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EDITORIAL

The role of interventional radiology in the management of hemodynamically compromised patients

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Introduction

The minimally invasive nature of interventional radiology (IR), supported by the advances in imaging and improvements in endovascular techniques, has resulted in expansion of its role as an alternative option for medical, endoscopic, or surgical interventions. While IR procedures are currently incorporated in several medical, oncological, and surgical practice guidelines, the levels of recommendations mainly depend on low-quality evidence lacking long-term outcomes and comparison to other treatment options. In this editorial, we provide an overview of the emerging role of IR procedures in management of hemodynamically compromised patients based on current clinical practice guidelines, with a focus on life-threatening bleeding, massive and submassive pulmonary embolism (PE), and sepsis. A summary of the related clinical practice guidelines is presented in Table 1. Angiographic images of selected representative cases are shown in Online Supplement Fig. 1.

Life-threatening bleeding

IR procedures have an important role in several conditions related to non-traumatic and traumatic bleeding (Table 1) (Supplement Fig. 1, panels 1 and 2). Although practice guidelines addressed the role of IR procedures in specific types of injuries and pathologies, the same concept of embolization and bleeding control can be generalized to other body parts and types of traumatic injuries.

Non-variceal gastrointestinal (GI) bleeding

Transarterial embolization using different embolic agents can be considered as an alternative to surgery in patients with GI bleeding after failed medical or endoscopic management. Transarterial embolization achieves control of the bleeding site in 40–80% of cases depending on the site of hemorrhage [1, 2]. The source of non-variceal bleeding is often identified by upper or lower endoscopy. In patients with an unidentified source with significant active bleeding (estimated at 0.5 mL/min or more), angiography can be used to identify the source followed by embolization. In patients with less active bleeding, CT angiography typically detects bleeding that exceeds 0.3–0.5 mL/min, and scintigraphy with ^{99m}Tc-labeled red blood cells can help identify the source of slower bleeds (0.05–0.1 mL/min). Once active extravasation is diagnosed, embolization of the bleeding vessel can follow. Although patients who are treated by transarterial embolization tend to be older and have more medical comorbidities than those managed with surgery, transarterial embolization is associated with lower morbidity and similar survival rates compared to surgery [1, 2]. However,

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Table 1 Summary of clinical practice guidelines regarding the possible role of IR procedures in management of different conditions in critically ill patients

