Review

Transcatheter thrombolysis centered stepwise management strategy for acute superior mesenteric venous thrombosis

Shuofei Yang, Xingjiang Wu, Jieshou Li

Department of General Surgery, Jinling Hospital, Medical School of Nanjing University, No. 305 East Zhongshan Road, Nanjing 210002, Jiangsu Province, PR China

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A B S T R A C T

Acute superior mesenteric venous thrombosis (ASMVT) is a rare but potentially lethal abdominal calamity. Outcome depends on prompt recognition and revascularization before progresses to bowel gangrene. Despite better understanding of pathogenesis and development of modern treatment technique, management of ASMVT remains a great clinical challenge. Transcatheter thrombolysis as the main revascularization method, combined with mechanical thrombectomy and other endovascular manipulations, alone or as a hybrid procedure, has got favorable outcomes. Thus on the basis of early diagnosis and close evaluation of intestinal ischemia and thrombus evolution, a coordinated stepwise management strategy involving a specialized approach of initial anticoagulation, preferred endovascular therapy, and damage-control surgery modality with surgical thrombectomy, may show benefits in rapid revascularization, prompt symptom improvement, and short bowel syndrome avoidance, with shortened hospitalization and less cost. This article presents an evidence-based review of the state-of-the-art advancements of this transcatheter thrombolysis centered stepwise management strategy for ASMVT.

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1. Introduction

Acute mesenteric ischemia (AMI) is an abdominal vascular emergency comparable to myocardial infarction or apoplexy. Mesenteric venous thrombosis (MVT) is the least common, about 9–16%, among four types of AMI, typically affecting the superior mesenteric vein and rarely the inferior mesenteric vein [1]. It approximately accounts for 1 in 5000 to 15,000 inpatient admissions [2]. Intestinal gangrene caused by mesenteric venous occlusion and treated by bowel resection was first reported by Elliot in 1895 [3]. But it was after the detailed description by Warren and Eberhardt in 1935 that MVT became a distinct clinical entity [4]. In 1960, it was demonstrated by Barritt and Jordan that manifest venous thromboembolism must be treated [5]. In Sweden, incidence of MVT has increased from 2.0 per 100,000 patient-years between 1970 and 1982 to 2.7 per 100,000 patient-years between 2000 and 2006, with equal incidence in both genders and highest incidence in the age category 70–79 years [6]. Poor understanding of its natural history and clinical trait and unacceptable delay before treatment are main reasons for its high mortality.

Acute superior mesenteric venous thrombosis (ASMVT) is usually segmental with hyperemia and hemorrhage of the bowel wall [7]. It leads to increased anaerobic metabolism, regional acidosis, focal sloughing of mucosa and initial hyperperistalsis with cramping pain and gut emptying, followed by intense ischemic pain from the secondary arteriospasm and transmural hypoperfusion [8]. Symptoms may vary from insidious onset of vague generalized to sudden onset of localized, severe and constant abdominal pain with vomiting and diarrhea. Bowel wall edema increased outflow resistance and blood viscosity, impeding arterial flow and resulting in bowel infarction [9]. Massive fluid influx into the bowel wall and lumen leads to systemic hypovolemia and hemoconcentration. During initial phase, peritoneal signs are not found on physical examination, with the classic “pain out of proportion to physical findings”. In the later stages with peritonitis and localized abdominal pain, presence of associated physical findings occur [10].

The etiology of ASMVT can be categorized based on Virchow’s triad of venous stasis, hypercoagulable state and endothelial injury, which may often coexist, as any venous thrombotic condition (Table 1) [11,12]. Local inflammatory factors are often associated with initial thrombus formation in the trunk of superior mesenteric
The throughout surveillance of intestinal reperfusion and thrombus evolution guides the step-up of treatment. The evaluation method itself develops from noninvasive portography to surgical exploration as well. Recent widespread use of contrast-enhanced computed tomography (CT) portography has facilitated early detection of ASMVT before laparotomy from 1 week in 1978–1995 to 1 day in 1995–2003, with a sensitivity over 90% [22]. It has become an effective assessment tool of both intestinal viability and thrombolysis response (Fig. 1A, B, E, F). The bowel segment with a homogenous, non-enhancing appearance represents necrotic bowel, whereas ischemic bowel is identified by layered enhancement pattern [23]. Digital subtraction angiography (DSA) portography, the gold-standard of MVT diagnosis, is reserved for equivocal cases on non-invasive imaging and also used in conjunction with catheter-directed thrombolysis (Fig. 1C, D, G, H). The “thumbprinting sign” on plain film and elevated serum lactate level are nonspecific and of limited value. During thrombolysis, coagulation should be closely monitored.

