World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Efficacy of angioembolization in lower gastrointestinal bleeds and analysis of associated complications: A retrospective study at an Australian Tertiary Hospital

Ali Mohtashami [1, 2, *], Jonathan Hew [1, 2], Krishna Kotecha [1], James Foote [1], Winnie Hsu [1] and Kah Hoong Chang [1, 2]

[1] *Department of Colorectal Surgery, Royal North Shore Hospital, Sydney, NSW, Australia.*
[2] *Faculty of Medicine and Health, University of Sydney, NSW, Australia.*

World Journal of Advanced Research and Reviews, 2025, 25(03), 1389-1398

Publication history: Received on 08 February 2025; revised on 16 March 2025; accepted on 19 March 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.25.3.0840

Abstract

Purpose: The management of lower gastrointestinal bleeding (LGIB) varies between institutions. Mesenteric embolization, first introduced in 1965, is less invasive than surgery, has more significant bleeding localization than colonoscopy, and thus has become a standard mode of minimally invasive treatment for patients with LGIB. Early catheter design and initial embolic materials, including autologous clot and gelatin sponge, were limited by high rates of bowel ischemia. Still, the development of microcatheter technology and super-selective embolization has reduced the incidence of bowel infarction and bleeding from adjacent collaterals. This study explores the data from a single center, aiming to prove that angioembolisation is efficacious as first-line management in the setting of LGIB.

Methods: 95 patients who underwent angioembolisation for LGIB were retrospectively analyzed amongst a cohort of 526 patients with a positive CT angiogram. Qualitative and quantitative data were collected. Summative data analysis was performed, including frequencies of binary variables and mean, median, range, and standard deviation of continuous variables. A comparison of quantitative variables was performed using the paired t-test. Potential predictive factors for embolization from patients with a positive CTA were initially assessed using univariable analysis, and then p-values less than 0.1 were included as part of multivariable analysis.

Results: Of the total 95 embolizations, 93 were technically successful, resulting in cessation of bleeding. The most used material for embolization was microcoils alone and a combination of microcoils and gelfoam. 19 patients rebled within 72 hours of embolization, of whom 16 were managed conservatively or with medical management. There were a total of 6 minor complications and 9 significant complications, of which a total of 3 required surgery, and 2 died. Multivariate logistic regression was performed to assess predictors of embolization amongst patients who underwent CTA for LGIB. Patients with a history of previous LGIB are more likely to undergo embolization compared to patients without a history of previous LGIB.

Conclusion: Transcatheter arterial embolization is an effective first-line means of managing LGIB, with a technical success rate and complication rate comparable to therapeutic colonoscopy. However, further randomized data are needed to compare various therapeutic methods

Keywords: Lower Gastrointestinal bleeding; Angioembolization; Colorectal Surgery; CTMA; Diverticular bleed

1. Introduction

Risk stratification of patients presenting with LGIB is vital. Conservative management of stable, minor LGIB allows for the allocation of resources to resuscitation and stabilization of unstable patients with significant bleeds. Although

* Corresponding author: Ali Mohtashami

colonoscopy can directly visualize bleeding lesions, this can be technically challenging in active bleeding and an emergently prepared colon. Colonoscopy identified a source of bleeding in only 13% to 40% of cases in some series (1). The use of diagnostic colonoscopy in acute LGIB has numerous drawbacks, and the same guideline recommends that computed tomography angiography (CTA) be performed as the fastest and least invasive means of bleeding localization. CTA has a reported sensitivity of 90% and a specificity of 92% (2), capable of detecting bleed rates as low as 0.3-1.0ml/min (3). Access to modern imaging technology allows all hospitals with available CT imaging capabilities to perform CTA. CT images have high density and spatial resolution and help plan management strategies, such as endoscopic hemostasis, radiological intervention, or surgery. Patients with severe contrast allergy, those at risk of contrast nephropathy (4), and with underlying conditions (e.g., patients taking metformin, those with pheochromocytoma, thyroid disease, or sickle cell disease) (5) may be precluded from an optimal contrast study.