Condition	Clinical practice guideline	Recommendation
Peptic ulcer bleeding	American College of Gastroenterology (2012)	If bleeding occurs after a second endoscopic therapeutic session, surgery or IR procedures with transcatheter arterial embolization is generally employed (conditional recommendation, low-quality evidence)
Acute lower gastrointestinal bleeding	American College of Gastroenterology (2016)	IR procedures should be considered in patients with high-risk clinical features and ongoing bleeding who have a negative upper endoscopy and do not respond adequately to hemodynamic resuscitation efforts and are therefore unlikely to tolerate bowel preparation and urgent colonoscopy (strong recommendation, very low quality evidence)
Acute variceal bleeding	American College of Gastroenterology (2007)	1. Esophageal varices: transjugular intrahepatic portosystemic shunt (TIPSS) is indicated in patients in whom hemorrhage from esophageal varices cannot be controlled or in whom bleeding recurs despite combined pharmacological and endoscopic therapy (recommendation class I, level of evidence C) 2. Gastric varices: TIPSS should be considered in patients in whom hemorrhage from fundal varices cannot be controlled or in whom bleeding recurs despite combined pharmacological and endoscopic therapy (recommendation class I, level of evidence B)
Blunt hepatic injury	Eastern Association for the Surgery of Trauma (2012)	1. Angiography with embolization may be considered as a first-line intervention for a patient who is a transient responder to resuscitation as an adjunct to potential operative intervention (recommendation level 2) 2. Angiography with embolization should be considered in a hemodynamically stable patient with evidence of active extravasation (a contrast blush) on abdominal CT scan (recommendation level 2)
Blunt splenic injury	Eastern Association for the Surgery of Trauma (2012)	1. Angiography should be considered for patients with American Association for the Surgery of Trauma (AAST) grade of greater than III injuries, presence of a contrast blush, moderate hemoperitoneum, or evidence of ongoing splenic bleeding (recommendation level 2) 2. Angiography may be used either as an adjunct to nonoperative management for patients who are thought to be at high risk for delayed bleeding or as an investigative tool to identify vascular abnormalities such as pseudoaneurysms that pose a risk for delayed hemorrhage (recommendation level 3)
Genitourinary trauma	Eastern Association for the Surgery of Trauma (2004)	The success of nonsurgical management may be enhanced by the use of angiographic embolization (recommendation level 3)
Pelvic trauma	Eastern Association for the Surgery of Trauma (2011)	1. Patients with pelvic fractures and hemodynamic instability or signs of ongoing bleeding after nonpelvic sources of blood loss have been ruled out should be considered for pelvic angiography/embolization (recommendation level 1) 2. Patients with evidence of arterial intravenous contrast extravasation (ICE) in the pelvis by CT may require pelvic angiography and embolization regardless of hemodynamic status (recommendation level 1) 3. Patients with pelvic fractures who have undergone pelvic angiography with or without embolization, who have signs of ongoing bleeding after nonpelvic sources of blood loss have been ruled out, should be considered for repeat pelvic angiography and possible embolization (recommendation level 2) 4. Patients older than 60 years with major pelvic fracture (open book, butterfly segment, or vertical shear) should be considered for pelvic angiography without regard for hemodynamic status (recommendation level 2)
	The European guideline on management of major bleeding and coagulopathy following trauma: fourth edition (2016)	In patients with ongoing hemodynamic instability despite adequate pelvic ring stabilization, early pre-peritoneal packing, angiographic embolization, and/or surgical bleeding control are recommended (recommendation grade 1B)
Blunt traumatic aortic injury	Eastern Association for the Surgery of Trauma (2015)	The use of endovascular repair in patients who do not have contraindications to endovascular repair is strongly recommended (grade framework)
	Society for Vascular Surgery (2011)	1. The clinical practice guidelines suggest that endovascular repair be performed preferentially over open surgical repair or nonoperative management (recommendation grade 2, level of evidence C) 2. The clinical practice guidelines suggest endovascular repair regardless of age if anatomically suitable (recommendation grade 2, level of evidence C)

