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Analysis of the efficacy of a prophylactic increasing blood pressure before the end of surgery to reduce postoperative bleeding after gastrectomy: a propensity score-matched analysis

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Abstract

Objective To investigate the efficacy of reducing post-gastrectomy hemorrhage by increasing blood pressure at the end of gastric surgery and to evaluate whether this clinical intervention affects the stability of patients' postoperative circulatory system.

Methods A retrospective analysis was conducted on 499 patients who underwent radical gastrectomy under general anesthesia at our center between January 2023 and January 2024. After 1:1 propensity score matching, the experimental group comprised 157 patients whose operation cavities were examined after increasing blood pressure before the end of gastrectomy, while the control group included 157 patients whose operation cavities were examined using routine procedures without increasing blood pressure.

Results The incidences of total postoperative bleeding (0% vs. 3.82%, $P=0.013$) and early postoperative bleeding (0% vs. 2.55%, $P=0.044$) were significantly lower in the experimental group compared to the control group. There were no significant differences between the two groups in delayed bleeding (0% vs. 1.23%, $P=0.156$), systolic blood pressure immediately upon returning to the ward (121.02 ± 18.196 vs. 120.34 ± 21.664, $P=0.795$), systolic blood pressure 48 h post-surgery (125.04 ± 16.242 vs. 126.23 ± 17.048, $P=0.529$), diastolic blood pressure immediately upon returning to the ward (83.83 ± 11.978 vs. 84.75 ± 12.422, $P=0.506$), diastolic blood pressure 48 h post-surgery (74.69 ± 9.773 vs. 75.76 ± 10.605, $P=0.353$), heart rate immediately upon returning to the ward (74.31 ± 11.610 vs. 75.15 ± 11.660, $P=0.522$), or heart rate 48 h post-surgery (80.49 ± 12.267 vs. 79.11 ± 10.969, $P=0.293$). Additionally, there were no statistically significant differences between the two groups regarding anastomotic fistula, intestinal obstruction, postoperative pneumonia, reoperation, mortality, combined organ resection, or postoperative hospital stay ($P>0.05$).

Conclusion Increasing blood pressure before the end of gastrectomy can effectively reduce the incidence of primary postoperative hemorrhage without affecting the stability of the perioperative circulatory system.

Keywords Gastrectomy, Postoperative bleeding, Treatment outcome, Prophylactic increasing blood pressure

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Introduction

Bleeding is a common occurrence during surgical procedures, primarily due to injury to blood vessels. In the context of gastrectomy, bleeding may result from tissue dissection, ligation of vessels, and manipulation of organs. Post-operative bleeding can also stem from inadequate hemostasis, infection, or wound dehiscence. The severity of such bleeding can vary significantly, ranging from minor oozing to life-threatening hemorrhages [1, 2].

Effective management of bleeding requires a comprehensive approach. During surgery, surgeons employ various techniques—including ligation, electrocautery, and the application of hemostatic agents—to control hemorrhage [3]. Following the operation, patients may require blood transfusions or medications to enhance coagulation. Severe postoperative hemorrhage may necessitate additional surgical intervention.

The consequences of bleeding can be substantial. Minor episodes may lead to patient discomfort, prolonged hospital stays, and an increased risk of infection. Conversely, severe bleeding can cause hemodynamic instability, shock, and even mortality. Furthermore, it complicates post-operative recovery by delaying wound healing and increasing the likelihood of complications—ultimately diminishing patient outcomes [4].

In this propensity score-matched analysis, we evaluate the effectiveness of prophylactically increasing blood pressure prior to the conclusion of gastrectomy as a means to reduce post-operative bleeding.

Materials and methods

This study received approval from the Institutional Ethics Review Committee of Weifang People's Hospital (KYLL20240313-4). Informed consent was waived by our Institutional Review Board due to the retrospective nature of this research.

Study population

All methods were conducted in accordance with the Declaration of Helsinki and relevant guidelines/regulations. From January 2023 to January 2024, a total of 499 patients underwent gastrectomy under general anesthesia at our hospital, comprising 359 males and 140 females.

Inclusion and exclusion criteria

The inclusion criteria were as follows: preoperative pathological confirmation of gastric cancer; radical surgical intervention for gastric cancer; and availability of comprehensive clinical data.

Exclusion criteria included: patients with coagulation disorders, severe renal insufficiency, significant cardiovascular diseases, and those allergic to vasopressor agents. Additionally, no local epinephrine was used to control bleeding during the operation.