Mesenteric embolization, first introduced in 1965, is less invasive than surgery, has more significant bleeding localization than colonoscopy (6), and thus has become a standard mode of minimally invasive treatment for patients with LGIB. Early catheter design and initial embolic materials, including autologous clot and gelatin sponge, were limited by high rates of bowel ischemia (7,8). Still, the development of microcatheter technology and super-selective embolization has reduced both the incidence of bowel infarction and bleeding from adjacent collaterals (9)

Royal North Shore Hospital (RNSH) is a tertiary referral center in Sydney, Australia, with 24/7 interventional radiology, endoscopy, and operational capability. At RNSH, CTA is the favored method for investigating patients presenting with LGIB. Patients with a positive blush who are hemodynamically unstable are initially managed with angiography and transcatheter embolization followed by escalation to endoscopy or surgery failing this. This study analyses the presenting features and outcomes of 526 CTAs performed at RNSH between 2012 and 2020. This study aimed to identify clinical variables that predict a positive CTA result, identify criteria for triage and indication for CTA in patients presenting with LGIB, and explore the efficacy and complications of angioembolization following a positive CTA for LGIB.

2. Material and methods

This retrospective cohort study was performed at a single tertiary hospital in Sydney, Australia. Ethics approval was submitted in March 2020 via modification of an existing protocol (NSLHD Ref: 2019/ETH08162), which analyses patients presenting to our center with hematochezia. All patients who had a CTA for LGIB between January 2012 and May 2020 were initially reviewed, and the following definitions were applied;

LGIB is defined as bleeding distal to the ligament of Treitz. Patients were excluded if a) the bleeding point was proximal to the ligament of Treitz, e.g., bleeding from duodenal ulcers, or b) the CTA was not performed to investigate LGIB.

The following scoring tools for LGIB were evaluated as indicators of hemodynamic stability. The modified shock index (MSI) is HR divided by mean arterial pressure (MAP). An MSI < 0.7 or > 1.3 strongly predicts death at presentation to an emergency department. The Oakland score aims to identify patients at low risk of experiencing adverse outcomes from LGIB and avoid hospitalization. (10). The Oakland score was calculated from seven inputs, age, sex, previous hospital admission with LGIB, digital rectal examination results, heart rate, systolic blood pressure, and hemoglobin concentration, to calculate a maximum score of 35 points. A score ≤ 8 indicates low risk and identifies a safe patient for outpatient management. (10).

2.1. CT procedure technique

Patients underwent supine craniocaudal scanning by multi-detector row CT while breath holding. Preliminary unenhanced scans display pre-existing hyper-attenuated material in the bowel lumen as a comparative measurement against the suspected region of active bleeding location. After this, 100ml of iodine-containing contrast was injected intravenously at 2-3ml/sec via an automatic injector, followed by a normal saline flush of 50ml. Images are acquired at a 0.5mm section width and 5-7mm reconstruction interval. Images from equilibrium-phase scanning performed 90 seconds after the start of contrast material injection are then analyzed for bleeding detection. Diagnostic features of a positive CTA bleed or blush include focal or circumferential bowel wall densities, contrast material in the bowel lumen greater than 90 Hounsfield units, or increased density of bowel content. Venous phase imaging is then performed to detect missed bleeding during the arterial phase.

2.2. Statistical analysis

Statistical analysis was performed using RStudio software (Vienna, Austria). Firstly, summative data analysis was performed. Binary variable frequency was calculated, and continuous variables' mean, median, range, and standard

deviation were assessed. A comparison of quantitative variables (if normal distribution) was performed using the paired t-test. The paired-Z test was used for categorical data. Potential predictive factors for blush, embolization, and rebleeding were initially assessed using univariable analysis, and then p values <0.1 were included as part of the multivariable analysis. Logistic regression was used for multivariate analysis, where the outcome was binary, and least squares regression (OLS) was used for multivariate regression analysis, where the result was continuous.

3. Results

3.1. Predictors of positive CTA

The location of the bleeding point identified on CTA is summarized in Table 1. There is no association between gender and positive CTA, with 0.38 of males in our study having positive CTA vs 0.32 of females (z = 1.2, p = 0.10). There is evidence that patients transferred to our facility are more likely to have positive CTA findings (0.42 of transferred vs 0.34 of non-transferred, z = -1.66, p = 0.04). There is solid evidence that those presenting with visible LGIB will have positive CTA findings (0.38 of visible LGIB have positive CTA findings vs 0.08 of those who do not, z = -3.72, p < 0.01). Table 2 summarizes the correlation between existing comorbidities and positive findings on CTA.