Table 1 continued

Condition	Clinical practice guideline	Recommendation
Penetrating abdominal trauma	Eastern Association for the Surgery of Trauma (2010)	Angiography may be necessary as an adjunct to initial nonoperative management of penetrating abdominal trauma. Further study is needed on the use of angiography and angioembolization in this patient population before a formal recommendation can be made
Ruptured AAA	European Society for Vascular Surgery (2011)	Endovascular aortic repair (EVAR) should be considered as a treatment option for ruptured AAA, provided that anatomy is suitable, and the center is appropriately equipped and the team experienced in emergency endovascular aneurysm procedures (level of evidence 2b, recommendation B)
Acute occlusive arterial ischemia	American College of Cardiology/American Heart Association (2005)	Percutaneous interventions (including transcatheter lytic therapy, balloon angioplasty, and stenting) are appropriate in selected patients with acute intestinal ischemia caused by arterial obstructions. Patients so treated may still require laparotomy (recommendation class IIb, level of evidence C)
	European society of trauma and emergency surgeons (ESTES) guidelines (2016)	Embolic acute mesenteric ischemia (EAMI): in cases where immediate surgical intervention is not required the decision to perform endovascular or open vascular surgery for EAMI should be determined by the personal experience and technical capabilities of the surgeon and the available resources (level IV) Thrombotic acute mesenteric ischemia (TAMI): when bowel integrity has not been compromised, endovascular techniques should be performed as first-line treatment for TAMI (level of evidence III)
Acute non-occlusive mesenteric ischemia	American college of cardiology/American heart association (2005)	1. Arteriography is indicated in patients suspected of having non-occlusive intestinal ischemia whose condition does not improve rapidly with treatment of their underlying disease (recommendation class I, level of evidence B) 2. Transcatheter administration of vasodilator medications into the area of vasospasm is indicated in patients with non-occlusive intestinal ischemia who do not respond to systemic supportive treatment and in patients with intestinal ischemia due to cocaine or ergot poisoning (recommendation class IIa, level B)
	ESTES guidelines (2016)	Non-occlusive mesenteric ischemia should be managed by correcting the underlying cause wherever possible and improving mesenteric perfusion by direct infusion of vasodilators. Infarcted bowel should be excised (level of evidence III)
Venous acute mesenteric ischemia	ESTES guidelines (2016)	Endovascular intervention should be offered to patients with venous acute mesenteric ischemia who deteriorate during medical therapy (level of evidence IV)
Acute massive (high-risk) pulmonary embolism	American Heart Association (2011)	Depending on local expertise, catheter embolectomy and fragmentation or surgical embolectomy is reasonable for patients with massive pulmonary embolism and contraindications to fibrinolysis or who remain unstable after fibrinolysis (recommendation class IIa; level of evidence C)
	European Society of Cardiology (2014)	Percutaneous catheter-directed treatment should be considered as alternative to surgical pulmonary embolectomy for patients in whom full-dose systemic thrombolysis is contraindicated or has failed (recommendation class IIa, level of evidence C)
	American College of Chest Physicians (2016)	In patients with acute PE associated with hypotension and who have (a) a high bleeding risk, (b) failed systemic thrombolysis, or (c) shock that is likely to cause death before systemic thrombolysis can take effect (e.g., within hours), if appropriate expertise and resources are available, we suggest catheter-assisted thrombus removal over no such intervention (recommendation grade 2, level of evidence C)
Acute submassive pulmonary embolism (intermediate)	American Heart Association (2011)	Catheter embolectomy or surgical embolectomy may be considered for patients with submassive acute PE judged to have clinical evidence of adverse prognosis (i.e., new hemodynamic instability, worsening respiratory failure, severe right ventricular dysfunction, or major myocardial necrosis) (recommendation class IIb; level of evidence C)
	European Society of Cardiology (2014)	Percutaneous catheter-directed treatment may be considered in treatment of intermediate- to high-risk patients if the anticipated risk of bleeding under thrombolytic treatment is high (recommendation class IIb, level of evidence B)
Sepsis	Surviving Sepsis Campaign: international guidelines for management of sepsis and septic shock (2016)	1. Recommend that a specific anatomic diagnosis of infection requiring emergent source control be identified or excluded as rapidly as possible in patients with sepsis or septic shock, and that any required source control intervention be implemented as soon as medically and logistically practical after the diagnosis is made (best practice statement) 2. Recommend prompt removal of intravascular access devices that are a possible source of sepsis or septic shock after other vascular access has been established (best practice statement)

The grading system of evidence and recommendations vary among guidelines. In this table, we listed the grades as originally published in different guideline documents. Readers are advised to refer to the original guidelines for further interpretation of specific recommendation. Please see the Online Supplement for a complete list of references

re-bleeding rate is higher with transarterial embolization compared to surgery and it is often related to coagulation disorders, inaccurate angiographic localization of bleeding, or inadequate embolization.

Variceal bleeding

In patients with acute esophageal variceal bleeding, the first line of therapy is endoscopic gastroesophageal variceal ligation or sclerotherapy combined with pharmacologic therapy [3]. Transjugular intrahepatic portosystemic shunt (TIPSS) is indicated in patients in whom hemorrhage from esophageal varices cannot be controlled or in whom bleeding recurs despite combined pharmacological and endoscopic therapy [3]. Results from randomized clinical trials suggest that TIPSS may be more effective than endoscopic and medical management in reducing the rate of recurrent variceal bleeding, without a survival benefit [4, 5]. Early creation of TIPSS within 72 h after admission is associated with lower rates of treatment failure and mortality compared to a combination of vasoactive therapy, beta-blockers, endoscopic ligation, and rescue TIPSS [6]. TIPSS is associated with higher rates of early hepatic encephalopathy [4, 5]. Additional IR procedures for the management of variceal bleeding include balloon-occluded retrograde transvenous obliteration (BRTO) of gastric varices, transhepatic embolization of gastroesophageal varices, portal vein recanalization/thrombectomy with or without TIPSS, and partial splenic artery embolization.

