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Superselective Embolization for Lower Gastrointestinal Hemorrhage: An Institutional Review Over 7 Years

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Abstract
Introduction Superselective embolization of visceral arterial branches has become integral in the management of acute lower gastrointestinal (GI) hemorrhage. The present study aimed to evaluate the success of superselective embolization as a primary therapeutic modality in the control of lower GI hemorrhage and to identify factors associated with rebleeding and surgical intervention after the procedure.
Methods We performed a retrospective review of all cases of superselective embolization for acute lower GI bleeding during a 7-year period (December 2000–October 2007) in a single 1,300-bed hospital in Singapore. Hemostasis was achieved with microcoils, polyvinyl alcohol particles, gelfoam, or by selective vasopressin infusion. Various clinical and hematologic factors were analyzed against rebleeding and surgical intervention after the procedure.
Results A total of 265 patients underwent mesenteric angiography for GI hemorrhage. Superselective embolization of visceral vessels for lower GI hemorrhage was performed in 32 patients (12%) whose median age was 66 years (range: 34–82 years). The group was of similar gender distribution, and the median follow-up was 8 months (range: 1–32 months). Location was the small bowel in 19% and the colon in 81%. The underlying etiologies included diverticular disease (59%), angiodysplasia (19%), ulcers (19%), and malignancy (3%). In 31 patients (97%) technical success was achieved, with immediate cessation of hemorrhage in every case. Clinical success was achieved in 20 patients (63%), all of whom were discharged well with no further intervention. Seven patients rebled, and 9 underwent surgery: 1 for incomplete hemostasis, 4 for rebleeding, 1 for infarcted bowel postembolization, and 3 on the basis of the surgeon's decision. There were 2 anastomotic leaks; 1 after surgery for postembolization ischemia and 1 after surgery for rebleeding. Overall mortality in this series was 9%. Rebleeding was more likely to occur if the site of bleeding was located in the small bowel compared to the colon (OR: 8.33, 95% CI 1.03–66.67). It was also more likely in patients with a hematocrit level $\leq$20.0% (OR: 7.52, 95% CI: 1.14–50.00) and a platelets level $\leq 140 \times 10^9$/l (OR: 9.35, 95% CI: 1.36–62.5) just before the procedure. Surgical resection was also more likely in patients with a hematocrit level $\leq$20.0% just before embolization (OR: 12.66, 95% CI: 1.96–83.33), and it appeared to be more likely if the underlying cause was diverticular disease (OR 8.70, 95% CI: 0.93–83.33).
Conclusions The use of superselective mesenteric embolization for the treatment of lower GI bleeding is highly successful and relatively safe—97% technical success and 3% postembolization ischemia in our series. In 63% of cases it is definitive without any further intervention. Postembolization ischemia and surgery may be associated with a higher risk of anastomotic leak. Greater vigilance must be adopted in treating patients who have active hemorrhage from the small bowel and in those with a hematocrit $\leq$20.0%.

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Introduction

Lower gastrointestinal (GI) hemorrhage, defined as bleeding distal to the ligament of Treitz, ranges from minor, self-

limited bleeding to life-threatening hemorrhage. Some 10%–15% of patients with life-threatening hemorrhage require invasive interventions to control bleeding either acutely or during the course of the hospitalization [1–3]. Emergency surgery typically results in significant morbidity and even death [4–6]. Colonoscopy is widely adopted as the diagnostic modality of choice in patients with lower GI hemorrhage, but endoscopic therapeutic intervention is successful in only a minority of patients [7–11].

As a result, angiography and embolization of causative vessels was introduced and accepted gradually and has transformed the management of lower GI hemorrhage. In the past 10 years significant improvements in technique have allowed superselective embolization to become a safer procedure, minimizing the risk of intestinal ischemia [12, 13]. It is widely employed in the management of acute lower GI hemorrhage.

To our knowledge, few reports have identified factors associated with rebleeding or surgical intervention in patients after superselective embolization. None were able to draw any significant relationship between the site(s) of bleeding or underlying diagnosis of the initial hemorrhage and the above negative outcomes.