Patients on antiplatelet agents are more likely to have positive CTA results (0.40 of those on antiplatelets vs. 0.33 of those not, z = -1.81, p = 0.03), as are patients with a positive initial digital rectal examination (0.38 of patients with a positive exam vs. 0.22 of those with the negative exam, z = -2.0, p = 0.02)

There is no evidence that patients with deranged shock index (0.73 in patients with positive CTA vs. 0.74 in patients with negative CTA, p = 0.53) or with higher modified shock index (1.01 in patients with positive CTA vs. 1.02 in patients with negative CTA, p = 0.63) will have a positive CTA. There is no evidence of reduced hemoglobin concentration in patients with positive CTA vs. negative CTA findings (103.0 g/L in patients with positive CTA vs 101.4 g/L in patients with negative CTA p = 0.23). There is no evidence that patients with positive CTA findings had deranged INR levels (1.27 in patients with positive CTA vs 1.32 in negative CTA, p = 0.79). There is strong evidence that patients with positive CTA results have higher transfusion requirements for pRBCs (3.3 units transfused in patients with positive CTA vs. 2.4 units in patients with negative CTA, p < 0.01), FFP (0.48 units vs 0.31 units, p = 0.04) and platelets (mean 0.26 vs 0.12 units, p < 0.01).

Multivariate logistic regression was then performed to assess for predictors of positive CTA. A total of 12 variables (p <0.1, or if clinically relevant) were included: patient transfer status, receiving antiplatelets, pRBCs or FFP on admission, history of use of clexane, warfarin, NSAID or DOAC, visible LGIB on admission, history of previous LGIB or ischemic heart disease and Oakland score on admission.

Patients presenting with visible LGIB are 8.65 times (95% CI 1.93 – 38.67 times) more likely (p <0.01) to have a positive CTA result than patients who do not have visible LGIB. Patients who have a history of NSAID use are 0.31 times more likely (95% CI 0.10 – 0.89 times; or 0.69 times less likely, p <0.01) to present with a positive CTA result than patients who do not have a history of NSAID use. Patients who have been transfused pRBCs on admission are 1.17 times (95% CI 1.07 – 1.27 times, p 0.03) more likely to have a positive CTA result than those patients who are not transfused pRBCs Predictors of arterial embolization outcomes

95 patients underwent radiologic embolization, with the materials used summarized in Table 3. There were 6 minor and 9 significant complications, of which 3 required surgery, and 2 were palliated. 30 patients rebled following embolization, with the time of bleeding summarized in Table 3. 1 patient had minor ischemia, managed conservatively, and observed on repeat colonoscopy. Five patients had significant ischemia. Four of these required bowel resection, and one patient was palliated after opting out of surgery.

There is no evidence that patients who undergo embolization have longer lengths of stay (13.0 days vs 10.5 days in patients who do not undergo embolization, p = 0.11), deranged SI on arrival (0.77 vs. 0.73, p = 0.13), or MSI on arrival (1.04 vs. 1.03 p = 0.38), lower Hb on arrival (101.01 vs. 105.67 p = 0.89), or higher INR on arrival (1.26 vs. 1.27). There was no evidence of the time difference to CTA in patients who had undergone embolization (484 minutes vs. 375 minutes, p = 0.15). Patients who undergo embolization have increased transfusion requirements of pRBCs (mean 4 units vs. 2.77 units, p < 0.01), FFP (mean 0.73 units vs. 0.33 units, p < 0.01), platelets (mean 0.38 vs. 0.14 units, p < 0.01).

Multivariate logistic regression was performed to assess predictors of embolization amongst patients who underwent CTA for LGIB. Based on clinical relevance and p <0.1 on univariate analysis, 12 variables were included: transfer status,

modified shock index on presentation, transfusion of pRBCs, FFP, platelets, and cryoprecipitate, syncope on presentation, history of previous LGIB, hypertension, heart disease, cardiac surgery, and history of NSAID use.