Since the need to preserve as much bowel as possible against being overly aggressive in resecting any questionably viable bowel, intraoperative assessment of bowel viability is of great significance. It consists of initial clinical evaluation then assessment for visible and palpable pulsations in the mesenteric arcade, normal color and appearance of the bowel serosa, peristalsis, and bleeding from cut surfaces. Nevertheless, each of these clinical judgments is subjective and inaccurate, with a sensitivity of only 82% and a specificity of 91% [24]. A nonviable segment could be implied with absence of pulsatile signals on the antimesenteric border detected by a continuous-wave 9–10 MHz Doppler ultrasound probe [25]. Highly accurate intraoperative quantification of intestinal perfusion using fluorescein and a perfusion fluorometer or laser Doppler flowmeter has been proposed, but less practical for routine use as special equipment requirements and technical difficulties [26,27]. The most recently developed intra-operative indocyanine green angiography, HyperEye Medical System (HEMS), has a unique and practical advantage in assessment of intestinal wall perfusion with a longer duration for imaging [28]. Upon completion of surgical revascularization, 20 min of reperfusion time should be permitted and then bowel viability must be reassessed [29].

Even after reperfusion and careful assessment, bowel viability it be determined with certainty at initial exploration. The second-look laparotomy in 24–48 h postoperatively was advocated to assess questionable viability and rethrombosis in 1971 [30]. The modern option of deferring bowel resection and reanastomosis and high rate of postoperative rethrombosis underscores the fundamental essentiality of a mandatory second-look procedure. The frequency of bowel resection is higher during second-look surgery than initial exploration and surgical revascularization (53% vs 31%) [13]. In another study of 31 cases of ASMVT, thrombosis recurred in 36% patients during the second-look exploration [31]. Once deciding to perform a second-look laparotomy, it should be firmly carried out because a significant proportion of patients without signs of clinical deterioration at this time do require further bowel resection. However, such a second-look operation is not always favorable and safe due to extra strikes of reoperation. Laparotomy itself is also a predisposing factor for MVT and only 23.5% rethrombosis rate of second-look surgery was reported in another study [32]. It is controversial about the routine use of second-look laparotomy.
artery occlusion since 1996. CT-angiography combined with therapy has been an effect treatment of acute superior mesenteric der local anesthesia. Combined urokinase and laparoscopic look exploration, even at bedside of intensive care unit (ICU) un-mally invasive, and direct-viewed method for initial and second-bene
early laparoscopic exploration and thrombolytic treatment have recognized as the mainstay therapy of MVT since postoperative cornerstone of the stepwise management strategy. It has been heparin bolus followed by continuous infusion, is the 3.1.1. Anticoagulation
3. Stepwise treatment algorithm
3.1. Step 1: systemic anticoagulation and intensive care
3.1.1. Anticoagulation