The objective of the present study was to evaluate the technical and clinical success of superselective embolization as a primary therapeutic modality in the control of lower GI hemorrhage. A secondary objective was to identify factors associated with rebleeding and surgical intervention after the procedure.

Methods

Study population

Tan Tock Seng Hospital is a 1,300-bed hospital, the second largest in Singapore, and provides secondary and tertiary medical care for about 2 million people. A review of the records of all patients who presented with GI hemorrhage that underwent mesenteric angiography in our institution from December 2000 to October 2007 was performed. These data were captured in a dedicated database of interventional radiological procedures.

Before October 2006, identification of the site of active lower GI bleeding was achieved through direct cannulation of the visceral branches; superselective embolization could then be performed immediately upon identification of the site of contrast extravasation. The practice has differed since then. Today, computed tomographic (CT)-assisted mesenteric angiography is used in the initial identification of the site of lower active GI bleeding, and if contrast extravasation from visceral branches is seen, a dedicated team of interventional radiologists and radiographers would be activated to perform superselective embolization after re-confirming the presence of active contrast extravasation during direct cannulation of the visceral branches. The materials used for mesenteric embolization in our institution included microcoils, gelfoams, and polyvinyl alcohol particles; selective vasopressin infusion is also used.

Definition of embolization

Successful embolization results in devascularization of a focal lesion or intentional reduction or cessation of blood flow to a target vascular bed or an entire organ. In accordance with the definitions and guidelines for percutaneous transcatheter embolization determined by the Society of Interventional Radiology [14], technical success in the present study was defined as the immediate cessation of hemorrhage evaluated by completion angiography, whereas clinical success was defined by the absence of rebleeding within 30 days of embolization. Rebleeding was defined as a drop in hemoglobin $\geq$1 g/dl in the presence of overt GI hemorrhage within 30 days. An ischemic event was defined as bowel ischemia or infarction that required surgery. A right-sided colonic lesion was defined as pathology arising from the cecum to the distal transverse colon, whereas a left-sided lesion was seen to arise from the splenic flexure distally.

The following data were collected: age, gender, race, comorbid conditions. The latter included cardiac disease, diabetes mellitus, hypertension, end-stage renal disease, and history of cerebrovascular accident. Other significant data included prior history of lower GI hemorrhage or history of GI malignancy. Apart from the presenting symptoms, important hemodynamic parameters such as heart rate (HR) and systolic blood pressure (BP) and laboratory values such as hematocrit (Hct) level, white blood cell (WBC) volume, platelet level, urea and creatinine levels, prothrombin time (PT), and partial thromboplastin time (PTT) were also documented. The hemodynamic parameters, Hct, WBC, and platelet levels of these patients just before superselective embolization was performed were also documented.

The angiographic site of bleeding and the underlying etiologies were also identified. The causes were diagnosed through various means: computed tomography (CT) scans, histological findings of resected specimens, and endoscopic and angiographic findings. The materials used for the embolization were also documented, as were the total amount of red blood cells transfused, the total length of stay (LOS) in the specialized care unit (either the surgical intensive care unit [SICU] or the high dependency unit [HDU]), and the total inpatient stay for each patient.

The outcomes measured included rebleeding and surgical intervention. The various characteristics of the above

two outcomes were tested against normal values by the chi square test; both the odds ratio (OR) and 95% confidence interval (CI) were reported. Analysis of variance (ANOVA) was also performed for some variables, with the mean and p value presented. All analyses were performed with the SPSS 13.0 statistical package (Chicago, IL), and all p values reported are two-sided; p values <0.05 were considered statistically significant.