Patients with a history of previous LGIB are 0.43 times (95% CI 0.22 – 0.87 times, p = 0.02) more likely to undergo embolization than patients without a previous LGIB history. That is, these patients are 57% less likely to undergo embolization. Patients who undergo platelet transfusion on admission are 3.21 times (95% CI 1.51 – 6.83 times, p <0.01) more likely to undergo embolization than patients who do not receive platelet transfusion. There is no evidence that older patients will rebleed after embolization when compared to younger patients (p >0.05). There is strong evidence that patients who rebleed within 24 hours after embolization have a higher shock index on admission (0.86 vs. 0.74, t = -1.85, p = 0.03), but not for patients rebleeding at 48 and 72 hours, and 7, 14 and 30 days (all p>0.05). There is also evidence that patients who rebleed at 24 hours have increased APTT (35.60s vs. 29.17s, t = -2.0, p = 0.02) on presentation and require administration of anticoagulation reversal agents (0.34 vs. 0.1, z = -3.2, p <0.01). Those managed conservatively after CTA are also more likely to rebleed at 24 hours (0.21 vs 0.08. z = -1.77, p = 0.03).

Administration of anticoagulation reversal agents on presentation was also a risk factor for rebleeding between 24 and 48 hours post-embolization. There is evidence that these patients have an increased FFP (1.11 units vs. 0.43 units, z = -1.74, p = 0.05) and cryoprecipitate (2.83 units vs. 0.65 units, z = -1.95, p = 0.03) transfusion requirement on admission.

Patients who rebleed between 48 and 72 hours (86.7g/L vs. 100.2 g/L, p = 0.03), 3 to 7 days (78.735 vs. 100.17 g/L, p = 0.01), and 7 to 14 days (77.1g/L vs. 100.2g/L, p = 0.01) post embolization are more likely to have a lower hemoglobin concentration initially. Those who rebleed at 72 hours are likely to have higher INR on presentation (1.6 vs 1.2, p = 0.02).

Evidence shows that patients with significant ischemia post-embolization have raised modified shock index on admission (mean MSI 1.2 vs. 1.0, p = 0.02).

Multivariate logistic regression was performed to assess for risk factors predicting rebleed within 24 hours of embolization. Based on clinical relevance and p <0.1 on univariate analysis, 8 dependent variables were included: Hb, INR, and APTT on presentation, administration of anticoagulation reversal agents, pRBCs, and cryoprecipitate transfused. Only patients who require cryoprecipitate transfusion before admission are 1.32 times more likely to rebleed within 24 hours post embolization (95% CI 1.04 – 1.67 times, p = 0.02), with no other statistically significant predictor of early rebleed.

4. Discussion

The management of LGIB has changed radically since the introduction of mesenteric angiography and embolization technology. However, adopting the technology is not universal and may depend on local preferences and diagnostic and treatment options availability. Due to 24/7 interventional radiology availability in our center, mesenteric embolization is favored in managing LGIB.

An essential difference between angioembolization and colonoscopic LGIB management is post-procedural intestinal ischemia. The relative lack of collateral vessels below the ligament of Treitz renders this part of the bowel more susceptible to ischemic insult after angioembolization. In our data, there were 6 patients in whom ischemia was reported, 1 of which was minor (mucosal) ischemia, which resolved with conservative management, and 5 patients with major transmural ischemia, requiring surgical intervention in 4 patients, and palliation for 1 patient. Earlier studies reporting angioembolization of LGIB favored large catheters and limited embolic agents, e.g., autologous clot and gelatin sponge. The more recent studies reflect a technology change, with a move to effective embolic agents such as micro coils, particles, polyvinyl alcohol particles, gel foam, and N-butyl 2- cyanoacrylate glue (NBCA), all resulting in lower complication rates. Technical failure is most commonly due to vasospasm and abnormal anatomy (tortuosity, atheroma, or stenosis) (11). Microcoils were our data's most frequently used embolic agent in our center. They are radiopaque, easy to visualize under fluoroscopy (therefore, relatively easy to position), and have a wide range of coil diameters, facilitating use in many vessels. (12) Comparatively, the position of other agents, such as gel foam or particles, cannot be controlled or monitored and is, therefore, more likely to lead to mucosal infarction (13).