Study methods

Data source

Baseline patient information was extracted from the medical records system.

Primary Outcome Measures:

1. Incidence of total postoperative bleeding, early bleeding, and delayed bleeding
2. Vital signs at different time points:
   (1) Systolic blood pressure (immediately upon returning to the ward; 48 h post-surgery)
   (2) Diastolic blood pressure (immediately upon returning to the ward; 48 h post-surgery)
   (3) Heart rate (immediately upon returning to the ward; 48 h post-surgery)

Secondary Outcome Measures:

1. Perioperative outcomes: anastomotic fistula, intestinal obstruction, postoperative pneumonia.
2. Other indicators: reoperation, mortality, combined organ resection, and postoperative hospital stay.

Grouping method

Experimental group

During the operation, the mean arterial pressure (MAP) was used as the standard, and blood pressure was increased before the end of the procedure. Specific surgical methods included:

1. The anesthesiologist administered norepinephrine intravenously at a dose of 2–10 μg/kg·min to elevate the patient's blood pressure by more than 20% above the average intraoperative MAP.
2. The abdominal cavity was irrigated with 2000 ml of water for injection.
3. The surgical cavity was examined for active bleeding for 5 min [5] (Figs. 1–2).

If intraoperative bleeding was detected, hemostasis was achieved using electrocautery, a hemostatic clamp, or silk sutures. All patients returned to the ward without any anesthesia-related incidents.

In our study, the initial dose of norepinephrine was set within the range of 2–10 μg/kg·min and subsequently adjusted based on factors such as the patient's weight, baseline blood pressure, and their initial

Fig. 1 Schematic diagram of intraoperative prophylactic blood pressure increase before surgery completion

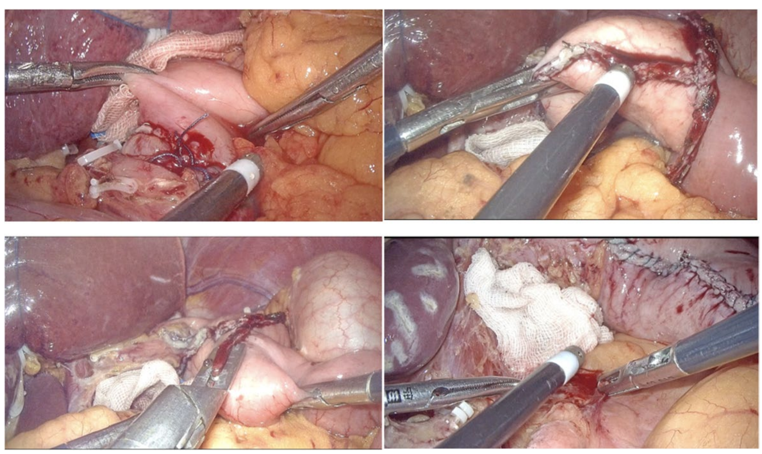

Fig. 2 Schematic diagram of intraoperative prophylactic blood pressure increase prior to surgery completion

response to norepinephrine. Throughout the operation, we meticulously monitored the patient's hemodynamic parameters—particularly blood pressure and heart rate—and modified the norepinephrine infusion rate in accordance with fluctuations in these parameters and clinical judgment. Key considerations for adjustment included:

1. Patient weight (to calculate an appropriate dosage)
2. Baseline blood pressure levels (to determine the necessary elevation)
3. Immediate responses to norepinephrine administration (such as the speed and extent of blood pressure increase)

Control group

Before the end of the operation, prophylactic blood pressure elevation was not performed. Instead, the abdominal cavity was irrigated with 2000 ml of water for injection and checked for active bleeding for 5 min. If bleeding was detected in the operative cavity, it was controlled using the aforementioned methods.

Statistical analysis

Statistical analyses were performed using SPSS version 26.0. Measurement data are expressed as mean ± standard deviation ($x \pm s$), and t-tests were conducted. Categorical data are presented as counts (percentages), and

χ^2 tests were performed. A *P*-value < 0.05 was considered statistically significant.

Propensity score matching (PSM) was conducted to reduce bias in baseline characteristics. The matched baseline information included age, sex, BMI, diabetes, hypertension, history of abdominal surgery, liver cirrhosis, abdominal infection, anastomotic fistula, number of lymph nodes removed, TNM stage, and neoadjuvant chemotherapy. Patients were matched in a 1:1 ratio using the nearest-neighbor matching method, with a caliper width set at 0.2 standard deviations.

