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ORIGINAL ARTICLE

Treatment outcomes of postoperative abdominal bleeding after oncologic surgery: a retrospective comparative study of surgical and interventional radiologic treatments

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Received: 25 May 2025, Accepted: 26 July 2025, Published online: 30 September 2025

ABSTRACT

Objective: Postoperative abdominal bleeding (POB) is a rare but life-threatening complication after abdominal oncologic surgery. POB can increase mortality by up to sixfold. Surgical treatment (ST) is generally preferred for early bleeding, while interventional radiologic treatment (IRT) is often favored for late bleeding; however, the literature remains inconclusive. This study aimed to compare the outcomes of ST and IRT in patients who developed POB after abdominal surgery for malignancy.

Methods: Patients who underwent abdominal surgery for malignancy between January 1, 2014, and December 31, 2024, were retrospectively reviewed. Bleeding occurring within 24 hours postoperatively was defined as early, while bleeding after 24 hours was considered late. Demographic data, clinical characteristics, treatment modalities, and outcomes were analyzed.

Results: Of 2,266 patients, 35 (1.54%) developed POB and were included. Seventeen (48.57%) had early bleeding, and 18 (51.43%) had late bleeding. ST was performed in 18 patients (51.43%), and IRT in 17 (48.57%). Median time from surgery to bleeding was significantly shorter in the ST group (1 vs. 14 days, $p<0.001$). The ST group also had lower median red blood cell transfusion requirements (6 vs. 25 units, $p<0.001$) and shorter hospital stays (15.5 vs. 33 days, $p=0.008$). Among four late-bleeding patients treated surgically, three (75%) died. Rebleeding occurred in three IRT patients (17.65%), two of whom had bleeding from pancreaticojejunal anastomosis. Overall mortality was 31.4%, with no significant difference between groups ($p=0.54$).

Conclusion: POB after malignant abdominal surgery is a serious condition. ST for early bleeding and IRT for late bleeding offer comparable success and mortality rates. However, IRT is associated with higher rate of rebleeding in cases of pancreaticojejunal anastomotic hemorrhage, while ST for late bleeding carries a high mortality risk. Major abdominal surgeries should be performed in centers equipped for IRT, and treatment decisions should be made within a multidisciplinary framework.

Keywords: intra-abdominal bleeding, interventional radiology, embolization, bleeding control, malignant abdominal surgery

INTRODUCTION

Despite advancements in surgical techniques and the standardization of operative procedures, postoperative bleeding remains a major cause of mortality following abdominal surgery. Postoperative intra-abdominal bleeding (POB) occurs in approximately 0.4% to 10% of abdominal procedures, with the majority of cases associated with pancreatic surgery [1,2]. Bleeding following pancreatoduodenectomy (PD) occurs in approximately 3% to 10% of cases and is associated with mortality rates as high as 50% in affected patients [3-5]. POB has been reported in 1% to 8% of cases following liver surgery, while its incidence after gastric surgery ranges from 1.3% to 3.8% [6-9].

The most widely accepted classification for POB is the postpancreatectomy hemorrhage (PPH) definition established by the International Study Group of Pancreatic Surgery (ISGPS) [10]. Bleeding occurring within the first 24 hours after surgery is categorized as early bleeding, while bleeding that occurs after 24 hours is defined as late bleeding. Based on this classification, various management algorithms have been proposed for the treatment of PPH [11]. Surgical treatment (ST) is generally recommended for early bleeding, while interventional radiologic treatment (IRT) is preferred for late bleeding. However, these recommendations remain controversial, and there is no universally accepted approach for managing POB following surgeries of other abdominal organs.

The aim of this study is to evaluate the characteristics and treatment outcomes of patients who developed POB after undergoing abdominal surgery for malignancy at our institution, a high-volume center specialized in oncologic surgery.

PATIENTS AND METHODS

Study design and patient selection

Patient data were retrospectively obtained from the hospital information system. Among 2,266 patients who underwent abdominal surgery for malignancy at our institution between January 1, 2014, and December 31, 2024, a total of 35 patients who received either surgical treatment (ST) or interventional radiologic treatment (IRT) for postoperative intra-abdominal bleeding (POB) were included in the study. The inclusion criteria were as follows: all adult patients who underwent laparoscopic or open surgery for malignancies of the pancreas, liver, biliary tract, stomach, colon, small intestine, or retroperitoneum and were subsequently treated with ST or IRT for POB. The exclusion criteria were as follows: patients under the age of 18; those who underwent abdominal surgery for non-malignant conditions; patients managed conservatively without surgical or interventional treatment following bleeding; and those who underwent surgery involving the kidneys or gynecologic organs. The process of patient selection is illustrated in Figure 1 as a flowchart.