Micro coils are difficult to use in narrow or tortuous vessels, and they are permanent and may preclude re-access to the same vessel in the future. Coils are also associated with rebleeding in coagulopathic patients (13). By comparison, NBCA, a liquid embolic agent, was explored by Frodsham et al. (14) as an alternative agent, along with Onyx®. A systematic review by Loffroy et al. (15) concludes that all of the above agents have advantages and disadvantages and that careful

selection of embolic agents according to the clinical situation may influence the outcome. A randomized trial exploring this would yield clinically valuable data.

There has also been a change in technique over time, focusing on identifying a specific target for an embolization on CTA. This enables interventional radiologists to concentrate on imaging more distal arterioles near the known bleeding site. This allows imaging of lower-order vessels, thus reducing contrast dose and fluoroscopy time. Consequent super-selective embolization involving three or fewer feeder arteries for LGIB was reported to be relatively tolerable with silent or self-limiting complications (16) and reduced mortality (an ischemia rate in our study of 6.3%) with morbidity compared to blind segmental colectomy (up to 60% mortality, and rebleeding of up to 75%) (6). Selective catheter embolization aims to target the vessel as close as possible to the site of bleeding, preferably the vasa recta, to minimize the risk of bowel ischemia. Super selective embolization of the bleeding vas rectum limits the potentially ischemic mucosal surface, as the given mucosa will be supplied by adjacent vasa recta. This method has developed so ischemia may be overrepresented in earlier case series. Kwon et al. (17) found that their significant complication rate was significantly lower in the group that received super-selective embolization (OR 0.087, $p < 0.001$), and Tan et al. (16) reported ischemia in 3% of embolization between 2000-2007. This compares well to our ischemia rate of 6.7%. There is limited data across other studies to compare less selective and super selective embolization, and randomized data is unlikely to become available.

Rectal bleeding may be fed by an end arterial branch of the internal iliac artery, stressing the need for angiographic exploration in LGIB of the superior and inferior mesenteric artery tributaries and potentially those of the bilateral internal iliac arteries. While LGIB has been traditionally defined as bleeding distal

to the Ligament of Treitz, some more extensive studies preferred to differentiate LGIB between the small & large intestines rather than supplying vascular territories (18). This is in keeping with the idea that bleeding from the small intestine is distinct from colonic bleeding regarding clinical presentation, management & outcomes (19, 20). However, Chen et al. (21) dispute that there were no statistically significant differences in the prediction of treatment failure when assessing the etiology or location of LGIB. It is, instead, the number of supplying arteries (>1) & the distance between the catheter tip & the bleeding vessel at the time of embolization (>5cm) that were statistically significant predictors of treatment failure.

Factors influencing the rebleeding rate after embolization must also be corrected. Hongasakul et al. (22) found that hemoglobin concentration and coagulopathy influenced rebleeding. Coagulopathy was shown to negatively affect the clinical success rate, with an increase in the OR to 19.5 for rebleeding accounting for the clinical failures. These factors should thus be corrected as early as possible before the procedure. In our data, we established an increased risk of rebleeding associated with systemic factors on presentation, such as shock index, APTT on presentation, administration of anticoagulation reversal agents, and INR.

Limitations

Unfortunately, reporting diagnostic accuracy, sensitivity, and specificity was not possible in this study as per the STARD (23) guidelines due to a lack of granular data. Although many CTAs were reported as positive or negative, they often lacked a reference standard – the majority of negative CTAs were managed conservatively, with cause and location of bleed not determined, and many of those patients underwent outpatient investigation in a variety of locations, of which data was not available within our medical record. Retrospective study design and a relatively small sample size are limitations, and a larger number of patients, particularly in subgroups, would lend greater power to the statistical analysis. Further subgroup analysis of patients presenting with Oakland score <10 undergoing CTA is warranted. The outcomes of these patients, deemed safe for discharge, would add to the volume of validation data surrounding using the score.

Additionally, the usefulness of deranged SI and MSI in subgroup analysis would lend more credibility to using these indices as predictors of embolization.