Results

General patient characteristics

Patient Characteristics: A total of 499 eligible patients were included in the study. Propensity score matching (PSM) was performed based on the following factors: age, sex, BMI, diabetes, hypertension, history of abdominal surgery, liver cirrhosis, abdominal infection, anastomotic fistula, number of lymph nodes dissected, TNM stage, and neoadjuvant chemotherapy. After 1:1 propensity score matching, 314 patients were enrolled, with 157 patients assigned to the experimental group and 157 to the control group. Table 1 summarizes the baseline clinical data according to PSM.

Before PSM, statistically significant differences were observed between the two groups in age (*P* = 0.031), BMI (*P* = 0.002), anastomotic fistula (*P* = 0.016), TNM stage(*P* = 0.010), and number of lymph nodes dissected (*P* = 0.041). After PSM, only the number of patients with diabetes differed significantly between the two groups (*P* = 0.048), while no significant differences were found in other baseline characteristics. PSM enhanced the reliability of the study results (Table 1).

Surgery and related complications

Table 2 shows the operative and postoperative complications in the two groups. There were no significant differences between the two groups in anastomotic stenosis, intestinal obstruction, postoperative pneumonia, reoperation, mortality, intraoperative blood transfusion, or combined organ resection (*P* > 0.05).

The incidence of total postoperative bleeding (0% vs. 3.82%, *P* = 0.013) and early bleeding (0% vs. 2.55%, *P* = 0.044) was significantly lower in the experimental group compared to the control group. However, there was no statistically significant difference in the incidence of delayed bleeding between the two groups (0% vs. 1.23%, *P* = 0.156).

The results suggest that a prophylactic increase in blood pressure before the end of surgery can effectively reduce the incidence of early postoperative bleeding after gastrectomy but does not significantly reduce the incidence of delayed bleeding. Specific analysis of the six patients with early and delayed hemorrhage in the control group is provided in Table 3.

Table 1 Baseline characteristics before and after propensity score matching (PSM)

	Before PSM			**After PSM**		
	Control group(*N* = 342)	**Experimental group(*N* = 157)**	***P***	**Control group(*N* = 157)**	**Experimental group(*N* = 157)**	***P***
age(≤ 75/ > 75)	304/38	149/8	0.031	152/5	149/8	0.395
Sex(man/women)	241/101	118/39	0.279	123/34	118/39	0.504
Hypertension(no/yes)	222/120	105/52	0.668	116/41	105/52	0.174
Diabetes(no/yes)	300/42	138/19	0.955	148/9	138/19	0.048
History of abdominal surgery(no/yes)	311/31	145/12	0.599	148/9	145/12	0.498
Liver cirrhosis(no/yes)	341/1	156/1	0.572	156/1	156/1	1.000
Neoadjuvant chemotherapy(no/yes)	319/23	144/13	0.533	143/14	144/13	0.840
BMI(≤ 24/ > 24)	206/136	117/40	0.002	120/37	117/40	0.694
Abdominal infection(no/yes)	315/27	147/10	0.546	150/7	147/10	0.454
Anastomotic fistula(no/yes)	324/17	156/1	0.016	156/1	156/1	1.000
Number of lymph nodes dissected(≤ 40/ > 40)	278/64	115/42	0.041	123/34	115/42	0.292
TNM stage			0.010			0.122
I	89	54		50	54	
II	81	29		34	29	
III	156	74		68	74	
IV	16	0		5	0	

Table 2 Surgery and related complications

Characteristics	Before PSM			After PSM		
	Control group($N=342$)	Experimental group($N=157$)	*P*	Control group($N=157$)	Experimental group($N=157$)	*P*
anastomotic stenosis(no/yes)	341/1	157/0	0.498	156/1	157/0	0.317
intestinal obstruction(no/yes)	340/2	157/0	0.337	156/1	157/0	0.317
postoperative pneumonia(no/yes)	301/41	151/6	0.04	145/12	151/6	0.145
second operation(no/yes)	334/8	156/1	0.185	153/4	156/1	0.176
death(no/yes)	338/4	157/0	0.174	156/1	157/0	0.317
ntraoperative blood transfusion(no/yes)	270/72	140/17	0.006	129/28	140/17	0.076
combined organ resection (no/yes)	329/13	154/3	0.266	149/8	154/3	0.125
Type of gastrectomy(no/yes)			0.078			0.106
Distal	205	92		97	92	
Total	105	40		47	40	
Proximal	32	25		13	25	
Postoperative hospital stay	12.97 ± 7.106	13.57 ± 3.751	0.318	12.77 ± 7.635	13.57 ± 3.751	0.238
Total postoperative bleeding cases(no/yes)	331/11	157/0	0.023	151/6	157/0	0.013
early hemorrhage	8	0	0.053	4	0	0.044
delayed bleeding	3	0	0.239	2	0	0.156