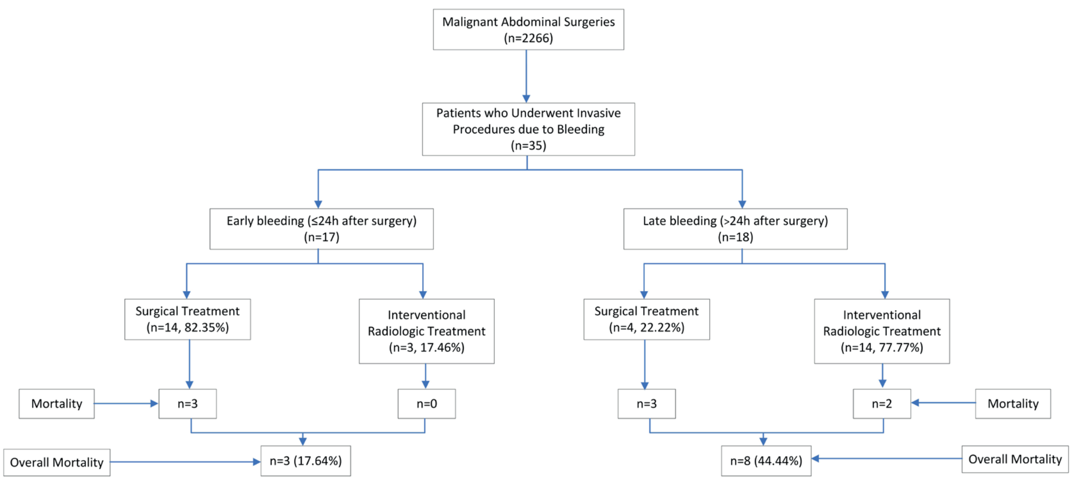

Figure 1. Flowchart

Ethical Approval: The study was approved by the Hacettepe University, Health Sciences Research Ethics Committee (Protocol no. 2025/05-48/18.02.2025). Written informed consent was obtained from all patients prior to treatment.

Demographic, clinical, and laboratory features

Data collected included patient age, sex, preoperative diagnosis, Charlson Comorbidity Index (CCI), type of index surgery, postoperative complications, Clavien–Dindo classification (C–D score), bleeding-related variables, characteristics of the surgical or interventional radiologic treatment performed for bleeding, and the outcomes of these interventions.

Definitions and classifications

In the postoperative period, the presence of hemorrhagic output from surgical drains or nasogastric tubes, as well as the development of hematemesis, melena, hematochezia, accompanying tachycardia, hypotension, oliguria, altered mental status, or a drop in hemoglobin levels, were clinically considered indicative of bleeding (Figure 2).

Figure 2. Appearance of hemorrhagic fluid coming from abdominal drain

Based on the ISGPS definition of PPH, bleeding occurring within 24 hours after abdominal surgery was defined as early bleeding, while bleeding after 24 hours was classified as late bleeding [10]. According to the same guideline, bleeding into the lumen of an intestinal organ was defined as intraluminal bleeding, while bleeding into the abdominal cavity was classified as extraluminal bleeding.

In line with the postoperative pancreatic fistula definition by the same study group, pancreatic fistulas were categorized as Grade A, B, or C, with Grade B and C fistulas considered clinically significant [12].

Rebleeding was defined as the occurrence of recurrent active bleeding after the initial hemostatic intervention had been performed.

Bleeding control procedures

Surgery

All surgical procedures were performed under general anesthesia with endotracheal intubation. The abdomen was accessed through reopening of the previous abdominal incision. After peritoneal lavage, the celiac trunk (CA), common hepatic artery (CHA), gastroduodenal artery (GDA), right hepatic artery (RHA), left hepatic artery (LHA), left gastric artery (LGA), splenic artery (SA), superior mesenteric artery (SMA), the surgical field, anastomotic sites, retroperitoneum, and diaphragmatic surfaces were systematically inspected for bleeding. Hemostasis was achieved, and after confirming the absence of active bleeding, the abdomen was closed with the placement of negative pressure closed-system silicone drains.

