes of antihypertensive; SD = standard deviation

ASA > II than those taking no antihypertensive medication. There were significantly more hypotensive episodes in the patients taking an ACEI/ARA plus a diuretic ($P = 0.04$). After adjusting for the possible effects of age and BMI, this difference was no longer statistically significant ($P = 0.07$). Also, vasopressor administrations were significantly more frequent in the antihypertensive group. There were no significant differences between the groups in terms of total dose of phenylephrine and ephedrine and volume of fluids administered.

Table 5 lists perioperative complications. No adverse events related to hypotension could be identified.

Discussion

Based on this retrospective review, our hypothesis was supported; namely, patients on antihypertensive medications undergoing surgery in the beach chair position did have significantly more episodes of intraoperative hypotension compared with patients not on antihypertensives. This was true even when adjusting for patient factors including age and BMI.

In this retrospective study, it is impossible to explain definitively why the total dose of vasopressor (a secondary endpoint) did not differ between the groups. Conceivably, anesthesia provider awareness of the risk of hypotension resulted in a multimodal approach to hypotension, including fluid boluses, reduced inspired volatile agent concentration, and judicious use of vasopressors.

In subgroup analysis, we found that the timing of ACEI/ARA administration had no impact on hypotensive episodes (Table 3). Also, in patients taking ACEI/ARA and a diuretic (Table 4), our results were very similar to our findings in the population of patients taking any antihypertensive, i.e., significantly more hypotensive episodes and more administrations of vasopressors compared with patients not on antihypertensives; however, after adjusting for the possible effects of age and BMI, this difference was no longer statistically significant. The total dose of vasopressor did not differ significantly between the groups.

Although in subgroup analysis there was no difference in terms of hypotension between patients taking an ACEI/ARA plus a diuretic and normotensive patients, it is important to note that this observational study may not have been adequately powered to detect such a difference. The risk of hypotension in ACEI/ARA patients should not be ignored, particularly when the beach chair position is planned.

For a number of reasons, many orthopedic surgeons prefer the beach chair position for shoulder arthroscopy. This position allows ready access to the entire shoulder, permits easy conversion to open or mini-open procedures,

Table 5 Perioperative complications

	Complication	No antihypertensive medication ($n = 185$)	At least one antihypertensive medication ($n = 199$)	Notes
Genitourinary	Urinary retention	18	22	
	Urinary tract infection	3	2	
Gastrointestinal	PONV	6	3	
	Mallory Weiss tear	0	1	
Cardiovascular	Arrhythmia	3	1	
	Congestive heart failure	1	0	
	Chest pain during hospitalization	4	2	MI ruled out
	Preoperative hypotension	1	0	Volume loaded, case proceeded
	Refractory hypotension	3	0	
	Phlebitis	0	1	
Respiratory	Pneumonia	2	1	
	Pleural effusion	1	0	Nonoperative side
	PACU: SOB/decreased oxygen saturation	0	4	
	Difficult intubation	1	0	
Central Nervous System	Decreased cognition	2	1	
	Facial/neck numbness	1	0	Resolved. Secondary to interscalene block
Musculoskeletal	Low back pain	1	1	
	Ear lesion	0	2	
	Shoulder rash	1	1	
	Olecranon bursitis	1	0	Aspirated
Difficult Pain Management	Readmission for pain	1	3	
Emergency Department visits	Urinary retention	6	1	
	Nausea/vomiting	0	1	
	SOB, anxiety	1	2	
	Chest pain	1	0	MI ruled out
Fever		1	1	1 positive culture
Other	Retained foreign object	1	0	Broken needle tip

Patients with more than one complication are listed in multiple categories.
PONV = postoperative nausea and vomiting;
PACU = postanesthesia care unit; SOB = shortness of breath; MI = myocardial infarction

avoids the use of traction, and can ease internal orientation for the surgeon. However, surgeons and primary care providers who evaluate patients preoperatively may not be aware of the risk of hypotension associated with the beach chair position.

Angiotensin converting enzyme inhibitors and ARAs may be associated with hypotension after induction of anesthesia. Comfere *et al.* studied the relationship between the time of discontinuation of ACEI/ARA and hypotension immediately post induction (< 30 min or less).[7] They found that patients who took these antihypertensives < 10 hr before anesthesia had a significantly greater risk of moderate hypotension within 30 min of anesthesia induction. In contrast, we did not find more episodes of intraoperative hypotension in patients in the beach chair position who took ACEI/ARAs < 10 hr before surgery; however, we analyzed the entire intraoperative period, not just the first 30 min (Table 3).