Comparison of postoperative systolic blood pressure, diastolic blood pressure, and heart rate between groups

There were no statistically significant differences in systolic blood pressure, diastolic blood pressure, or heart rate between the two groups before surgery, indicating that the groups were comparable at baseline. Additionally, there were no statistically significant differences in systolic blood pressure, diastolic blood pressure, or heart rate at different time points (immediately upon returning to the ward after surgery and 48 h post-surgery). These results suggest that increasing blood pressure before the end of surgery does not influence the stability of the circulatory system (Table 4).

Discussion

First, this study found that the total postoperative bleeding rate and early bleeding rate in the experimental group with prophylactic blood pressure increase were significantly lower than those in the control group without such intervention. In general anesthesia surgeries, most anesthetic agents have vasodilatory effects, leading to intraoperative blood pressure typically being lower than normal. Prophylactically increasing blood pressure prior to the conclusion of surgery for abdominal cavity examination can enhance the early detection of potential bleeding sites, including vascular stumps, surgical wounds, and gastrointestinal remnants [6, 7]. Higher blood pressure facilitates verification that cut or damaged blood vessels have been adequately addressed, thus preventing unhealed vessels from causing postoperative bleeding [8]. This allows for more thorough hemostasis and reduces the risk of postoperative primary hemorrhage.A review of previous surgical video data from the experimental group revealed that three patients (1.91%) required additional hemostatic measures during surgery; however, none experienced early postoperative bleeding. In contrast, four cases of early postoperative bleeding were observed in the control group. This study indicates that performing a preventive increase in blood pressure prior to concluding gastric resection significantly reduces the probability of postoperative primary hemorrhage (0% vs. 2.55%, $P=0.044$). Notably, while the experimental group demonstrated significant results in reducing early postoperative bleeding, there were no substantial differences between the two groups regarding the rate of delayed bleeding (0% vs. 1.23%, $P=0.156$). Delayed bleeding is often associated with tissue injury, inadequate anastomotic healing, or vascular remodeling during surgical procedures [9]. These factors can contribute to increased fragility of the blood vessel wall in the postoperative period, rendering it susceptible to rupture and subsequent bleeding. Additionally, infection serves as a significant contributor to delayed bleeding by potentially triggering inflammation, compromising the integrity of blood vessel walls, or promoting thrombosis [10]. Furthermore, various elements such as the patient's preexisting medical conditions, postoperative care quality, and individual patient differences may also play a crucial role in the incidence of delayed bleeding.

Regarding the impact of prophylactic hypertension on delayed bleeding, we contend that due to the complexity and heterogeneity inherent in delayed bleeding cases, it

Table 3 Specific analysis of 6 patients with early hemorrhage and delayed hemorrhage in the control group

	1	2	3	4	5	6
Bleeding classification						
early hemorrhage		Within 24 h after surgery		Within 24 h after surgery	Within 24 h after surgery	Within 24 h after surgery
delayed bleeding	18 days after surgery		10 days after surgery			
Bleeding site						
Anastomotic stoma		1				
artery			Intraoperative Exploration: Jet bleeding was observed approximately 1 cm from the root of the gastroduodenal artery			
vein						
unknown	1			1	1	1
Abdominal infection(no/yes)	1					
Anastomotic fistula(no/yes)						
Diagnostic method						
Clinical symptoms (abdominal drainage tube > 100 ml)			1	1	1	1
endoscope		1				
arteriography						
CT	1					
ultrasonic						
Treatment method						
Conservative methods (acid suppression, fluid rehydration, hemostasis, blood transfusion, etc.)				1	1	1
Interventional therapy	1					
Endoscopic therapy		1				
Second operation			1			
Hemorrhage related mortality	0	0	0	0	0	0

