



# Intraoperative Blood Pressure Lability Is Associated with Postoperative Hemorrhage after Uncomplicated Bariatric Surgery

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## Abstract

**Background** Postoperative hemorrhage is a rare complication in bariatric surgery. We aim to determine if differences in blood pressure or perioperative medication administration contribute to postoperative bleeding in patients who were hemodynamically stable intraoperatively.

**Methods** This was a retrospective case-control study of all bariatric surgery patients from 2014 to 2017 at a high volume academic center. We identified controls based on age, gender, ethnicity, type of procedure, and pre-operative blood pressure.

**Results** Patients with postoperative hemorrhage had a significantly lower MAP during the portion of the surgery in which the abdominal contents were inspected for leaks and bleeds. The timing of enoxaparin or ketorolac administration was not associated with bleeding.

**Conclusion** Blood pressure lability, but not enoxaparin or ketorolac administration, is associated with postoperative hemorrhage.

**Keywords** Bariatric surgery · Postoperative hemorrhage · Blood pressure lability · Anticoagulation

## Introduction

Bariatric surgery is a very safe procedure with complication rates on par with gallbladder surgery or hip replacement [1], but it is not without risk. One complication that has received

increasing attention is postoperative hemorrhage, which occurs in approximately 3% of all cases [2] and is defined in this study as “bleeding after surgery resulting in a hematocrit drop and leading to patients receiving a blood transfusion.” Postoperative hemorrhage is especially challenging when it occurs after uncomplicated cases completed with minimal blood loss. Many factors could increase the risk of postoperative bleeding, and in this study, we examined the role of perioperative blood pressure status and postoperative medication use.

Blood pressure status is frequently assessed in the context of postoperative hemorrhage [3, 4], and many studies report that postoperative hypertension is associated with increased risk of bleeding [5]. A retrospective case-control study conducted by Janik et al. found that bariatric surgery patients with hemorrhagic complications had decreased postoperative systolic blood pressure, although their results were not statistically significant. The contribution of perioperative medications such as enoxaparin and ketorolac to postoperative hemorrhage has been studied [6, 7], but whether the timing of their administration affects postoperative bleeding in bariatric surgery is unclear. In this retrospective nested case-control analysis, we attempt to determine whether perioperative blood pressure lability or perioperative medication use is associated with postoperative hemorrhage.

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## Methods

This is a retrospective nested case-control study of bariatric surgery patients at a large, urban academic medical center that performs over 500 bariatric cases per year. In reviewing all bariatric surgeries from 2014 to 2017, we identified nine patients who experienced a significant postoperative hemorrhagic complication requiring transfusion, but had left the operating room appearing hemodynamically stable and with minimal intraoperative blood loss recorded (Fig. 1). Patients who were undergoing a revision procedure were excluded. The database was searched to identify controls for each of these patients based on the following criteria: age, gender, ethnicity, type of procedure, blood pressure at pre-operative office visit closest to surgery date. The baseline characteristics of the patients and their controls are summarized in Table 1. The following information was then extracted from each patient’s electronic medical record: blood pressure the morning of surgery (taken in the pre-operative holding area), intraoperative blood pressure readings (recorded every 3 min for the entirety of the case), blood pressure readings on postoperative day 0 (recorded in the recovery room and on the surgical floor), time of first enoxaparin dose, time of first ketorolac dose. These results are presented in Table 2. All patients were given 5000 units of subcutaneous heparin injection just prior to induction of anesthesia. In order to assess blood pressure lability, the absolute value of blood pressure differences from the patient’s baseline value, as measured at their pre-operative visit, was calculated at different time points: the morning of surgery, intraoperatively, and postoperative day 0. Statistical significance was calculated using two-tailed *T* tests, and analysis was performed using Prism 7 (GraphPad, version 7.0). Results are presented as the mean ± standard error of the mean (sem) with *p* value, for cases versus controls. This study and all its procedures were conducted with the approval of the Institutional Review Board.