In our series, only 8 cases of 526 total CTAs were diagnosed as angiodysplasia, arteriovenous malformation, or other vascular pathology, which is likely an underrepresentation of the actual occurrence in the population. Angiodysplasia occurs due to increased muscularis propria contractility, likely secondary to increased bowel transit time. Chronic obstruction of submucosal vessels results in congestion of venous capillaries and failure of valves. This stimulates angiogenesis and the formation of luminal collaterals, which are more likely to bleed. Sami et al. (24) also found 54 – 81% of angiodysplasia lesions in the caecum and ascending colon. This supports our data on SMA distribution, with the right colon being the most common site of bleeding despite the diverticular disease being most prevalent in the left

colon. Multiple studies (25, 26, 27) recognized that non-bleeding vascular lesions, such as arterio-venous malformations and angiodysplasia, accounted for most negative CTA examinations. Kennedy et al. (27) found that all four patients with AVM or angiodysplasia had a transfusion requirement of at least 4 units of pRBCs with multimodal intervention. Although intermittent hemorrhage without active blush would decrease the visibility of vascular malformations, the inability of CTA to detect AVM and angiodysplasia can be viewed as a potential shortcoming.

Table 1 Location of bleeding point on CTA

Vascular territory of bleed	**N = 192**
Coeliac axis	14
Superior mesenteric artery	95
Inferior mesenteric artery	77
Internal iliac artery	6
Anatomical location of bleed	**N = 192**
Small bowel	47
Right colon and	50
caecum Hepatic	21
flexure Transverse	11
colon Splenic flexure	8
Descending colon	24
Sigmoid	53
Rectum	24
Anal canal	2
Entire colon	1

Table 2 Comorbidities and positive CTA

Past Medical History	**Proportion with positive CTA**	**Proportion without medical history with positive CTA**	**Z**	**p**
Previous LGIB	0.42	0.33	-2.17	0.02
Hypertension	0.40	0.33	-1.79	0.04
Ischaemic Heart disease	0.45	0.33	-2.66	<0.01
CABG/Valvular surgery	0.46	0.36	-1.47	0.07
Stroke/TIA	0.38	0.36	-0.36	0.36
Diabetes	0.46	0.34	-2.29	0.01
Colonic cancer	0.36	0.37	0.01	0.50

Table 3 Arterial embolization data

Category	**Frequency (%)**
Embolised	95

Material used	
Coils	26
Gelatin	0
sponge	8
Particles	5
Gelfoam	0
Onyx	1
Glue	0
NBCA	11
Pharmacological/physiological vasospasm	20
Combination	20
Coils and gelfoam	2
Coils and particles	1
Coils, particles and gelfoam	1
Coils, gelatin sponge, gelfoam	4
Particles and gelfoam	35
Outcomes	132
Technical failures	93
Negative study (to identify bleeding vessel)	12
Successful, but not embolised Embolised	1
Proceed to endoscopy	4
Proceed to surgery Death/Palliated	17
Nuclear medicine scan	14
Nuclear medicine scan Positive nuclear medicine scan	3
Rebleed after embolization	30
Within 24 hours	10
24 – 72 hours	9
72 hours to 7 days	5
7 days to 14 days	3
14 days to 30 days	3
Management of rebleed	
Endoscopic	5
Embolised	6
Surgery	4
Conservative/Medical	24
Palliative/died	3
Complications	
Minor complications	6

Major complications	9
Complications management	
Managed conservatively	8
Managed endoscopically	2
Managed surgically	3
Died/palliated	2
Ischemia	
Minor ischaemia	1
Major ischaemia	5
Ischemia management	
Conservatively	1
Surgery	4
Died/palliated	1
Total who underwent Surgery	
Failure of embolization	8
Failure to visualize source on CTA	9
Failure to visualize source on DSA	13
Failure of conservative management	3
Surgery is the best option for the pathology	12