Table 4 Postoperative vital signs of two groups of patients

	Number of cases	Systolic blood pressure(mmHg)	Diastolic blood pressure(mmHg)	Heart rate(times/min)
Control group	157			
Before operation		126.62 ± 16.996	79.73 ± 10.434	78.59 ± 13.648
Return to ward immediately after surgery		148.46 ± 21.940	83.83 ± 11.978	74.31 ± 11.610
48 h after surgery		125.04 ± 16.242	74.69 ± 9.773	80.49 ± 12.267
Experimental group	157			
Before operation		128.36 ± 19.260	77.59 ± 10.259	77.70 ± 10.828
Return to ward immediately after surgery		143.43 ± 21.138	84.75 ± 12.422	75.15 ± 11.660
48 h after surgery		126.23 ± 17.048	75.76 ± 10.605	79.11 ± 10.969
P(Before operation)		0.397	0.068	0.525
P(Return to ward immediately after surgery)		0.039	0.506	0.522
P(48 h after surgery)		0.529	0.353	0.293

may be challenging to effectively address these underlying mechanisms solely through preoperative or intraoperative hypertension management [11]. For instance, when dealing with delayed bleeding resulting from conditions such as a ruptured pseudoaneurysm or severe infection, more intricate surgical interventions or pharmacological treatments may be necessary for effective hemorrhage control.

Consequently, future research will aim to delve deeper into the underlying mechanisms contributing to delayed bleeding and evaluate how different treatment strategies influence these mechanisms.

However, the prevention of postoperative bleeding extends beyond merely managing elevated blood pressure prior to the conclusion of surgery. Controlling intraoperative hemorrhage is equally critical. Previous studies have demonstrated a strong correlation between increased intraoperative blood loss and the risk of postoperative bleeding. Consequently, it is imperative to implement various strategies during the surgical procedure to minimize bleeding as much as possible.To minimize postoperative bleeding, addressing intraoperative bleeding is crucial. According to relevant clinical studies, deep neuromuscular block and near-infrared (NIR) guided surgery are considered essential strategies for reducing intraoperative bleeding, which ultimately contributes to a decrease in postoperative complications [12, 13]. Therefore, by integrating current advanced technologies, we can more effectively mitigate the risk of postoperative bleeding. Combining these techniques with prophylactic blood pressure elevation prior to the conclusion of surgery may further reduce the risk of postoperative bleeding following gastrectomy.

In evaluating the impact of this strategy on patients' circulatory stability following surgery, this study revealed no significant differences in key vital signs, including systolic and diastolic blood pressure, as well as heart rate, between the two groups. This finding suggests that a prophylactic increase in blood pressure can effectively mitigate the risk of postoperative bleeding without adversely affecting perioperative circulatory stability [14]. Consequently, this result not only enhances the clinical acceptability of this approach but also provides robust support for its broader implementation in gastric cancer surgeries.

In addition, the study evaluated various perioperative indicators, including anastomotic fistula, intestinal obstruction, postoperative pneumonia, reoperation, mortality, combined organ resection, and length of postoperative hospital stay [15–19]. However, no statistically significant differences were observed in these indices between the two groups ($P > 0.05$). This lack of difference may be attributed to the limited sample size of this study as well as the uniformity in postoperative management protocols. Future research should aim to increase the sample size and further investigate the impact of different postoperative management strategies on perioperative outcomes.

It is important to acknowledge that, while this study has yielded significant findings, it is not without limitations. For instance, the retrospective nature of this research may introduce potential selection and information biases. Additionally, the limited sample size could compromise the reliability of the results. Consequently, future investigations should aim to include a larger sample size and implement more rigorous randomized controlled trials to further validate the effectiveness and safety of this strategy.

Conclusion

Postoperative bleeding poses significant medical risks and can seriously compromise patient safety. Prophylactically increasing blood pressure and examining the surgical cavity before the conclusion of gastric cancer surgery can help identify potential bleeding points in advance, thereby reducing the incidence of postoperative primary bleeding. Additionally, this clinical intervention did not adversely affect the stability of the perioperative circulatory system.

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Authors' contributions
Guangxu Zhu, Qihang Sun, Qingshun Zhu, Lei Yu, Xuren Lu, Xiaomin Lang and Xin Yin conjectured the study and reviewed the paper; Guangxu Zhu and Shengjie Zhou analyzed the data and wrote the draft; Jianjun Qu selected the patients and collected the data.

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Data availability
The datasets utilized and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of Weifang People's Hospital and was conducted according to the Declaration of Helsinki. Due to the retrospective nature of the study design, the ethics committee waived the requirement for participant consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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