In recent years, laparoscopy is used as a safe, expedient, minimally invasive, and direct-viewed method for initial and second-look exploration, even at bedside of intensive care unit (ICU) under local anesthesia. Combined urokinase and laparoscopic therapy has been an effect treatment of acute superior mesenteric artery occlusion since 1996. CT-angiography combined with early laparoscopic exploration and thrombolytic treatment have beneficial effects regarding mortality compared to early bowel resection with thrombectomy. It is more widely applied for second-look exploration with shortened operating time, and minimal physiological disturbance. Leaving the laparoscopic port in place after initial evaluation may enable a quick and easy second-look after local thrombolytic therapy. Some authors considered that laparoscopic second-look intervention could totally replaced second-look laparotomy as the routine procedure. However, evidence-based guidelines of the european association for endoscopic surgery in 2006 pointed out that since radiographic imaging accurately identified most cases of mesenteric ischemia, it is unlikely that diagnostic laparoscopy will prevent a negative laparotomy. Extensive intestinal paralysis with dilated bowel loops may be impossible to evaluate at laparoscopy. Actually, laparoscopic manipulation itself is a remarkable cause of ASMVT. It is imprudent to draw the conclusion at present as there is no control study of laparoscopy versus open surgery for initial or second-look exploration in ASMVT patients. Moreover, intra-abdominal pressure during laparoscopy cannot exceed 20 mmHg to avoid exacerbation of intestinal hypoperfusion. Enteroscopy is recommended as adjuvant tool to detect the early mucosal ischemia.

3.1.2. Intensive care management

Every patient with ASMVT should receive emergent treatment in a surgical ICU. Fluid resuscitation should be commenced immediately with intravenous crystalloids and blood products under proper monitoring to stabilize hemodynamics as general endothelial disintegration within a few hours leading to volume displacement. Damage control resuscitation characterized by permissive hypotension, limiting crystalloid intravenous fluids, and delivering higher ratios of plasma and platelets to red blood cells is recommended for critically ill patients. Pain must be dealt with adequately. Nasogastric suction is applied to diminish the bowel movements as well as intraluminal pressure. Broad-spectrum prophylactic antibiotics (e.g. second-generation cephalosporin...
Endovascular therapy has increased significantly in the modern era and altered the management of AMI [70]. Compared to open surgery, endovascular treatment is associated with decreased mortality, lower rates of bowel resection and total parenteral nutrition, and shorter length of stay [71]. Early revascularization by endovascular technique is still utilized in severe AMI patients [72]. However, successful use of endovascular treatments needs a preexisting standard algorithm with adequate equipment and timely staffing at the emergency center.

3.3. Step 3: damage control surgery

Emergency operation is imperative for patients with diffuse, severe peritonitis and bloody vomit, stool and ascites, which are signs of transmural infraction or perforation [73]. During endovascular procedure, prompt laparotomy is indicated in patients who develop new or worsening signs of peritonitis, particularly in those who have complete occlusion of the main trunk of the SMV. Delayed bowel resection may be needed after mesenteric recanalization due to the secondary stricture [58]. Multiple bowel segments are commonly affected and bowel viability in the transient zone is hard to determine. Before 1990s, resection and primary anastomosis was the standard procedure, with high thrombus recurrence rate at the anastomotic site. Extensive resection is often forced to operate with poor prognosis and high risk of SBS. A mandatory second-look procedure is still debatable.

Damage control surgery is well established in the trauma setting and extends to many nontraumatic areas [74,75]. It has been advocated as an option to improve the survival of AMI patients requiring laparotomy since 2005 [76]. A damage-control approach for ASMVT involves 3 consecutive phases (Fig. 2). Phase 1: emergency resection of bowel and other organs with clear transmural necrosis and intraoperative thrombectomy with no attempt to restore gastrointestinal continuity. Some authors recommend resection by stapling and dividing at healthy margins. The stapled bowel ends are simply returned to abdomen with peritoneal lavage performed. Anastomosis are deferred until second or third-look laparotomy at 24–48 h to make certain further necrosis and failure of anastomosis do not occur [8,76–78]. Expedient temporary, skin-only, abdominal wall closure with an V.A.C.® dressing system or “Bogota bag” sandwich technique can be applied [76,77]. Due to the constant bacterial translocation caused by growing intraluminal pressure of stapled bowel ends and need of reoperation to assess the bowel viability, resection and double ileostomy is preferred as an alternative approach for poor risk patients [79,80]. For patients with high risk of abdominal compartment syndrome, open abdomen technique is recommended [81]. This modality enables the patient to avoid the risk of anastomotic insufficiency following primary anastomosis as well as the hazards related to a second-look operation owing to the direct observations of the color tone of the double ileostomy or from the open abdomen. Intravenous administration of heparin for anticoagulation to prevent rethrombosis of mesenteric vessels should initiate early with damage control closures despite the risk of hemorrhage. Phase 2: prompt transfer to a surgical ICU for ventilation, rewarming, inotropic support, correction of coagulopathy and dialysis as indicated. Further postoperative critical care management to maintain hemodynamical stability with organ function and nutrition support are performed. Angiography is arranged to plan transcatheter thrombolysis in an attempt to salvage more ischemic bowel [76]. Thrombus evolution must be continuously assessed by contrast-enhanced CT portography throughout the thrombolysis. Phase 3: If the bowel perfusion is well restored in a short time, definite anastomosis can be completed in 72 h to 1 week. For patients with major ischemia-reperfusion injury, definite