Results

From December 2000 until October 2007, a total of 265 patients underwent mesenteric angiography for GI hemorrhage at our institution. Superselective embolization of visceral vessels for lower GI hemorrhage was performed in 32 patients (12%) after the presence of a contrast blush was confirmed on angiography. These 32 patients were of similar gender distribution (M:F, 1:1), with a median age of 66 (range: 34–82) years; most were of Chinese ethnicity (91%). The median follow-up was 8 (1–32) months. Eleven patients (34%) had a history of a lower GI bleed, 8 of which were attributed to diverticular disease. Thirteen (41%) patients had three or more of the co-morbidities cited in the above section, with hypertension ($n = 24$, 75%) being the commonest. Three patients (9%) had previous surgery for malignancy. Table 1 illustrates the characteristics of these 32 patients.

Twenty-nine patients (91%) presented with passing fresh blood per rectum while the remaining 3 reported passing bloody or malenic stools. Comparing the hemodynamic parameters on admission and that just before the procedure for these 32 patients, the median heart rate (HR) rose from 81 beats per minute (bpm) (range: 62–124 bpm) to 91 bpm (range: 66–140 bpm), respectively; whereas the median systolic BP dropped from 123 mmHg (55–186 mmHg) to 106 mmHg (55–167 mmHg).

The median Hct dropped from 29.8% (11.9%–39.6%) on admission to 21.1% (10.4%–36.4%) just before embolization. The median platelets level saw a similar drop, from 272×10^9/l (81–565) to 181×10^9/l (80–402), respectively. The median white blood cells level was similar from 11.5×10^9/l (6.2–29.0) to 10.7×10^9/l (4.5–19.5).

Looking at the other laboratory results captured on admission, the median urea level was 7.9 mmol/l (3.2–49.8), median creatinine level was 90 μmol/l (43–656), and the recorded median prothrombin time (PT) and partial thromboplastin time (PTT) were 14.0 s (12.2–31.5) and 32.3 s (20.9–>120), respectively.

The type of embolic material used was at the discretion of the interventional radiologist, and some materials were used in combination. Microcoils were used in isolation in 23 patients (72%), in combination with particles in 3 (9%), or with gelfoam in 1 (3%). Particles were used in isolation in 2 patients (6%), gelfoam in 1 (6%), and vasopressin infusion in the remaining 2 patients (6%). Three patients developed femoral hematomas after withdrawal of the femoral sheath, but no subsequent intervention was required and the hematoma resolved in every case.

Of the 32 patients who underwent superselective embolization, technical success was achieved in 31 (97%), with immediate cessation of hemorrhage. Figure 1 documents the disposition of the 265 patients who underwent angiography and the outcome of the 32 patients who underwent superselective embolization for acute lower GI hemorrhage. The single embolization failure resulted from inability to cannulate the extremely small jejunal branches, so vasopressin infusion was started for the patient and he was promptly brought to the operating theater.

The sites and causes of lower GI hemorrhage are described in Table 2. The location of the bleeding was in

Table 1 Characteristics of the 32 patients who underwent superselective embolization

Characteristic	Results (range)
Median age (years)	66 (34–82)
Median follow-up (months)	8 (1–32)
Race	
Chinese	29 (91%)
Malay	3 (9%)
Gender	
Male	16 (50%)
Female	16 (50%)
Co-morbidities	
Hypertension	24 (75%)
Diabetes mellitus	15 (47%)
Ischemic heart disease	11 (34%)
Cerebrovascular accident	6 (19%)
Renal impairment	5 (15%)
Number of co-morbidities	
0–2 conditions	19 (59%)
3–5 conditions	13 (41%)
History of lower BGIT	
No	21 (68%)
Yes	11 (34%)
	8 diverticular disease
	2 rectal ulcers
	1 upper GI hemorrhage
History of GI malignancy	
No	29 (91%)
Yes	3 (9%)
	1 curative resection (colon)
	2 surgical bypasses (pancreas and stomach)