## Results

During this study period, in total, we identified nine patients who left the operating room appearing hemodynamically stable but developed postoperative hemorrhage requiring blood transfusion. Of these, four cases occurred in patients who had undergone laparoscopic sleeve gastrectomies (LSG) and five cases occurred in patients who received laparoscopic roux-en-Y gastric bypasses (LRGB). Their baseline characteristics are listed in Table 1. During this period, a total of 1188 laparoscopic sleeve gastrectomies and 376 laparoscopic gastric bypasses were performed. Chi-square analysis suggests that these events occur more frequently after LRGB than LSG (chi-square value 4.92, *p* = 0.03), with a relative risk ratio of 3.95 (95% CI 1.07 to 14.63, *p* = 0.04).

### Patients Who Experienced Significant Postoperative Hemorrhage Were Hypotensive During the Critical Window in Which the Abdomen Was Inspected for Bleeding

The patient’s blood pressure that was recorded at their last pre-operative clinic visit was used to calculate a baseline mean arterial pressure (MAP), and overall, there was no significant difference between the two groups (Table 1.  $97.9 \pm 2.1$  vs.  $99.1 \pm 2.5$ . *p* = 0.7). There was a significant difference between the two groups when each patient’s pre-operative MAP was compared with their MAP recorded by nursing staff at intake in the pre-operative holding area on the morning of surgery (Table 2.  $13.6 \pm 2.2$  vs.  $5.7 \pm 0.9$ . *p* = 0.01). There was also a significant difference between the pre-operative MAP and the average MAP on postoperative day zero (Table 2.  $10.2 \pm 1.9$  vs.  $4.7 \pm 1.1$ . *p* = 0.02). However, there was no difference when the pre-operative MAP was compared with the average intraoperative MAP (recorded every 3 min by anesthesia during the case (Table 2.  $17.2 \pm 4.2$  vs.  $13.6 \pm 3.8$ . *p* = 0.5).