3.2. Step 2: endovascular therapy

Persistent worsening of abdominal pain despite 48–72 h of systemic anticoagulation or high risk of bowel infarction at admission are indications to step up to endovascular therapies. With rapid development of endovascular treatment technique and device, patients with high suspicion of bowel necrosis could receive endovascular therapy to achieve prompt recanalization under appropriate general conditions. This strategy aims to salvage more potentially reversible segments and avoid the dramatic attack of early operation. New criteria for prompt surgery has been suggested as bowel-wall thickness and bowel-wall enhancement on the arterial phase of CT because peritonitis may not strictly correlate with bowel infarction. In 2005, Hollingshead et al. retrospectively studied 20 patients with transcatheter thrombolysis [58]. Three patients had complete resolution, 12 had partial resolution, and 5 had no resolution. 85% had resolution of symptoms. No patients required bowel resection after thrombolytic therapy. Currently, endovascular thrombolysis has been the core method of recanalization of this stepwise management strategy. Literature reports on endovascular therapy of MVT has continued to increase (Table 2).

There 4 routes of endovascular therapy for ASMVT: percutaneous transhepatic (PT), transjugular intrahepatic portosystemic shunt (TIPS), SMA, intraoperative catheterization. Under ultrasound or X-ray guidance, PT access is technically easier and prone to remove larger thrombus within the trunk of SMV [59–61]. But coil embolization of the tract is required to prevent intraperitoneal or subcapsular hemorrhage as this approach traverses hepatic capsule and followed by thrombolysis [62,63]. For patients with ascites or coagulation disorder, TIPS approach is safer and allows additional manipulations such as venoplasty and stent placement for elastic recoil or stenosis [64]. Despite the technical difficulty and potential risk of hepatic function injury and intra-abdominal bleeding, it is the most widely used manner [65]. Indirect thrombolytic therapy via SMA is technically simpler and more efficient in resolving thrombi within capillaries and venules [66]. Moreover, papaverine can be selectively administered into SMA to relieve the secondary mesenteric arteriospasm. However, this approach may result in lytic agents diverting through patent branches or collaterals and prolongation of thrombolysis [67]. Endovascular mechanical manipulations (e.g. mechanical thrombectomy, stent implantation, angioplasty, TIPS creation and aspiration thrombectomy) have evolved as a significant part of thrombolysis to augment the ability of rapid thrombus removal, particularly when there is a structural reason. Rapid thrombus dissolution can be achieved by TIPS and stent placement to create a low-pressure run-off [68]. However, complicated endovascular manipulations may cause acute injury to vessel wall thereby promoting thrombus reformation and bleeding. Aspiration thrombectomy is recommended due to its minor injury and high efficiency. Newer mechanical thrombectomy devices such as the Angiojet® reholytic mechanical thrombectomy system (Possis Medical) has demonstrated promising results with a complete resolution of a MVT [69].
<table>
<thead>
<tr>
<th>Author, Year</th>
<th>N</th>
<th>Intervention</th>
<th>Agent</th>
<th>Route</th>
<th>Duration</th>
<th>Total dose</th>
<th>Lysis outcome</th>
<th>Surgery</th>
<th>Complication</th>
</tr>
</thead>
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<td>Yankes JR, 1988</td>
<td>1</td>
<td>Thrombolysis + angioplasty dilatation</td>
<td>UK</td>
<td>PT</td>
<td>4 h</td>
<td>9.6 million</td>
<td>Complete</td>
<td>Laparotomy + ileal resection</td>