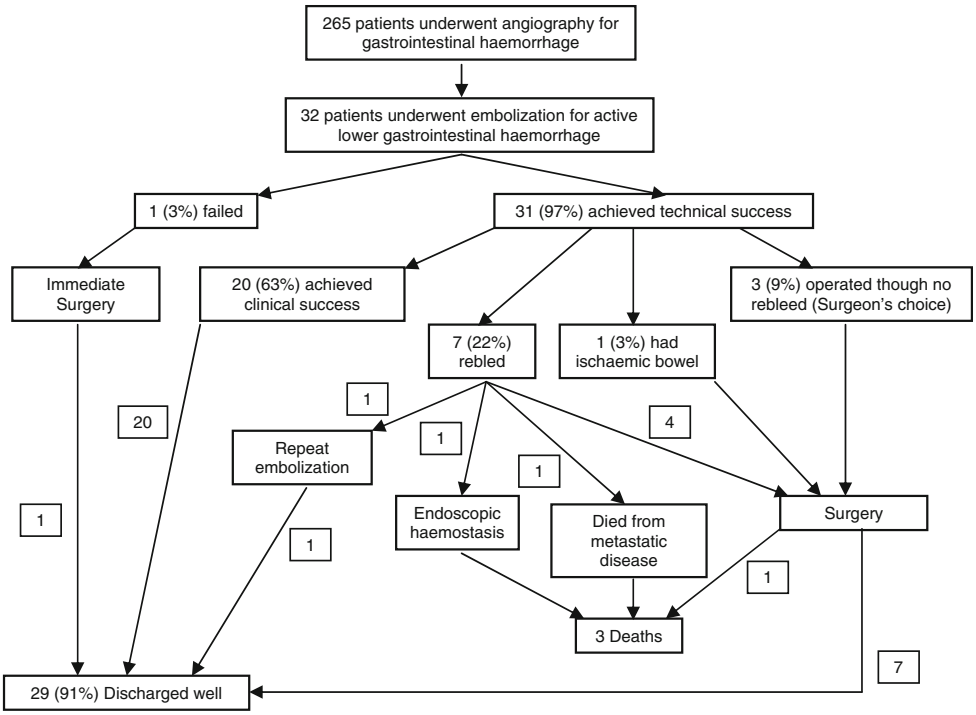

Fig. 1 Outcome of the 265 patients who underwent angiography, and the 32 patients who underwent superselective embolization for lower gastrointestinal hemorrhage

Table 2 Location and etiologies of the lower gastrointestinal (GI) hemorrhage in 32 patients

Location/etiologies	Number of patients	Rebleeding	Surgery
Small bowel	6 (19%)		
Diverticular disease	2	1	1 (failed embolization)
			Small bowel resection
Ulcers	2	2	0
Angiodysplasia	2	0	1 (ischemia)
			Right hemicolectomy
Right-sided colon	19 (59%)		
Diverticular disease	14	4	7 (3 by surgeon's choice)
			5 Right hemicolectomy
			2 Total colectomy
Angiodysplasia	4	0	0
Tumor	1	0	0
Left-sided	7 (22%)		
Diverticular disease	3	0	0
Ulcers	4	0	0
3 solitary rectal ulcer			
1 colonic ulcer			

the small bowel ($n = 6$; 19%), right colon ($n = 19$; 59%), and left colon and the rectum ($n = 7$; 22%). The commonest cause was diverticular disease ($n = 19$; 59%).

Clinical success was achieved in 20 patients (63%), all of whom were all discharged well. Of the remaining 12 patients (37%), 1 underwent immediate operation after unsuccessful embolization, 7 rebled, the primary surgeon elected to operate on 3 patients during the same admission despite the absence of rebleeding, and 1 patient experienced post-embolization ischemia. This patient complained of increasing tenderness in the right iliac fossa on the third day postprocedure. A CT scan showed findings suggestive of ischemic bowel, and the patient underwent immediate operation at which an infarcted bowel was confirmed. Postoperatively, he stayed in the intensive care unit and required inotropes for the treatment of severe septic shock. His prolonged stay in hospital was further complicated by anastomotic breakdown requiring further surgery. Despite all these complications, he was eventually discharged well.