Interventional radiologic treatment

For interventional radiologic procedures, vascular access was obtained via the femoral or brachial artery using the Seldinger technique. A microcatheter was advanced in a superselective manner into branches of the CA, SMA, or abdominal aorta. Based on the location of the bleeding, mechanical or liquid embolic agents were used to achieve hemostasis following catheterization. Control angiographic images were obtained to confirm the absence of contrast extravasation (Figure 3).

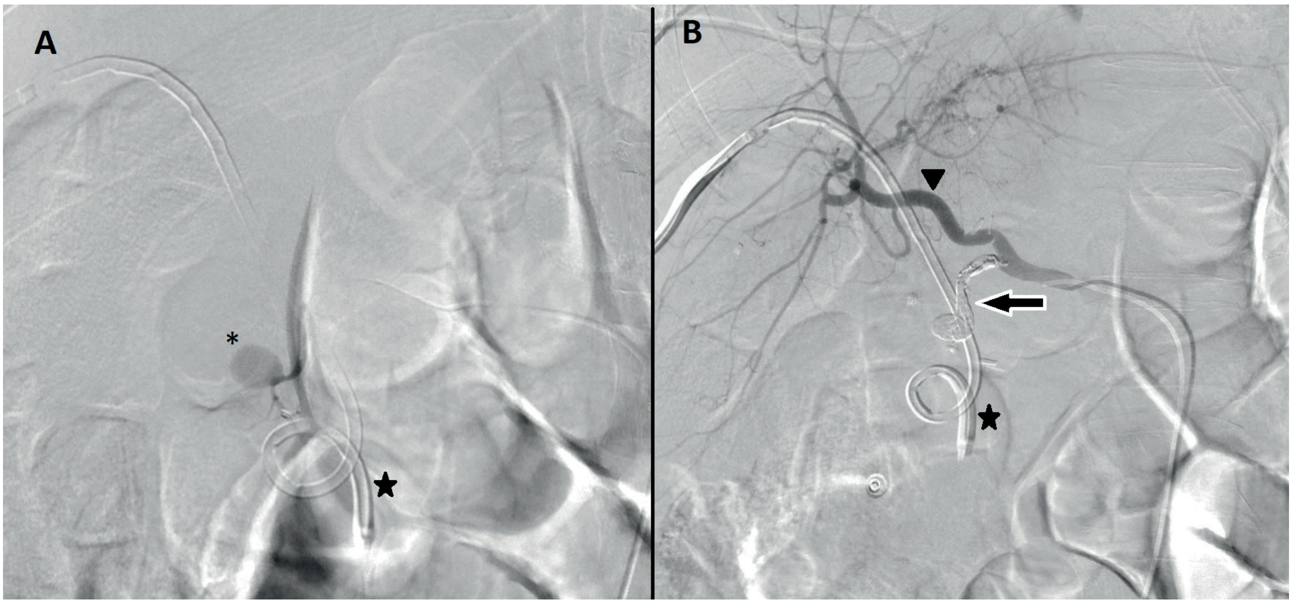

Figure 3. Interventional radiologic treatment. A 67-year-old male patient underwent an open subtotal gastrectomy with D2 lymphadenectomy for gastric adenocarcinoma. During his hospital stay, he was being managed for a postoperative duodenal stump leak with antibiotics and a drainage catheter. On postoperative day 28, the patient developed hemodynamic instability. Laboratory tests revealed a hemoglobin level of 5.5 g/dL. After initial resuscitation, imaging demonstrated active bleeding from a gastroduodenal artery pseudoaneurysm. The patient was successfully treated with coil embolization. A. Fluoroscopic image obtained during active bleeding. The asterisk indicates a pseudoaneurysm in the gastroduodenal artery; the black star indicates the drainage catheter. B. Fluoroscopic image after successful bleeding control with coil embolization. The black-and-white arrow indicates the embolized gastroduodenal artery; the black arrowhead indicates the proper hepatic artery; the black star indicates the drainage catheter.