In a study population of 12,381 operative cases, Kheterpal *et al.* found that hypotension was associated more with patients on a chronic diuretic plus ACEI/ARA therapy than with patients on diuretic therapy alone. Further, the hypotension persisted throughout the intraoperative period, not just immediately after induction.[8] Notably, the institutional standard of care for these patients was to instruct them to discontinue ACEI/ARA therapy the day of surgery, although the long-term impact of withholding ACEI/ARA therapy *vs* continuing the therapy on the day of surgery is

unknown.[9] In our study, we also found more hypotensive episodes among ACEI/ARA patients also taking a diuretic *vs* patients on no antihypertensives.

Measurement of blood pressure during procedures performed in the beach chair position remains controversial. While some authors have argued that blood pressure should be measured at the level of the brain,[A] others have argued that the cerebral circulation acts more like a "siphon" (*vs* a "waterfall"), and therefore, the site of blood pressure measurement is not of primary concern.[B] Rather, the argument follows, maintaining blood pressure reasonably close to preoperative values is the primary concern regardless of where the blood pressure is measured.

It is CPP and not the transmural pressure provided by a blood pressure cuff that is crucial in the context of cerebral blood flow. Through autoregulatory mechanisms, the cerebral vasculature can compensate for reduced CPP; however, at some critical level, autoregulation is no longer operative and inadequate cerebral blood flow may result. High-risk patients, such as those with cerebrovascular disease or cervical spinal stenosis, may be at increased risk of devastating neurologic injury when undergoing surgery in the beach chair position, particularly if deliberate hypotension is used. Excessive head rotation, flexion, or extension may further compromise oxygen delivery to the brain or spinal cord. Complicating matters, there is significant intra- and inter-individual variability in cerebral vasculature (e.g., $> 50\%$ of the population has an abnormal pattern of Circle of Willis, including absent segments),[10] making it difficult to identify high-risk patients.

Although controversy persists regarding blood pressure measurement during surgery in the beach chair position, at least there is expert opinion that intentional hypotension should be avoided, that noninvasive blood pressure measurements should be taken in the arm and not the leg, and that blood pressure should be kept within 30% of baseline.[C] This can be challenging in hypertensive patients who have taken their antihypertensive medications the morning of surgery. Medication-induced vasodilatation combined with anesthesia induction drugs can bring about hypotension that is difficult to manage and even refractory.[5] Venous pooling in the beach chair position may exacerbate this situation.

Weaknesses of our study result primarily from its retrospective nature. Although our hypothesis was supported, we cannot say with certainty that the difference in hypotensive episodes between the groups was due solely to the use of antihypertensive medications. The groups differed in other important ways, including age and BMI, although these factors did not significantly influence the primary outcome measure. Furthermore, our results are consistent with other studies of the impact of antihypertensive medications on intraoperative blood pressure.

As is true in any retrospective study, possible missing data undermine the strength of any conclusion. Although in a number of cases ($n = 9$) we found documentation of a surgeon's request to lower the blood pressure to aid visualization, it is possible that there were undocumented requests. Iatrogenic lowering of blood pressure could artificially increase the number of episodes of hypotension; therefore, we eliminated from analysis all cases where antihypertensives were used intraoperatively. However, there may have been undocumented cases where the surgeon requested a lower blood pressure and a volatile agent was used.

In terms of vasopressors, we included 13 patients in the study who received phenylephrine infusions for sustained hypotension. We were unable to quantify the total dose of vasopressor in these patients, so the total dose of phenylephrine is likely underestimated. However, excluding these patients would underestimate the incidence of moderate hypotension, our primary endpoint. Of interest, 11 of the 13 patients who required phenylephrine infusions were receiving preoperative antihypertensive medication.

The majority but not all surgical patients received interscalene or supraclavicular blocks. Those patients with successful blocks may be at increased risk for hypotension during the procedure due to blunted sympathetic responses to painful surgical stimuli. Therefore, we eliminated from analysis patients who did not undergo a block; however, there may have been cases of unsuccessful blocks and patients with an intact blood pressure response to painful surgical stimulation. This scenario could artificially decrease the number of episodes of hypotension. Finally, our study did not evaluate the impact of the timing of antihypertensive use (other than ACEI/ARA) and intraoperative hypotension.

In conclusion, preoperative use of antihypertensive medication was associated with an increased incidence of intraoperative hypotension. Compared with normotensive patients, more doses of vasopressors may be needed for these patients to maintain normal blood pressure. The use of techniques, such as pre-induction fluid loading and induction agents (e.g., etomidate), may reduce the incidence of intraoperative hypotension. Further studies are indicated to evaluate intraoperative hypotension and timing of antihypertensive use as well as intraoperative hypotension caused by combinations of antihypertensives. Additional studies are also necessary to quantify any

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relationship between hypotension (including severity and duration of hypotensive episodes) in the beach chair position and postoperative neurocognitive changes.

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Conflicts of interest None declared.

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