Table 3 Characteristics of patients who rebled after superselective embolization versus those who did not

Characteristic	Patients who did not rebleed	Patients who rebled	Odds ratio (95% confidence interval)
Age group (years)			
≤60	7	4	1.00
>60	17	3	0.31 (0.05–1.75)
Race			
Chinese	22	6	1.00
Malay	2	1	1.83 (0.14–23.82)
Gender			
Male	12	4	1.00
Female	12	3	0.75 (0.14–4.10)
Number of co-morbidities			
0–2 conditions	14	5	1.00
3–5 conditions	10	2	0.56 (0.09–3.49)
History of lower BGIT			
No	14	6	1.00
Yes	10	1	0.23 (0.02–2.25)
History of GI malignancy			
No	23	5	1.00
Yes	1	2	9.2 (0.69–122.4)

BGIT bleeding from the gastrointestinal (GI) tract

For these 32 patients undergoing superselective embolization, the median length of stay (LOS) in the specialized care unit (SICU and HDU) was 4 days (range: 0–80 days) and the median total inpatient stay was 8 days (range: 3–127 days). The mean total amount of red blood cells transfused was 2,985 ml (SD, 1,382 ml).

Rebleeding

Of the 7 patients that rebled, 1 underwent a successful repeat superselective embolization, 4 underwent emergency surgery, and 1 underwent successful colonoscopic adrenaline hemostasis of a bleeding distal ileal ulcer. The seventh patient died from advanced metastatic disease, with the family declining further intervention.

Tables 3 and 4 illustrate the differences in rebleeding after the procedure in the two groups of patients; with or without rebleeding after the embolization. Factors such as age, race, gender, number of co-morbidities, and relevant medical history did not reveal any significant difference. However, a Hct level ≤20.0% (OR: 7.52, 95% CI: 1.14–50.00) and a lowered platelet level ≤140 × 10^9/l (OR: 9.35, 95% CI: 1.36–62.5), as measured just before the procedure, were associated with a significantly higher risk of rebleeding after the procedure. Similarly, a higher risk of

Table 4 Comparison of hemodynamic parameters and laboratory results of patients who rebled after superselective embolization versus those who did not

	Patients who did not rebleed	Patients who rebled	Odds ratio (95% confidence interval)
Heart rate on admission (bpm)			
≤100	19	5	1.00
>100	5	2	1.52 (0.22 – 10.30)
Heart rate just before embolization (bpm)			
≤100	14	5	1.00
>100	10	2	0.56 (0.09 – 3.49)
Systolic BP on admission (mmHg)			
≥90	22	6	1.00
<90	2	1	1.83 (0.14 – 23.81)
Systolic BP just before embolization (mmHg)			
≥90	18	4	1.00
<90	6	3	2.25 (0.39 – 12.99)
Hct on admission (%)			
>30.0	14	1	1.00
≤30.0	10	6	8.40 (0.87 – 83.33)
Hct just before embolization (%)			
>20.0	18	2	1.00
≤20.0	6	5	7.52 (1.14 – 50.00)
WBC on admission (× 10^9/l)			
≤10.0	10	3	1.00
>10.0	14	4	0.95 (0.17 – 5.23)
WBC just before embolization (× 10^9/l)			
≤10.0	12	1	1.00
>10.0	12	6	6.00 (0.62 – 57.68)
Platelets on admission (× 10^9/l)			
>140	22	7	$p > 0.05$
≤140	2	0	
Platelets just before embolization (× 10^9/l)			
>140	21	3	1.00
≤140	3	4	9.35 (1.36 – 62.5)
Urea level on admission (mmol/l)			
≤9.0	17	2	1.00
>9.0	7	5	6.07 (0.94 – 39.05)
Creatinine level on admission (μmol/l)			
≤110	16	3	1.00
>110	8	4	2.67 (0.48 – 14.90)
PT on admission (s)			
≤14.0	12	4	1.00
>14.0	12	3	0.75 (0.14 – 4.10)
PTT on admission (s)			
≤36.0	20	4	1.00
>36.0	4	3	3.75 (0.59 – 23.66)

bpm beats per minute; *Hct* hematocrit; *WBC* whole blood count; *PT* prothrombin time; *PTT* partial thromboplastin time