Statistical analysis

Categorical variables were summarized as frequencies and percentages, while non-normally distributed continuous variables were presented as medians with corresponding minimum and maximum values. The Mann–Whitney U test was used to compare non-normally distributed continuous variables. The Pearson chi-square test or Fisher's exact test was applied for the analysis of categorical and ordinal variables, as appropriate. A two-tailed p-value of <0.05 was considered statistically significant. All statistical analyses were conducted using IBM SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Among 2,266 patients who underwent intra-abdominal surgery for malignancy during the study period, 35 patients (1.54%) who required treatment for postoperative bleeding were included in the study. Of these, 23 patients (65.7%) were male. ST was performed in 18 patients (51.43%), while IRT was applied in 17 patients (48.57%). When the demographic characteristics of the patients were analyzed, no statistically significant differences were observed between the groups in terms of age, CCI, ASA score, use of antithrombotic medications, or receipt of neoadjuvant therapy. In the ST group, bleeding occurred following pancreatic surgery in nine patients, colorectal surgery in five, resection of intra-abdominal masses in three, and liver surgery in one patient. In the IRT group, bleeding occurred after pancreatic surgery in nine patients, gastric surgery in six, and colorectal surgery in two. Demographic data and primary malignancy etiologies are summarized in Table 1.

When patients were evaluated based on the timing of bleeding, 17 (48.57%) experienced early bleeding, while 18 (51.43%) had late bleeding. Among early bleeding cases, 14 patients (82.35%) were treated with ST, whereas 14 patients (77.77%) with late bleeding received IRT. The mortality rate

Table 1. Patient characteristics and demographic data

	Surgical management (n=18)	Interventional radiologic management (n=17)	p-value
Gender (m/f)	9/9	14/3	0.07
Age, median (min-max)	63 (44-78)	56 (22-70)	0.07
Charlson Comorbidity Index, median (min-max)	4 (2-10)	4 (2-7)	0.36
ASA score, median (min-max)	2 (1-3)	2 (1-3)	0.22
Use of antithrombotic drug (n)	2/18	1/17	0.52
Etiology of primary malignancy, (n)			
Pancreas	9	9	
Ductal adenocarcinoma	8	6	
Neuroendocrine tumor	0	3	
Metastasis (Renal cell carcinoma)	1	0	
Stomach	0	6	
Adenocarcinoma	0	6	
Colon and rectum	5	2	
Adenocarcinoma	4	2	
Gastrointestinal stromal tumor	1	0	
Intraabdominal mass	3	0	
Leiomyosarcoma	1	0	
Carcinosarcoma	1	0	
Liposarcoma	1	0	
Liver	1	0	
Malign mesenchymal tumor	1	0	
Neoadjuvan treatment			
Chemotherapy, n (%)	5 (27.78)	6 (35.29)	0.63
Radiotherapy, n (%)	2 (11.11)	0	0.48

ASA: American Society of Anesthesiologists.

was 17.64% in the early bleeding group and 44.44% in the late bleeding group; however, this difference was not statistically significant (p=0.14).

When perioperative characteristics were examined, 28 patients (80%) had extraluminal bleeding, while 7 patients (20%) had intraluminal bleeding. In the ST group, extraluminal bleeding was observed in 15 patients and intraluminal bleeding in 3 patients. In the IRT group, 13 patients had extraluminal and 4 had intraluminal bleeding (p=0.10). Regarding the source of bleeding, no hemorrhagic drainage was detected in 18 patients (51.43%), whereas 10 patients (28.57%) showed blood in their abdominal drainage tubes. In the evaluation of the bleeding site, all patients in the IRT group (100%) underwent computed tomography angiography (CTA), while only one patient (5.55%) in the ST group, who experienced bleeding on postoperative day 9, underwent CTA. The median time from the index operation to the onset of bleeding was significantly shorter in the ST group compared to the IRT group (1 vs. 14 days, respectively; p<0.001). Similarly, the median red blood cell transfusion (RBC) requirement after bleeding diagnosis was significantly lower in the ST group than in the IRT group (6 vs. 25 units, respectively; p<0.001). Length of hospital stay was significantly shorter in the ST group (median 15.5 vs. 33 days, respectively; p=0.008). However, there were no statistically significant differences between the groups regarding ICU admission, number of lymph nodes removed, or in-hospital mortality. Likewise, when comparing early postoperative complications between groups, no statistically significant differences were found in rates of pancreatic fistula, biliary leakage, anastomotic leakage, sepsis, or intra-abdominal abscess (p=0.26, 0.73, 0.23, 0.60, and 0.07, respectively). C-D scores were also similar between the groups (p=0.83). The results are presented in Table 2.