5. Conclusion

Older patients are likely to have more co-morbidities, are more likely to be hemodynamically unstable on presentation, and should receive aggressive medical management. Patients presenting with visible bleed on admission (and thus having a higher bleed flow rate) are more likely to have a positive CTA result. However, these patients are less likely to require embolization, as most LGIB self-resolves. Patients taking blood thinners (antiplatelets, DOACs, warfarin) and NSAIDs are likely to have mucosal bleeding that is undetectable as a single point or vessel on CTA. Transarterial embolization has a high technical success rate, acceptable rebleeding rate, and low rate of serious complications. This study supports the primary use of Angioembolisation in LGIB.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] Kouanda AM, Somsouk M, Sewell JL, Day LW. Urgent colonoscopy in patients with lower GI bleeding: a systematic review and meta- analysis. Gastrointest Endosc. 2017;86(1):107-117.e1. doi:10.1016/j.gie.2017.01.035

[2] He B, Yang J, Xiao J, et al. Diagnosis of lower gastrointestinal bleeding by multi-slice CT angiography: A meta-analysis. Eur J Radiol. 2017;93:40-45. doi:10.1016/j.ejrad.2017.05.020

[3] Kennedy DW, Laing CJ, Tseng LH, Rosenblum DI, Tamarkin SW. Detection of active gastrointestinal hemorrhage with CT angiography: a 4(1/2)-year retrospective review. J Vasc Interv Radiol. 2010;21(6):848-855. doi:10.1016/j.jvir.2010.01.039

[4] Moos SI, van Vemde DN, Stoker J, Bipat S. Contrast induced nephropathy in patients undergoing intravenous (IV) contrast enhanced computed tomography (CECT) and the relationship with risk factors: a meta-analysis. Eur J Radiol. 2013;82(9):e387-e399. doi:10.1016/j.ejrad.2013.04.029

[5] RANZCR Iodinated contrast guidelines 2015, available from https://www.ranzcr.com/college/document-library/ranzcr-iodinated-contrast- guidelines; accessed December 2020

[6] Oakland K, Chadwick G, East JE, et al. Diagnosis and management of acute lower gastrointestinal bleeding: guidelines from the British Society of Gastroenterology. Gut. 2019;68(5):776-789. doi:10.1136/gutjnl-2018-317807

[7] Nicholson AA, Ettles DF, Hartley JE, Curzon I, Lee PW, Duthie GS, Monson JR. Transcatheter coil embolotherapy: a safe and effective option for major colonic haemorrhage. Gut. 1998 Jul;43(1):79-84. PubMed PMID: 9771409; PubMed Central PMCID: PMC1727187.

[8] Bulakbaşi N, Kurtaran K, Ustünsöz B, Somuncu I. Massive lower gastrointestinal hemorrhage from the surgical anastomosis in patients with multiorgan trauma: treatment by subselective embolisation with polyvinyl alcohol particles. Cardiovasc Intervent Radiol. 1999 Nov-Dec;22(6):461-7. PubMed PMID: 10556404.

[9] Oakland K et al. Diagnostic and therapeutic treatment modalities for acute lower gastrointestinal bleeding: a systematic review. Endoscopy International Open 2017; 05: E959–E973

[10] Oakland K, Kothiwale S, Forehand T, Jackson E, Bucknall C, Sey MSL, et al. External Validation of the Oakland Score to Assess Safe Hospital Discharge Among Adult Patients With Acute Lower Gastrointestinal Bleeding in the US. JAMA Netw Open. 2020 Jul 7;3(7):e209630.

[11] Ledermann HP, Schoch E, Jost R, Decurtins M, Zollikofer CL. Superselective coil embolisation in acute gastrointestinal hemorrhage: personal experience in 10 patients and review of the literature. J Vasc Interv Radiol. 1998 Sep-Oct;9(5):753-60. Review. PubMed PMID: 9756062.

[12] Lubarsky M, Ray C, Funaki B. Embolisation agents-which one should be used when? Part 2: small-vessel embolisation. Semin Intervent Radiol. 2010 Mar;27(1):99-104. doi: 10.1055/s-0030-1247891. PubMed PMID: 21359018; PubMed Central PMCID: PMC3036509.