Table 5 Comparing the materials used and the causes and sites of the bleeding among patients who rebled after superselective embolization versus those who did not

	Patients who did not rebleed	Patients who rebled	Odds ratio (95% confidence interval)
Materials used for embolization			
Coils only	18	5	1.00
Other materials	6	2	1.20 (0.18 – 7.88)
Cause of bleeding			
Other diagnoses	12	5	1.00
Diverticular disease	12	2	2.11 (0.34 – 13.16)
Site of bleeding			
Large bowel	22	4	1.00
Small bowel	2	3	8.33 (1.03 – 66.67)

rebleeding was seen in the group of patients with a Hct level ≤30.0% on admission (OR: 8.40, 95% CI: 0.87–83.33) and a higher urea level >9.0 mmol/l, (OR: 6.07, 95% CI: 0.94–39.05), although these were not statistically significant.

Rebleeding was more likely if the site of bleeding was located in the small bowel, as compared to the colon and rectum (OR: 8.33, 95% CI 1.03–66.67), but the underlying diagnosis was not related to rebleeding (Table 5). There was no significant difference in the LOS between the 2 groups of patients. And not surprisingly, the group of patients that rebled consumed more red blood cells (4,050 ml versus 2,626 ml; $p = 0.011$).

Surgical resection

Nine patients (28%) underwent surgical resection during their admissions: 4 for rebleeding, 1 for incomplete hemostasis, 1 for infarcted bowel postembolization, and 3 by surgeon's choice. The surgeries performed included 6 right hemicolectomies, 2 total colectomies, and 1 small bowel resection (Table 2).

As illustrated in Table 6, the characteristics and background medical history of the patients did not reveal any significant relationship with the outcome of surgical resection. However, a Hct level ≤20.0% was associated with surgical resection (OR: 12.66, 95% CI: 1.96–83.33; Table 7). Furthermore, patients with diverticular disease were also more likely than those with all other etiologies combined to undergo surgical resection (OR: 8.70, 95% 0.93–83.33), but the location of the bleeding was not related to the need for surgery (Table 8). Not surprisingly, the group of patients who underwent surgery stayed longer

Table 6 Characteristics of patients who underwent surgery after superselective embolization versus those who did not

	Patients who did not undergo surgery	Patients who underwent surgery	Odds ratio (95% confidence interval)
Age group (years)			
≤60	7	4	1.00
>60	16	5	0.55 (0.11–2.67)
Race			
Chinese	20	9	N.A. ($p > 0.05$)
Malay	3	0	
Gender			
Male	11	5	1.00
Female	12	4	0.73 (0.16–3.45)
Number of co-morbidities			
0–2 conditions	12	7	1.00
3–5 conditions	11	2	0.31 (0.05–1.83)
History of lower BGIT			
No	15	6	1.00
Yes	8	3	0.94 (0.18–4.79)
History of GI malignancy			
No	20	9	N.A. ($p > 0.05$)
Yes	3	0	

N.A. not applicable

in the hospital (OR: 6.56, 95% CI: 1.10–39.32) but not in the specialized care unit, and they too consumed more red blood cells (4,044 ml versus 2,591 ml; $p = 0.005$).

Mortality

In our series, 3 patients (9%) eventually died: 1 from metastatic disease, 1 from severe pneumonia, and 1 as a direct result of lower GI tract bleeding. The latter patient underwent superselective embolization for bleeding cecal diverticular disease, and when rebleeding occurred after the procedure, a right hemicolectomy was performed. Unfortunately, this was complicated by an anastomotic leak from ischemic segments. After reoperation, the patient's course was further complicated by wound dehiscence; he deteriorated further and eventually succumbed to severe septicemia and end-stage renal failure.