Table 2. Perioperative characteristics of patients

	Surgical treatment (n=18)	Interventional radiologic treatment (n=17)	p-value
Type of Initial Surgery (n)			
Hepatectomy	1	0	
Segmentectomy (Segment 4)	1	0	
Pancreatic surgery	9	9	
Pancreaticoduodenectomy	8	8	
Laparoscopic distal pancreatectomy	1	0	
Enucleation	0	1	
Gastric surgery	0	6	
Subtotal gastrectomy	0	2	
Total gastrectomy	0	3	
Laparoscopic total gastrectomy	0	1	
Colorectal surgery	5	2	
Low anterior resection	2	0	
Right hemicolectomy	1	1	
Left hemicolectomy	1	0	
Total abdominal colectomy	1	0	
Total abdominal colectomy-HIPEC	0	1	
Intraabdominal tumor excision	3	0	
Postoperative early complications, n/total (%)			
Sepsis	3/18 (16.67)	1/17 (5.88)	0.60
Pancreatic fistula	4/9 (44.44)	2/10 (20)	0.26
Biliary leakage	1/9 (11.11)	1/8 (12.5)	0.73
Anastomotic leakage	1/13 (7.69)	4/16 (25)	0.23
Intraabdominal abscess	3/18 (16.67)	8/17 (47.05)	0.07
Claviden dindo classification, median (min-max)	4 (3-5)	4 (3-5)	0.83
Site of blood (n)			0.10
Extraluminal	15	13	
Dissection area	6	0	
Anastomosis	1	2	
Vascular	7	11	
Pancreatic duct	1	0	
Intraluminal	3	4	
Anastomosis	2	3	
Aortoenteric fistula	0	1	
Stress ulcer	1	0	
Source of bleeding (n)			0.06
Bleeding abdominal drainage tube	7	3	
Hematemesis	1	6	
None	10	8	
RBC transfusion*, unite, median (min-max)	6 (1-30)	25 (4-56)	<0.001
Time interval between index operation to hemorrhage, day, median (min-max)	1 (0-9)	14 (1-36)	<0.001
Number of Lymph node, median (min-max)	12 (0-31)	10 (0-33)	0.59
Length of Hospital stay, day, median (min-max)	15.5 (6-83)	33 (9-202)	0.008
ICU stay, day, median (min-max)	8.5 (0-32)	9 (0-80)	0.50
In-hospital mortality, n (%)	6 (33.33)	5 (29.41)	0.54

RBC: red blood cell; HIPEC: Hyperthermic Intraperitoneal Chemotherapy; ICU: Intensive care unit.

*The amount of transfusion after diagnosis of bleeding.

Table 3. Bleeding sites and treatment characteristics in patients who underwent interventional radiologic treatment

Patient Number	Source of hemorrhage	Endovascular treatment method
1	Left superior vesical artery	Glue
2	Aortoenteric fistula	Endovascular graft
3	Celiac artery	Glue
4	Segment 2-3 artery	Coil+Glue
5	Gastroduodenal artery	Coil
6	Gastroduodenal artery	Coil
7	Right external iliac artery	Endovascular graft
8	Gastrojejunostomy anastomosis line	Glue
9	Hepatic artery	Glue
10	Splenic artery	Coil
11	Pancreaticojejunostomy anastomosis line	Coil
12	Replaced right hepatic artery	Coil
13	Gastroduodenal artery	Coil
14	Gastroduodenal artery	Coil
15	Pancreaticojejunostomy anastomosis line	Glue
16	Gastroduodenal artery	Coil
17	Pancreaticojejunostomy anastomosis line	Coil

Table 4. Perioperative characteristics of patients who developed rebleeding

Patient	Initial management following bleeding	Interval between the initial and secondary procedures (day)	Secondary procedure	Location	Dead/Alive
1	Glue embolization	1	Relaparotomy	P-J anastomosis	Alive
2	Coil embolization	2	Relaparotomy	GDA	Alive
3	Coil embolization	9	Relaparotomy	P-J anastomosis	Alive

P-J: pancreaticojejunostomy; GDA: gastroduodenal artery.

When patients were analyzed according to the source of bleeding, it was found that in the ST group, eight patients had bleeding from the surgical site, three from the anastomotic line, two from behind the superior mesenteric vein, two from mesenteric vessels, one from the gastroduodenal artery (GDA), one from the gonadal vein, and one from the portal vein. The bleeding sites and treatment modalities in the IRT group are presented in Table 3.