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<td>Bilbao, 1989</td>
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<td>PT</td>
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<td>2.2 million U</td>
<td>Complete</td>
<td>None</td>
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<td>rt-PA</td>
<td>SIV + SMA</td>
<td>Bolus once</td>
<td>100 mg + 50 mg</td>
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<td>None</td>
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<td>None</td>
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<td>rt-PA</td>
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<td>UK</td>
<td>Ti</td>
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<td>70–100 mg</td>
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<td>UK</td>
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<td>2 d</td>
<td>7.5 million U</td>
<td>Complete</td>
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<td>SIV</td>
<td>3 d</td>
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<td>None</td>
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<td>SMA</td>
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<td>9.8 million U</td>
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<td>5</td>
<td>Thrombectomy + thrombolysis</td>
<td>rt-PA</td>
<td>Intraoperative SMV catheter</td>
<td>2–3 d</td>
<td>7 million U</td>
<td>Complete</td>
<td>Exploratory laparotomy</td>
<td>None</td>
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<td>Train, 1998</td>
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<td>UK</td>
<td>SMA</td>
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<td>14.7 million U</td>
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<td>10 d</td>
<td>200 mg</td>
<td>Complete</td>
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<td>None</td>
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<td>UK</td>
<td>SMA</td>
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<td>18 mg</td>
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<td>None</td>
<td>None</td>
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<td>Thrombolysis + thrombectomy</td>
<td>rt-PA</td>
<td>SMA + PT</td>
<td>16 h</td>
<td>180 mg</td>
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<td>None</td>
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<td>Schaefer, 2000</td>
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<td>Thrombolysis + TIPS</td>
<td>UK</td>
<td>SIV</td>
<td>7 d</td>
<td>3 million U</td>
<td>Complete</td>
<td>None</td>
<td>None</td>
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<td>Sze, 2000</td>
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<td>UK</td>
<td>SMA</td>
<td>16 h</td>
<td>1.6 million U</td>
<td>Partial</td>
<td>Laparotomy + jejunum resection</td>
<td>GI bleeding</td>
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<td>Sehga, 2000</td>
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<td>UK</td>
<td>Ti</td>
<td>1 d</td>
<td>4.3 million U</td>
<td>Partial</td>
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<td>None</td>
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<td>Antoch, 2001</td>
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<td>Thrombolysis</td>
<td>UK</td>
<td>SMA</td>
<td>5–8 d</td>
<td>16.8 million U</td>
<td>Complete</td>
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<td>None</td>
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<td>Tateishi, 2001</td>
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<td>UK</td>
<td>SIV + SMA</td>
<td>3 d + 11 d</td>
<td>2.8 million U</td>
<td>Partial</td>
<td>Exploratory laparotomy</td>
<td>None</td>
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<td>Ayetkin, 2001</td>
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<td>UK</td>
<td>Ti</td>
<td>4 h</td>