Follow-up

During the follow-up period, 13% of patients ($n = 4$) experienced a repeat lower GI hemorrhage 30 days or more after the procedure. Three had been diagnosed previously as having diverticular disease, 2 involving the right side and 1 with left-sided disease. The latter patient had

Table 7 Comparison of the hemodynamic parameters and laboratory results of patients who underwent surgery after superselective embolization versus those who did not

	Patients who did not undergo surgery	Patients who underwent surgery	Odds ratio (95% confidence interval)
Heart rate on admission (bpm)			
≤100	17	8	1.00
>100	6	1	0.35 (0.04–3.46)
Heart rate just before embolization (bpm)			
≤100	13	6	1.00
>100	10	3	0.56 (0.09–3.49)
Systolic blood pressure on admission (mmHg)			
≥90	21	8	1.00
<90	2	1	1.31 (0.10–16.67)
Systolic blood pressure just before embolization (mmHg)			
≥90	6	3	1.00
<90	17	6	1.42 (0.27–7.52)
Hct on admission (%)			
>30.0	12	4	1.00
≤30.0	11	5	1.36 (0.29–6.41)
Hct just before embolization (%)			
>20.0	18	2	1.00
≤20.0	5	7	12.66 (1.96–83.33)
WBC on admission ($\times 10^9$/l)			
≤10.0	10	3	1.00
>10.0	13	6	1.54 (0.31–7.72)
WBC just before embolization ($\times 10^9$/l)			
≤10.0	10	4	1.00
>10.0	13	5	0.96 (0.20–4.54)
Platelets on admission ($\times 10^9$/l)			
>140	22	8	1.00
≤140	1	1	2.75 (0.15–50.00)
Platelets just before embolization ($\times 10^9$/l)			
>140	19	5	1.00
≤140	4	4	3.80 (0.69–20.83)
Urea level on admission (mmol/l)			
≤9.0	14	6	1.00
>9.1	9	3	0.78 (0.15–3.93)
Creatinine level on admission (μmol/l)			
≤110	13	7	1.00
>110	10	2	0.37 (0.06–2.19)
PT on admission (s)			
≤14.0	11	5	1.00
>14.0	12	4	0.73 (0.16–3.45)
PTT on admission (s)			
≤36.0	17	8	1.00
>36.0	6	1	0.35 (0.04–3.46)

angiodysplasia involving the terminal ileum. The bleeding episodes in all of these patients resolved spontaneously and did not require any further intervention.

Table 8 Comparing of the material used and the causes and sites of the bleeding among patients who underwent surgery after superselective embolization versus those who did not

	Patients who did not undergo surgery	Patients who underwent surgery	Odds ratio (95% confidence interval)
Materials used for embolization			
Coils only	16	7	1.00
Other materials	7	2	0.65 (0.11–3.97)
Cause of bleeding			
Other diagnoses	12	1	1.00
Diverticular disease	11	8	8.70 (0.93–83.33)
Site of bleeding			
Large bowel	19	7	1.00
Small bowel	4	2	1.36 (0.20–9.09)

Discussion

Our series of 32 patients comprises one of the largest in the literature evaluating the role of superselective embolization with the intention to treat lower GI bleeding. The effectiveness and safety of superselective embolization have been well documented in the literature, with the main complications of bowel ischemia and rebleeding often mentioned. The present study, with a technical success rate of 97%, concurred with several other reports in the literature citing technical success of over 90% [15–18], and these procedures were carried out with minimal local complications. Only 3 of our patients had groin hematomas after the removal of the femoral sheath, and all resolved spontaneously without intervention.

The risk of ischemia has decreased with better embolization techniques, with only 1 patient (3%) in our series suffering from ischemic complications that required immediate surgical intervention but resulted in an anastomotic leak. Another patient also had an anastomotic leak after operation for rebleeding, giving a leak rate of 22% (2/9) for patients undergoing operation.

The incidence of ischemic events can be expected to decrease further with better techniques and technology, but the risk will be ever-present, and must be accepted considering the alternatives. However, as shown in our series and others, although the risk of ischemic complication is low, it carries a high risk of morbidity, with several reports highlighting a higher risk of anastomotic leak in patients with primary anastomosis done initially for ischemic or infarcted bowel [16–18]. In addition, the reported mortality among the patients who suffered postembolization ischemia was higher [16–20]. Perhaps it would be prudent not to perform primary anastomosis in patients with complications

after mesenteric embolization because vascularity of the remaining bowel is questionable. This consideration can only be determined by future larger studies.