Rebleeding occurred in three patients (17.65%) who underwent IRT for bleeding. All of these patients subsequently underwent surgical intervention to achieve bleeding control. No IRT-related mortality was observed in any of the patients. Perioperative characteristics of the patients are summarized in Table 4.

Despite treatment, in-hospital mortality occurred in 11 patients (31.4%). Six of these patients were in the ST group, and five were in the IRT group. Among these cases, the median survival time following bleeding control was 6 days. The final cause of death was identified as intra-abdominal sepsis in five patients, multiorgan failure secondary to hypovolemic shock in four patients, and pneumonia in two patients. Data on patients who experienced post-treatment mortality are presented in Table 5.

Table 5. Characteristics of patients who died following bleeding

Patient number	Index operation	Interval between index operation and death (day)	Bleeding source	Final treatment	Cause of death
1	Whipple operation	3	Dissection area	Relaparotomy	Pneumonia
2	Whipple operation	0	Uncinate process	Relaparotomy	Hipovolemic shock
3	Intraabdominal tumor resection	9	Gastroduodenal artery	Relaparotomy	Intraabdominal Sepsis
4	Left hemicolectomy	2	Retroperitoneal plane	Relaparotomy	Hipovolemic shock
5	Right hemicolectomy	0	Superior mesenteric artery	Relaparotomy	Hipovolemic shock
6	Laparoscopic distal pancreatectomy	1	Left adrenal gland	Relaparotomy	Hipovolemic shock
7	Total gastrectomy	36	Aortoenteric fistule	Graft	Intraabdominal Sepsis
8	Subtotal gastrectomy	28	Coeliac artery	Glue embolization	Intraabdominal Sepsis
9	Laparoscopic total gastrectomy	6	Gastroduodenal artery	Coil embolization	Pneumonia
10	Whipple operation	14	Pancreaticojejunostomy	Coil embolization	Intraabdominal Sepsis
11	Total gastrectomy, splenectomy, distal pancreatectomy	10	Gastroduodenal artery	Coil embolization	Intraabdominal Sepsis

DISCUSSION

Postoperative bleeding requiring treatment was observed in 1.54% of patients who underwent intra-abdominal surgery for malignancy. Among these, 48.57% were classified as early bleeding and 51.42% as late bleeding. Although not statistically significant, mortality was clinically higher in patients with late bleeding compared to those with early bleeding (17.65% vs. 44.44%, respectively; p=0.14). The overall mortality rate among patients with postoperative bleeding was 31.42%. ST was more commonly employed in early bleeding cases, whereas IRT was more frequently used for late bleeding. Notably, among patients who underwent ST for late bleeding, the mortality rate was 75%. Patients treated with ST had a lower requirement for RBC transfusion and a shorter length of hospital stay. IRT achieved a 100% technical success rate, with a 17.65% incidence of rebleeding and an 82.35% clinical success rate. Both treatment modalities yielded comparable morbidity and mortality outcomes. However, in cases of bleeding originating from pancreaticojejunostomy (P–J) anastomoses, rebleeding occurred in 66.66% of patients following IRT.

Advancements in oncology and innovations in neoadjuvant therapies have enabled surgical intervention for tumors that were previously considered locally advanced, unresectable, or inoperable. In parallel, progress in surgical techniques has led to more frequent performance of vascular resections. As a result, the incidence of POB has increased compared to previous years [13-16]. Although POB is most commonly observed after pancreatic surgery, it can occur following any type of abdominal operation. In cases of bleeding after pancreatic procedures, mortality rates can reach up to 50%, and the risk of death is reported to be up to six times higher in patients who experience bleeding compared to those who do not [4,17].

The most widely accepted definition of POB is the PPH classification proposed by the ISGPS [10]. This classification can also be applied to bleeding that occurs following intra-abdominal surgery for malignancy [18]. Bleeding within the first 24 hours after surgery is defined as early bleeding, while bleeding that occurs thereafter is classified as late bleeding. Early bleeding is often associated with inadequate intraoperative hemostasis or bleeding masked by vasoconstriction that goes undetected at the end of the procedure. In contrast, late bleeding is considered the result of a more complex postoperative process and has been shown to be associated with complications such as intra-abdominal abscesses, anastomotic leakage, biliary leakage, and pancreatic fistulas [19-22]. Additionally, during peritumoral lymph node dissection, the adventitial layer of the vessels may be removed, leaving the vessels unprotected and more susceptible to injury [15]. Intra-abdominal fluid collections can erode the weakened vascular wall, leading to the development of pseudoaneurysms or sudden hemorrhage. In our study, early bleeding occurred in 17 patients (48.57%), while late bleeding was observed in 18 patients (51.42%). All pancreatic and gastric surgeries in the cohort involved lymph node dissection around the CA and CHA. Despite this, there was no statistically significant difference in early postoperative complications between the early and late bleeding groups—an observation that differs from what has been commonly reported in the literature.