<td>1.7 million U</td>
<td>Complete</td>
<td>None</td>
<td>Portal cavernoma</td>
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<td>Kercher, 2002</td>
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<td>UK</td>
<td>PT</td>
<td>45 h</td>
<td>56.5 million U</td>
<td>Complete</td>
<td>None</td>
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<td>Lopera, 2002</td>
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<td>UK</td>
<td>PT</td>
<td>36</td>
<td>36 million U</td>
<td>Complete</td>
<td>None</td>
<td>None</td>
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<td>Liu B, 2003</td>
<td>2</td>
<td>Thrombolysis</td>
<td>UK</td>
<td>SMA</td>
<td>7 d</td>
<td>60–70 million U</td>
<td>Complete</td>
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<td>Thrombolysis</td>
<td>rt-PA</td>
<td>SMA</td>
<td>2 d</td>
<td>96 mg</td>
<td>Complete</td>
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<td>None</td>
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<td>Atsuko, 2003</td>
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<td>Thrombolysis</td>
<td>UK</td>
<td>Ti</td>
<td>40 d</td>
<td>8.4 million U</td>
<td>Complete</td>
<td>None</td>
<td>None</td>
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<td>Espeel B, 2004</td>
<td>2</td>
<td>Thrombolysis</td>
<td>rt-PA</td>
<td>SMA</td>
<td>17–24 h</td>
<td>34–51 mg</td>
<td>Complete</td>
<td>Bowel resection</td>
<td>None</td>
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<td>Kaplan, 2004</td>
<td>1</td>
<td>Thrombolysis</td>
<td>rt-PA</td>
<td>Intraoperative SMV catheter</td>
<td>44 h</td>
<td>40 mg</td>
<td>Complete</td>
<td>Exploratory laparotomy</td>
<td>None</td>
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<td>Hyun, 2005</td>
<td>11</td>
<td>7 Thrombectomy, 10 thrombolysis</td>
<td>UK, t-PA, rt-PA</td>
<td>PT</td>
<td>UK 0.33–45 h, t-PA 0.33–45 h, rt-PA 29–45 h</td>
<td>0.41–34 million U, 3.3–2250 mg, 420.5–1350 U</td>
<td>10 complete</td>
<td>None</td>
<td>1 Hemorrhax</td>
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<td>Naoto, 2005</td>
<td>1</td>
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<td>UK</td>
<td>PT</td>
<td>3 d</td>
<td>7.2 million U</td>
<td>Complete</td>
<td>Bowel resection</td>
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<td>1</td>
<td>Thrombolysis</td>
<td>rt-PA</td>
<td>SMA</td>
<td>3 d</td>
<td>90 mg</td>
<td>Complete</td>
<td>None</td>
<td>Suspected cerebral hemorrhage</td>
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<td>Michael, 2005</td>
<td>20</td>
<td>Thrombolysis</td>
<td>UK, t-PA</td>
<td>PT, SMA</td>
<td>UK 23–72 h, t-PA 2.3–48 h</td>
<td>18.4–135 million U, 4–41 mg</td>
<td>3 Complete</td>
<td>None</td>
<td>2 bleeding, 2 dislodged catheters, 1 death due to septic shock and GI hemorrhage</td>
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<td>30 million U</td>
<td>Complete</td>
<td>Exploratory and second-look laparotomy</td>
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<td>2</td>
<td>Thrombectomy + angioplasty + thrombolysis</td>
<td>t-PA</td>
<td>PT</td>
<td>Bolus in 1 case + 2 d in 1 case</td>
<td>2 mg bolus + 36 mg</td>
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<td>None</td>
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<td>Ferro C, 2007</td>
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<td>Thrombectomy + thrombolysis</td>
<td>UK</td>
<td>Ti</td>
<td>7 d</td>
<td>2 million U bolus + 4.9 million U</td>
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<td>–</td>
<td>Ti</td>
<td>–</td>
<td>–</td>
<td>Complete</td>
<td>None</td>
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</table>
Aspiration thrombectomy
Van, 2009
1
Thrombolysis rt-PA
SMA
12 d
55 mg
Complete
None
None
4 Small hematomas at puncture site
None