Solid organ injury

The Eastern Association for the Surgery of Trauma (EAST) guidelines recommend surgical interventions for the management of solid organ abdominal traumatic injuries in hemodynamically unstable patients. The same guidelines suggest embolization as an adjunctive treatment in hemodynamically stable patients responding to resuscitative measures with evidence of active extravasation, or in those at high risk for the development of delayed bleeding from vascular injuries or pseudoaneurysms [7]. Published series report clinical success rates of hepatic, splenic, and renal embolization of 80%, 85%, and 90%, respectively [8], although recurrent bleeding occurs in up to 25% depending on the American Association for the Surgery of Trauma (AAST) grade of injury and embolization techniques [8].

Blunt traumatic aortic injuries

Endovascular repair with stent grafting is increasingly being performed in lieu of open surgical repair owing to improvement of stent design and delivery (Supplement Fig. 1, panel 2). Findings from the RESCUE prospective nonrandomized multicenter study and the AAST multicenter study demonstrate that endovascular aortic repair, compared to open surgical repair, is associated with significantly less blood loss, lower incidence of stroke, paraplegia, and mortality, and shorter hospital stay [9].

Massive and submassive PE

Based on current evidence, the 2016 American College of Chest Physicians guidelines suggest the use of systemic thrombolysis over catheter-directed therapy (CDT) in patients with acute PE [10]. Nonetheless, if appropriate expertise and resources are available, the use of CDT is suggested in patients with acute PE who have hypotension and are at a high risk of bleeding or have failed systemic thrombolysis or are in shock that is likely to cause death before systemic thrombolysis can take effect [10]. CDT can be mechanical and/or pharmacological. There are several low-profile catheters (6–10 Fr) used to facilitate pulmonary reperfusion. The use of a specific catheter depends on operator's experience, risk for bleeding, patient's condition, and the need for immediate reperfusion. Mechanical CDT entails either thrombus disruption or fragmentation. Alternatively, thrombus removal can be performed using manual suction catheters or thrombectomy devices. Pharmacological CDT uses specific infusion catheters, with or without ultrasound agitation, allowing for administration of lower doses of thrombolytics compared to systemic therapy and mechanical device for thrombus removal to further accelerate pulmonary reperfusion (Supplement Fig. 1, panel 3). Given the emerging nature of some of these techniques, data about the effectiveness of each device are derived mainly from observational studies. A recent systematic review reported 16 prospective and retrospective studies between 2008 and 2016 and included 860 patients primarily treated with ultrasound-assisted CDT with a mean tPA dose of 24 mg [11]. This analysis showed that ultrasound-assisted CDT was associated with a significant decrease in pulmonary artery systolic pressures (mean drop of 15 mmHg) and significantly reduced the right ventricle/left ventricle ratio [11]. The rate of major bleeding was estimated at 4.7%, most requiring transfusion only, while intracranial hemorrhage occurred in 0.35% [11]. The in-hospital mortality of massive PE following CDT was 13% and 0.7% for submassive PE [11]. Given the complexity and the multidisciplinary nature of management of massive and submassive PE, the concept of pulmonary embolism response team (PERT) has emerged, in which intensivists and interventional radiologists are typically core members [12]. Initial data describing the experience with PERT showed that up to 18% of patients received CDT, 5–11% of patients were

given systemic thrombolytics, and nearly 70% of patients received anticoagulation only [13, 14].

Sepsis

The Surviving Sepsis Campaign guidelines for management of sepsis and septic shock recommend early identification and control of specific anatomic source of infection using the least invasive effective option to avoid complications in these critically ill patients [15]. IR procedures are minimally invasive and often effective in source control of infection sites that are amenable for drainage, such as percutaneous drainage of abscesses, percutaneous transhepatic biliary drainage, and cholecystostomy and nephrostomy tube placement [15]. Surgical intervention should be considered when other IR procedures are inadequate or cannot be provided in a timely fashion [15].

In conclusion, IR procedures have an important role in properly managing selected hemodynamically compromised critically ill patients. While IR procedures carry generally lower morbidity, further studies are needed to evaluate survival and long-term outcomes in comparison to medical or surgical alternatives.

Electronic supplementary material

The online version of this article (https://doi.org/10.1007/s00134-018-5236-3) contains supplementary material, which is available to authorized users.

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Compliance with ethical standards

Conflicts of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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