Surgical treatment is generally the recommended approach for managing early bleeding [18,19]. In the past, ST was also the initial recommendation for managing late bleeding. Although relaparotomy may be considered effective not only for controlling bleeding but also for evaluating the abdominal cavity and addressing other potential complications, postoperative mortality rates of 32.3% to 37% have been reported following relaparotomy [23,24]. Due to its less invasive nature, high success rates, and rapid recovery outcomes compared to ST, IRT has increasingly become the first-line option, particularly in the management of late postoperative bleeding [24,25]. Some authors argue that hemodynamic stability is a prerequisite for performing IRT [26]. However, in a study investigating which type of emergency intervention should be performed, univariate analysis did not identify any significant predictors [27]. In our study, 14 (82.35%) of the 17 patients with early bleeding were treated with ST, while 14 (77.77%) of the 18 patients with late bleeding underwent IRT. Among the four late bleeding patients who received ST, the mortality rate was 75%. These findings are consistent with the literature, which recommends ST for early bleeding and IRT for late bleeding.

In studies examining the outcomes of IRT in the literature, technical success rates have been reported to range between 82% and 100%, rebleeding rates between 7% and 30%, hepatic complications between 12% and 63%, and mortality rates between 7% and 54% [28,29]. In a study evaluating 24 patients who developed POB after gastrectomy and were treated with IRT, the reported outcomes included a technical success rate of 100%, 30-day mortality of 12%, persistent bleeding in 4.16% of cases, rebleeding in 4.16%, and a clinical failure rate of 21% [30]. In contrast, a meta-analysis evaluating 163 cases found no significant differences between IRT and ST in terms of hemostasis, complication rates, or mortality [31]. Due to factors such as the limited number of cases and the emergency nature of the condition, there are no randomized controlled trials directly comparing IRT and ST. In a recent study by Habib et al., it was emphasized that endoscopic treatment of intraluminal bleeding is often unsuccessful due to massive hemorrhage and hemodynamic instability, which may delay the initiation of IRT [24]. The study also highlighted that IRT can achieve high success rates even in cases of intraluminal bleeding. In our study, none of the patients received endoscopic treatment. All six patients who developed POB after gastric surgery were treated with IRT. The technical success rate of IRT was 100%. Rebleeding occurred in 3 patients (17.64%) following IRT, resulting in a clinical failure rate of 17.64% and a clinical success rate of 82.36%. No IRT-related complications or organ failure were observed. Upon analysis of the three rebleeding cases, one was found to originate from the gastroduodenal artery (GDA), while the remaining two originated from the P–J anastomosis. Among the patients treated with IRT, three had P–J anastomotic bleeding, and two of these (66.66%) experienced rebleeding. Based on these findings, surgical treatment may be a more appropriate approach for patients with P–J anastomotic bleeding.

Despite literature suggesting surgical intervention in patients with postoperative complications, 14 of the patients (82.35%) in our study who underwent IRT had postoperative complications. Furthermore, there was no statistically significant difference between the IRT and ST groups in terms of postoperative complication rates (Table 2). Unlike previous reports, our findings demonstrate comparable success rates between the two treatment modalities, even in the presence of complications. Among the 14 patients who underwent ST for early bleeding, complications developed in 6 patients (42.85%) during follow-up, and mortality occurred in 3 patients (21.42%). These results highlight the critical importance of achieving meticulous hemostasis during the initial surgical procedure.