Mao-Qiang Wang, e
2009
2 partial
Thrombolysis TI
2-6 d
3.6 million U
Complete
None
4 Small hematomas at puncture site
None

Mao Qiang Wang,
e
2010
16
Thrombolysis SMA
5-11 d
7.2 million U
Complete
None
10 mg bolus + 0.4 mg/min + 5 mg/kg bolus
30 mg
4 Bloody at puncture site

G. Mauri, 2011
1
Thrombolysis rt-PA TI
3 h
15 mg bolus + 0.12 mg/min + 10 mg bolus + 0.4 mg/min + 2.5 mg
Complete
None
10 mg bolus + 0.4 mg/min + 10 mg bolus + 0.4 mg/min + 2.5 mg

Jidong Wu, 2013
4
Thrombolysis SK
48 h
2.4 million U
Complete
None
10 mg bolus + 0.4 mg/min + 10 mg bolus + 0.4 mg/min + 2.5 mg

Annabelle, 2013
1
Thrombolysis rt-PA Intraoperative
4 d
2 mg bolus + 0.4 mg/min + OV catheter
Complete
None

Garg D., 2013
1
Thrombolysis tPA TI
24 h
24 mg
Complete

UK, urokinase; SK, streptokinase; rt-PA, recombinant tissue plasminogen activator; SMA, superior mesenteric artery; PT, percutaneous transhepatic; TI, transjugular intrahepatic; OV, omental vein; SIV, systemic intravenous; PV, portal vein; SMV, superior mesenteric vein; GI, gastrointestinal; Lysis outcome: complete 90–100%, partial 50–90%, none 0–50%.

**REVIEW**

Operative thrombectomy, which was first reported by Mergenthaler and Harris in 1968, is an important part of damage control surgery for ASMVT [83]. It is carried out in order to immediately reduce thrombus burden, especially in the case involving portal venous reconstructions, such as liver transplantation. In one case series, surgical thrombectomy was carried out in six patients with acute porto-mesenteric thrombosis after liver transplantation, with a success rate of 83%, demonstrating its high efficacy [84]. In addition, operative thrombectomy affords the surgeon an opportunity to inspect the vascular Anastomosis site. Thrombectomy can help decrease a large clot burden limited to the larger vessels, but otherwise nontherapeutic for the venous arcades and vasa recta [85]. As small adherent thrombi attached to the vessel wall are extremely difficult to completely remove and serve as a nidus for thrombus propagation, the trend is thus to infuse thrombolytics to treat these undetected foci of thrombus [86].

This damage control surgery approach has a number of advantages in surgical treatment of ASMVT. Patients spend a relatively short period of time in the operating theater undergoing the insult of major surgery. There is opportunity to correct multi-organ failure, acidosis, coagulopathy and hypothermia in ICU prior to definitive operation. Moreover, the omentum can be retracted superiorly and bowel is observed directly through the dressing. Wound closure is tension free so problems related to abdominal compartment syndrome are avoided. Finally, infusion catheter can be placed into the superior mesenteric vein intraoperatively to facilitate postoperative portography and multiple endovascular therapy. Endovascular thrombolysis are implemented as hybrid procedures to reserve more questionable bowel thereby to avoid SBS, and prevent progression or further development of the thrombosis postoperatively [80].

### 3.4. Step 4: postreperfusion care

In the initial postoperative phase it is particularly important to be vigilant of ischemia-reperfusion injury on abdominal, cardiac, pulmonary and renal function, which may extend to a potentially lethal multiple organ dysfunction syndrome [18]. Patients should be managed in ICU with close monitoring and support to prevent and manage multiple organ dysfunction. Some authors recommend use of oxygen free-radical scavengers (e.g. allopurinol, angiotensin-converting enzyme inhibitors) [7]. Local infection and bacterial translocation may lead to a septic clinical episode requiring artificial ventilation and dialysis in the longer term. Intravenous heparin and broad spectrum antibiotics commenced preoperatively should be continued until culture results are available and adjusted accordingly [87]. Infusion of vasodilators such as intravenous glucagon or intra-arterial papaverine is continued under hemodynamically stable conditions [88]. Fluid balance and serum electrolytes are supposed to be monitored closely and corrected. Wound care must be taken carefully, particularly in patients with enterostomy and open abdomen. Total parental nutrition needs to be managed by specialist teams. Early enteral nutrition should be introduced as soon as possible to protect intestinal mucosal function [89]. The intestinal juice from proximal stoma is collected and transfused back to the distal stoma. Anticoagulation should be continued in the postoperative period to prevent rethrombosis of mesenteric vessels in all patients unless there are contraindications. Oral anticoagulation therapy of warfarin is maintained for 6 months after discharge for patients with known reversible factors...
but permanently for patients who is idiopathic or with thrombophilia, with the international normalized ratio (INR) 2–3 times the control value to confirm satisfactory anticoagulation level [90,91].