[13] Walker TG, Salazar GM, Waltman AC. Angiographic evaluation and management of acute gastrointestinal hemorrhage. World J Gastroenterol. 2012 Mar 21;18(11):1191-201. doi: 10.3748/wjg.v18.i11.1191. Review. PubMed PMID: 22468082; PubMed Central PMCID: PMC3309908

[14] Frodsham A, Berkmen T, Ananian C, Fung A. Initial experience using N- butyl cyaDOACrylate for embolisation of lower gastrointestinal hemorrhage. J Vasc Interv Radiol. 2009 Oct;20(10):1312-9. doi: 10.1016/j.jvir.2009.06.031. PubMed PMID: 19800541

[15] Loffroy R et a l. When all else fails – radiological management of severe gastrointestinal bleeding. J Best Pract and Res. Clin. Gast. 2019, 42-43 101612

[16] Tan KK, Wong D, Sim R. Superselective embolisation for lower gastrointestinal hemorrhage: an institutional review over 7 years. World J Surg. 2008 Dec;32(12):2707-15. doi: 10.1007/s00268-008-9759-6. PubMed PMID: 18843444.

[17] Kwon J, Kim MD, Han K, Choi W, Kim Y, Lee J, Kim G, Won J, Lee D. Transcatheter arterial embolization for acute lower gastrointestinal haemorrhage: a single-centre study. Eur J Radiol 209 29:57-67 DOI: 10.1007/s00330-018-6687-8

[18] Kwak HS, Han YM, Lee ST. The clinical outcomes of transcatheter microcoil embolisation in patients with active lower gastrointestinal bleeding in the small bowel. Korean J Radiol. 2009 Jul-Aug;10(4):391-7. doi: 10.3348/kjr.2009.10.4.391. Epub 2009 Jun 25. PubMed PMID: 19568468; PubMed Central PMCID: PMC2702049

[19] Yap FY, Omene BO, Patel MN, Yohannan T, Minocha J, Knuttinen MG, Owens CA, Bui JT, Gaba RC. Transcatheter embolotherapy for gastrointestinal bleeding: a single center review of safety, efficacy, and clinical outcomes. Dig Dis Sci. 2013 Jul;58(7):1976-84. doi: 10.1007/s10620-012-2547-z. Epub 2013 Jan 30. PubMed PMID: 23361570

[20] Prakash C, Zuckerman GR. Acute small bowel bleeding: a distinct entity with significantly different economic implications compared with GI bleeding from other locations. Gastrointest Endosc. 2003 Sep;58(3):330-5. PubMed PMID: 14528203

[21] Chen YL, Yu CY, Chen RC, et al. Transarterial treatment of acute gastrointestinal bleeding: prediction of treatment failure by clinical and angiographic parameters. J Chin Med Assoc 2012;75:376—83

[22] Hongsakul K, Pakdeejit S, Tanutit P. Outcome and predictive factors of successful transarterial embolisation for the treatment of acute gastrointestinal hemorrhage. Acta Radiol. 2014 Mar;55(2):186-94. doi: 10.1177/0284185113494985. Epub 2013 Jul 31. PubMed PMID: 23904090

[23] Bossuyt PM, Reitsma JB, Bruns DE, et al. STARD 2015: an updated list of essential items for reporting diagnostic accuracy studies. BMJ. 2015;351:h5527. Published 2015 Oct 28. doi:10.1136/bmj.h5527

[24] Sami SS, Al-Araji SA, Ragunath K. Review article: gastrointestinal angiodysplasia - pathogenesis, diagnosis and management. Aliment Pharmacol Ther. 2014;39(1):15-34. doi:10.1111/apt.12527

[25] Yoon W, Jeong YY, Shin SS, et al. Acute massive gastrointestinal bleeding: detection and localization with arterial phase multi-detector row helical CT. Radiology. 2006;239(1):160-167. doi:10.1148/radiol.2383050175

[26] Huprich JE, Fletcher JG, Alexander JA, Fidler JL, Burton SS, McCullough CH. Obscure gastrointestinal bleeding: evaluation with 64-section multiphase CT enterography--initial experience. Radiology. 2008;246(2):562-571. doi:10.1148/radiol.2462061920

[27] Kennedy DW, Laing CJ, Tseng LH, Rosenblum DI, Tamarkin SW. Detection of active gastrointestinal hemorrhage with CT angiography: a 4(1/2)-year retrospective review. J Vasc Interv Radiol. 2010;21(6):848-855. doi:10.1016/j.jvir.2010.01.039