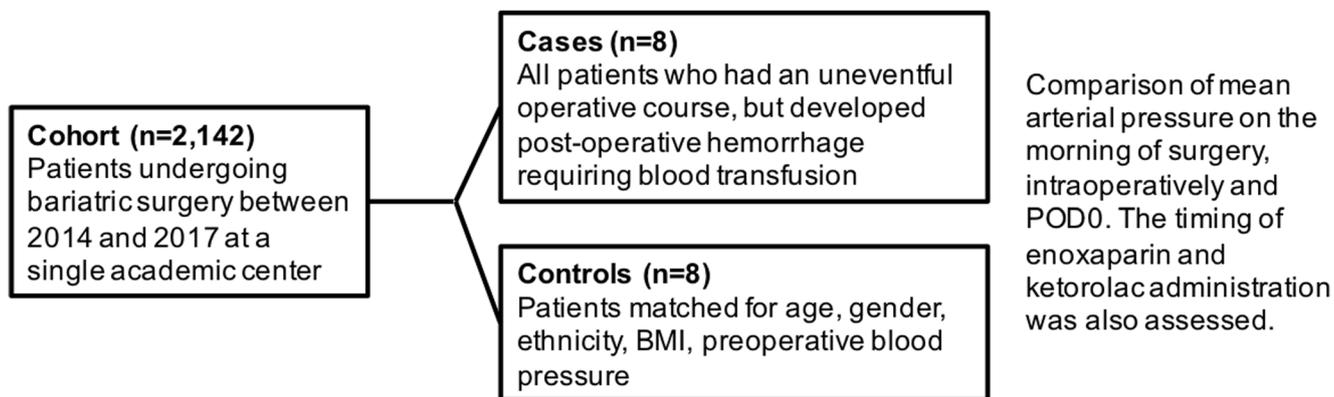


Fig. 1 Study design flowchart

**Table 1** Baseline characteristics of cases and controls

Patient	Age	Sex	Ethnicity	Operation date	Pre-op BMI	Pre-op MAP	Units transfused	Procedure	HTN	DM	OSA	GERD
Bleed A	55.5	F	White	7/13/17	44.1	89.7	1	Sleeve	Y	N	N	N
Bleed B	44.5	F	White	12/29/16	42.6	103.3	2	Bypass	Y	N	Y	Y
Bleed C	48.4	F	White	10/26/16	40.7	100.7	4	Bypass	Y	Y	N	Y
Bleed D	51.0	F	White	9/27/16	44.2	100.7	2	Sleeve	Y	Y	Y	N
Bleed E	37.3	F	White	8/30/16	45.2	98.0	2	Bypass	Y	N	Y	Y
Bleed F	29.9	F	Black	8/11/16	75.2	98.7	2	Sleeve	N	N	Y	Y
Bleed G	64.5	F	White	3/31/16	42.1	92.0	2	Bypass	N	N	N	Y
Bleed H	56.8	F	White	9/10/15	39.5	108.0	2	Sleeve	Y	N	Y	Y
Bleed I	43.3	F	Black	2/18/14	55.0	90.0	2	Bypass	Y	N	Y	N
Control A	54.9	F	White	3/17/15	44.1	92.0	0	Sleeve	Y	N	Y	Y
Control B	46.9	F	White	12/11/17	42.8	100.0	0	Bypass	N	N	Y	Y
Control C	48.2	F	White	11/30/17	38.6	101.0	0	Bypass	Y	N	Y	Y
Control D	50.2	F	White	3/17/16	45.2	92.7	0	Sleeve	N	Y	Y	Y
Control E	38.9	F	White	7/7/14	45.6	94.7	0	Bypass	Y	Y	N	N
Control F	29.9	F	Black	5/8/14	76.6	112.7	0	Sleeve	Y	Y	Y	N
Control G	61.0	F	White	12/25/15	41.9	98.0	0	Bypass	N	N	N	N
Control H	56.1	F	White	5/27/14	38.9	108.7	0	Sleeve	Y	N	N	Y
Control I	45.8	F	Black	8/2/17	51.3	92.0	0	Bypass	Y	Y	Y	Y

HTN Hypertension, DM diabetes mellitus type 2, OSA obstructive sleep apnea, GERD gastroesophageal reflux disease, Y Yes, N No

We next looked more closely the intraoperative blood pressure differences between the transfusion group and the control group. Overall, there was no significant difference in the average MAP measured across the entire procedure (Table 2.  $82.0 \pm 4.5$  vs.  $89.3 \pm 4.6$ .  $p = 0.3$ , or between the average intraoperative MAP and the average MAP on postoperative day 0 (Table 2.  $17.8 \pm 2.2$  vs.  $17.1 \pm 3.6$ .  $p = 0.9$ ). However, patients who experienced a significant postoperative hemorrhagic complication requiring transfusion displayed a much wider range of intraoperative blood pressure readings during the entirety of the procedure (Table 2.  $61.2 \pm 3.4$  vs.  $43.7 \pm 5.3$ .  $p = 0.01$ ). Furthermore, we calculated the patient's mean arterial blood pressure during the portion of the surgery just prior to removing the laparoscopic ports and closing in which the staple lines or anastomoses were inspected for leak (via an air

insufflation leak test) and potential bleeding sources were inspected. Based on surgeon experience, this routinely occurs anywhere from 25 to 15 min before port removal and skin closure. Compared with the control group, patients who experienced a postoperative hemorrhage requiring transfusion had a significantly lower MAP during the critical period prior to closure when the abdomen is checked for bleeding (Table 2.  $75.9 \pm 4.6$  vs.  $89.83 \pm 5.5$ .  $p = 0.03$ ).

### Perioperative Medication Administration Is Not Significantly Associated with Postoperative Transfusion

Lastly, we sought to determine if the timing of enoxaparin and ketorolac administration was associated with postoperative

**Table 2** Comparison of blood pressure and medication administration between cases and controls

	Cases ( $n = 8$ )	Controls ( $n = 8$ )	$p$ value
Pre-op MAP vs. surgery morning MAP	$13.6 \pm 2.2$	$5.7 \pm 0.9$	*0.01
Pre-op MAP vs. POD0 MAP	$10.2 \pm 1.9$	$4.7 \pm 1.1$	*0.02
Pre-op MAP vs. Intra-op MAP	$17.2 \pm 4.2$	$13.6 \pm 3.8$	0.5
Average Intra-op MAP	$82.0 \pm 4.5$	$89.3 \pm 4.6$	0.3
Intra-op MAP vs. POD0 MAP	$17.8 \pm 2.2$	$17.1 \pm 3.6$	0.9
Intra-op MAP range	$61.2 \pm 3.4$	$43.7 \pm 5.3$	*0.01
Average MAP during closing	$75.9 \pm 4.6$	$89.8 \pm 5.5$	*0.03
Minutes until Enoxaparin	$649.9 \pm 48.6$	$552.5 \pm 20.2$	0.1
Minutes until Ketorolac	$157.2 \pm 61.2$	$294.8 \pm 94.7$	0.2