4. Complications

Hemorrhage, wound infection, sepsis, re-thrombosis, SBS are most common complications. In patients with peritoneal signs, the morbidity is as high as 32–71% [92]. ASMVT patients who undergo extensive bowel resection are often left with SBS, despite less common than mesenteric arterial ischemia [93]. In Mayo Clinic case series of MVT, the incidence of SBS is 26%, in significant correlation with 30-day and 5-year mortality [15,31]. Bleeding during anticoagulation alone is less than 10% and related to the underlying high risks of hemorrhage [22,94]. Gastrointestinal bleeding, especially in the mucosa necrosis site, is the most common type, but hardly associated with death except the intracranial hemorrhage. Undoubtedly, local anticoagulation together with thrombolysis increases the possibility of massive hemorrhage. However, there are no comparative data on different thrombolytics, dosage or intervention routes and the risk of hemorrhage among ASMVT patients at present. The available data from current reports are conflicting. In one report on use of urokinase or recombinant tissue plasminogen activator for catheter-directed peripheral arterial and venous thrombolysis, the rate of intracranial hemorrhage reached 1.2% [95]. Hollingshead et al. reported a high bleeding rate of 60%, with 1 death from gastrointestinal bleeding, in 20 cases of transcatheter thrombolysis for ASMVT [58]. But there are only 2 and 4 bleeding episodes during thrombolysis in other two reports of 32 and 11 portomesenteric thrombosis patients [96,97]. Ret-thrombosis rate is 0–25% in ASMVT but decreases to 0–3% with continuous anticoagulation [46]. Approximately 14% of patients who undergo resection have repeated MVT within 6 weeks [98]. Innate thrombophilia and oral contraceptive are known factors of thrombosis recurrence [94].

5. Summary and prospect

As a regular process from technical innovation to strategy optimization during the treatment evolution, management strategy update is inevitable for ASMVT with rapid development of high-
resolution CT scan, laparoscope, endovascular techniques and better understanding of pathophysiological processes. This life-saving and gut-conserving strategy meets the principle of early MVT recognition, simple algorithm with minimal physiological disturbance, and close focusing on intestinal viability. The step-wise management modality takes CT venography as main diagnostic method, initial anticoagulation as the treatment cornerstone, prompt endovascular therapies as key recanalization technique, coupled with damage control surgery operation and operative thrombectomy, has the potential to improve clinical outcome significantly. This strategy evolves in a step-up manner based on continuous assessment of intestinal viability and thrombus evolution (Fig. 3).

Due to the rareness of ASMVT, it is difficult to organize a clinical random control trial. Current treatment algorithms are mainly dependent on surgeon’s clinical experience and personal judgment, with weak basis of evidence. There are still lots of open questions in this area. Initial catheter-directed thrombolysis and local anticoagulation are better than early surgery in ASMVT patients without peritonitis, but no comparative results are available among patients with peritonitis. Definitive serum markers for early diagnosis of ASMVT are in urgent need due to the low specificity and limited clinical application of existing targets[99]. No method of differentiation between transmural and mucosal necrosis is available before bowel resection. There are no studies to help establish the indication of endovascular treatment for MVT. Criteria for different routes of transcatheater thrombolysis, for specific etiology, diverse thrombus location and extent, are lacking. All these questions have fueled more clinical evaluation and animal experiments in the future.

This new stepwise management strategy for ASMVT is an integration of modern recanalization techniques rather than a technical innovation. With this strategy, the mortality has decreased to 3% in the single institution’s experience of 34 cases of MVT at Istanbul university recently [100]. More studies with large series and systematic reviews are needed to clarify the effect and safety of this modern treatment strategy further.

Conflict of interest

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Ethical approval

This paper was designed according to the ethical principles outlined by the Declaration of Helsinki and approved by the local ethic’s committee of Jinling Hospital.

Author contribution

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Paper revision and checking: Jieshou Li.

References