Rebleeding is the other major complication of superselective embolization, and the rate has been reported to be as high as 33% [16–20]. The underlying diagnosis could play a significant role. Though our study concurred with the literature that angiodysplasias are more common in the right colon [21–23], we did not find that they were more likely to rebleed after embolization. Instead, we found that bleeding from small bowel pathology was associated with an increased rebleeding rate, as compared to colorectal lesions. This could be explained by the excellent but extremely narrow vascular arcades in the small bowel. This bleeding is made worse with patients in shock from acute bleeding and thus likely accounted for the only case of technical failure in our series. We therefore postulate that the rich vascular anatomy of the small bowel, more than the underlying pathologies, may be more important in determining success with embolization. In addition, small bowel lesions are harder to evaluate and treat endoscopically, and the expertise required for small bowel evaluation is still suboptimal compared to the skills developed for evaluating the colon.

Our series also highlighted the finding that some factors are present that could perhaps predict rebleeding after the procedure. These included a Hct level $\leq$30.0% and a urea level >9.0 mmol/l on admission, as well as a Hct level $\leq$20.0% and platelets levels $\leq 140 \times 10^9$/l just prior to embolization. We postulate that the results may simply indicate that a more severe initial bleed is associated with an increased risk of rebleeding, for which the underlying mechanism is unclear. The role of serum urea in upper gastrointestinal hemorrhage has been explored extensively [24, 25], but no data have yet been reported that reflect the role of urea in superselective embolization, something perhaps worth exploring in future larger studies.

All the factors reported here led us to recommend a higher degree of vigilance in dealing with patients with low Hct and platelet levels together with small bowel pathology in conjunction with acute lower GI hemorrhage. Early surgical resection should be considered in these instances.

There is a disparity between rebleeding and subsequent surgery in our series because not all patients with rebleeding were deemed to require surgery. One third of the surgeries performed in our series were due to surgeons' choices in the absence of rebleeding. In each case, rebleeding occurred in a patient with right-sided colonic diverticular disease.

The incidence of right-sided diverticular disease is higher among Asians than people of other race/ethnicity, and it is also more common than left-sided disease as compared to Western populations [26–28]. In addition, local published reports demonstrated that right-sided diverticular disease tended to present more often with massive bleeding that was often severe and required surgical intervention [29–31]. This local knowledge could have influenced our surgeons to opt for earlier surgical intervention in the treatment of right-sided colonic diverticular disease to prevent future episodes of life-threatening hemorrhage. Another important consideration is the lower morbidity associated with an emergency right hemicolectomy as compared to any emergency surgery for left-sided diverticular disease [31–33]. All of the above factors could have resulted in a significant proportion of our patients undergoing surgical resection.

As with most studies, there were several limitations in the present one. This series of patients was enrolled from a single institution and the data were reviewed retrospectively. The small number of patients may also mask several other important factors that could be accountable for the outcomes measured. Surgeon bias and inconsistent institution guidelines in managing patients with this condition would also be significant in determining the various outcomes. Although these limitations are significant, this study remains important in looking at the effectiveness and safety of superselective embolization in the definitive management in lower GI bleeding. It has also identified various factors that could help predict patients who have a higher risk for rebleeding that requires surgical intervention, and maybe even the type of surgery to be performed. As technology to localize acute lower GI hemorrhage continues to improve, and as additional diagnostic and therapeutic algorithms are being developed, prospective analysis documenting their effect would be vital and imperative.

Conclusions

Superselective embolization is a relatively safe and highly successful procedure in patients with significant lower GI hemorrhage. Ischemic complications are uncommon but carry a high risk of morbidity. A higher level of vigilance must be adopted in patients with active hemorrhage from the small bowel, as well as in patients with an Hct $\leq$20.0%.

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