In angiographic treatment, polyvinyl alcohol, glue, or coils are commonly used as embolic agents. When the bleeding vessel can be directly accessed, coils are preferred; for embolization of distal branches that cannot be directly catheterized, glue is typically used [28]. In previous studies, the most commonly reported bleeding vessels include the GDA, CA, CHA, LHA, RHA, SA, SMA, and LGA [32,33]. The risk of hepatic infarction following complete embolization of the CHA has been reported to be as high as 30% [34]. Selective embolization in GDA bleeding aims to preserve hepatic blood flow; however, although technically challenging, it carries a high risk of rebleeding [33]. Therefore, graft placement techniques have been developed to minimize both ischemic complications and the risk of rebleeding. Successful application of this method requires that the bleeding artery be anatomically suitable for graft placement [35]. However, graft-related complications such as infection and thrombosis have been reported. Additionally, antiplatelet therapy is typically recommended following graft placement, but in patients with POB, the necessity of antiplatelet use after treatment remains a matter of debate due to the increased risk of recurrent bleeding [36]. In our study, coil embolization was the most frequently used technique in IRT; however, no cases of organ dysfunction or procedure-related mortality were observed. Additionally, in line with the literature, the most commonly treated bleeding sources were the GDA, branches of the HA, and P–J anastomotic sites.

In our study, among patients who developed mortality, four had undergone pancreatic surgery, four had gastric surgery, two had colorectal surgery, and one had intra-abdominal tumor resection. The mortality rate was 29.41% among patients treated with IRT and 33.33% among those treated with ST. When evaluated according to the timing of bleeding, mortality was 17.65% in the early bleeding group and 44.44% in the late bleeding group. Although this difference was not statistically significant, it was considered clinically relevant. The overall mortality rate was 31.42%, which is consistent with previous literature. The similar mortality rates between ST and IRT suggest that both treatment modalities offer comparable success in managing POB. However, in clinical practice, a higher mortality risk should be anticipated in patients presenting with late bleeding.

In this study, comparison of perioperative characteristics between the two treatment groups revealed that the median RBC transfusion requirement was significantly lower in the ST group (6 vs. 25 units, respectively; $p<0.001$). Regarding the time interval between the index operation and the onset of hemorrhage, the median duration was 1 day in the ST group and 25 days in the IRT group ($p<0.001$). When comparing the length of hospital stay, it was significantly shorter in the ST group (median 15.5 vs. 33 days, respectively; $p=0.008$). These findings suggest that early bleeding is more frequently managed with ST, requires fewer RBC transfusions, and results in shorter hospitalization. The observed differences may be attributed to the fact that patients treated with IRT often had ongoing postoperative, surgery-specific complications, which necessitated prolonged hospitalization and additional blood product support even before the onset of bleeding.

One study reported that CT angiography was diagnostic in only 45% of cases, suggesting that it should not be routinely performed in all patients [24]. In our study, CT angiography was performed in only one patient (5.55%) in the ST group, and this was a late bleeding case on postoperative day nine. In contrast, all patients in the IRT group underwent CT angiography. Based on these findings, it can be concluded that in cases of early bleeding, treatment can often be planned without the need for pre-intervention imaging.

Our study has several limitations. The retrospective design, the use of data from a single center, and the relatively small sample size were among the primary limitations. Additionally, the lack of accessible data regarding sentinel bleeding—an important indicator for the early detection of severe hemorrhage in POB patients—was another major limitation. Moreover, factors such as the type of energy devices used during surgery, variations in perioperative patient management, and the use of minimally invasive techniques are potential variables that may have influenced the study outcomes.

CONCLUSION

Postoperative bleeding following intra-abdominal surgery for malignancy is a life-threatening complication. As in pancreatic surgery, ST for early bleeding and IRT for late bleeding appear to offer acceptable success rates in surgeries involving other abdominal organs as well. However, in cases of bleeding from P–J anastomoses, ST should be prioritized as the first-line treatment. Additionally, in early bleeding, pre-intervention imaging may not be necessary. In conclusion, major abdominal oncologic surgeries should be performed in tertiary centers where IRT is readily available. In the event of POB, treatment decisions should be made on a case-by-case basis through a multidisciplinary approach involving both general surgeons and interventional radiologists.

Author contribution

Study conception and design: HAD, NA, OC, DD, FC, FGE and ABD; data collection: HAD, NA, SK, DD, ST, SEY, OC, FC, FCE and ABD; analysis and interpretation of results: HAD, NA, SK, DD, ST, SEY, OC, FC, FCE and ABD; draft manuscript preparation: HAD, NA, SK, DD, ST, SEY, OC, FC, FCE and ABD. All authors reviewed the results and approved the final version of the manuscript.

Ethical approval

The study was approved by the Hacettepe University, Health Sciences Research Ethics Committee (Protocol no. 2025/05-48/18.02.2025).

Funding

The authors declare that the study received no funding.

Conflict of interest

The authors declare that there is no conflict of interest.

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