All results presented as mean  $\pm$  standard error of mean. \*Indicates statistical significance ( $p < 0.05$ )

hemorrhage. All patients received 5000 units of subcutaneous heparin prior to incision and all patients received prophylactic enoxaparin dosing postoperatively. There was no significant difference between the two groups with regard to the timing of their first enoxaparin dose (Table 2.  $649.9 \pm 48.6$  min vs.  $552.5 \pm 20.2$  min.  $p = 0.1$ ). Ketorolac was administered to five patients who experienced significant postoperative hemorrhage, and to four of patients in the control group. Patients who required transfusion received ketorolac sooner than those who did not, although the difference was not statistically significant (Table 2.  $157.2 \pm 61.2$  min vs.  $294.8 \pm 94.7$  min.  $p = 0.2$ ).

## Discussion

We present a retrospective nested case-control study which analyzed all cases of significant postoperative bleeding from 2014 to 2017 at a large academic medical center. We found that during the “critical window” near the end of the LSG or LRGB when potential bleeding sources such as staple lines or anastomoses were inspected prior to removing the laparoscopic ports and closing, the patients who experienced significant postoperative hemorrhage were more hypotensive compared with the control group. We hypothesize that because these patients were relatively hypotensive at the time of the last abdominal inspection, we were not able to identify dormant areas which may have bled if blood pressures were closer to these patients’ normal ranges. Upon arousal from anesthesia, these dormant areas of potential bleeding may have become active as the patient’s blood pressure rose. In fact, others have shown that patient hypertension may be linked with increased risk for postoperative bleeding [8], but more specific studies are required to determine if raising a patient’s blood pressure to their baseline prior to closure can safely identify possible sources of hemorrhage by revealing occult bleeding sources.

Moreover, our results suggest that the patients who experienced significant postoperative hemorrhage requiring transfusion may have had more labile blood pressures in general. This is supported first by the larger range of intraoperative blood pressures recordings in the transfusion group compared with controls. Although the anesthesiology staff differed from patient-to-patient, it is unlikely that this could have caused the significant difference we observed. Additionally, in the transfusion group, we also observed a significantly larger absolute difference between the baseline blood pressure (taken at the patient’s last pre-operative office visit) and their blood pressure both on the morning of surgery and on the first postoperative day. In our pre-admission process, it is standard practice to ask patients to take their blood pressure medications the morning of surgery, except for diuretics, ace-inhibitors, or angiotensin II receptor blockers. However, it is difficult to determine the precise cause of the higher blood pressure variability in the transfusion group. For example, some of these

patients may have held their blood pressure medications that morning (as instructed to, or on their own accord). Alternatively, patients may have taken their medications shortly before arriving at the hospital. Regardless, the data suggests this group may represent a cohort of patients who do not have proper long-term blood pressure control in general. It must be noted that blood pressure lability may not necessarily be harmful, as some studies have even suggested it may be associated with decreased 30-day mortality [9]. However, our results suggest that at least in this cohort, greater blood pressure lability contributed to their postoperative hemorrhagic complications.

Finally, we sought to determine whether the timing of two commonly administered perioperative medications, ketorolac and enoxaparin, was associated with the development of postoperative hemorrhage requiring transfusion. Our results indicate that the use of these medications was not associated with postoperative bleeding in our cohort.

## Conclusion

Postoperative hemorrhage requiring transfusion in bariatric surgery patients who, at the time of closing, do not appear to have any evidence of bleeding is a rare but challenging complication. We found that patients who hemorrhaged postoperatively were relatively hypotensive compared with their baseline blood pressure during a critical window of the surgery when the operation is complete and the abdomen is inspected for potential bleeding from the operative bed (staple lines and transected surfaces). Future prospective studies will be required to determine if normalizing blood pressures intraoperatively is safe and can decrease the incidence of postoperative hemorrhage.

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## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Ethical Statement** This was a retrospective study, which was approved by the Institutional Human Investigation Committee not required (ID: 2000021987) and was conducted in accordance with the ethical standards of this institution, the national research committee, as well as the 1964 Helsinki Declaration and its later amendments.

**Informed Consent Statement** This was a retrospective study which was approved by the Institutional Human Investigation Committee and determined that formal consent was not required. The IRB protocol ID is 2000021987.

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