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Review Article

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Diagnosis and Management of Isolated Superior Mesenteric Artery Dissection: A Systematic Review and Meta-Analysis

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ABSTRACT

The objective of this study was to analyze the three different management modalities for isolated superior mesenteric artery (SMA) dissection. We did a comprehensive literature search and found 703 articles on the initial search, out of which 111 articles consisting of 145 patients were selected for analysis. The mean age was 55.7 years (standard deviation,9.7;33–85) and 80.6% were male. These patients were managed conservatively (41.3%), endovascularly (28.1%) or surgically (30%). The median follow-up was 10 months (interquartile range [IQR], 4–18 months), 12 months (IQR, 6–19 months) and 14 months (IQR, 6–20 months) respectively. Contrast-enhanced computed tomography (CT) was the most commonly used diagnostic tool in the conservative group (43.8%), while conventional CT scan was the most widely used in endovascular (58.1%) and surgical group (50%). 17% percent of the conservative group had SMA angiography for diagnosis, while this was less than 3% in the other groups. Of these patients, 96.7%, 97.4%, and 100.0% recovered successfully in the conservative, endovascular, and surgical groups respectively. There was no significant difference in the mortality between the three groups (Pearson χ^2=0.482). This suggests a conservative and endovascular approach could be used in most patients, which can reduce costs and surgery-related morbidity and mortality. Surgical management should be reserved for cases having infarction or widespread bowel ischemia and in cases where other treatment modalities fail.

Keywords: Arterial dissection; Spontaneous dissection; CT angiography; Arteriography Endovascular repair

INTRODUCTION

Aortic dissection can frequently extend into its peripheral territories. Medical literature reports many cases of renal, coronary, intracranial and visceral artery involvement in aortic dissection.[1)2)] However it is rare for these branches to have dissection in the absence of main

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The authors have no financial conflicts of interest.

Author Contributions
Conceptualization: Ullah W; Data curation: Abdullah HMA, Ahmad A; Formal analysis: Ullah W, Mukhtar M, Abdullah HMA, Ahmad A, Ur Rashid M, Hurairah A, Sarwar U, Figueredo VM; Investigation: Mukhtar M; Resources: Sarwar U; Supervision: Ullah W, Figueredo VM; Validation: Figueredo VM; Visualization: Hurairah A; Writing - original draft: Ullah W, Ahmad A; Writing - review & editing: Ullah W.

aortic trunk involvement.[3] Among visceral arteries, superior mesenteric artery (SMA) is the commonest type of dissection when compared with other gastrointestinal arteries such as the splenic, hepatic, celiac and gastric arteries.[4] However, isolated SMA dissection is believed to be rare. Due to its rarity, clinical presentation, use of imaging studies, management, and outcome of SMA dissection has not been investigated in detail. The purpose of this systematic review is to identify the burden, provide a classification tool and delineate the diagnostic and management algorithms of isolated SMA dissection.

Watson[5] in 1956 for the first time introduced arterial dissection as a condition resulting from blood penetration into arterial wall, causing a split between the vessel layers, with or without a tear of the tunica intima (inner vessel layer). However, the first case of SMA dissection was reported before that by Bauersfeld[6] in 1947 as an incidental autopsy finding in a patient who died of multiple vessels aneurysms. Since then, there was a gradual increase in SMA dissection related deaths and 11 more cases were found on autopsy findings up to 1972.

From 1975 to 1999 the number of SMA dissection cases rose to 23, with 71 cases reported from 2000 to 2009. Interestingly, the incidence of SMA dissection related mortality during this period decreased significantly and only one case of SMA dissection related death was reported since 1972.[7] Since 2009, fifty two more cases of SMA dissection were reported, with a further decline in mortality, with only one case resulting in death.[8] This higher incidence and decreased mortality related to SMA dissection is likely due to the introduction of contrast-enhanced computed tomography (CT) scan for abdominal pain investigation, which results in an earlier diagnosis. Patients can have a self-limited course or the SMA dissection can potentially be fatal depending upon the nature of vessel involvement and the underlying health condition of the patients. It generally can have one of the four courses; cessation of SMA dissection with no long term sequelae, progressive involvement of the whole vessel, dissecting aneurysm joining the true lumen, or rupture of the vessel causing severe bleeding.

The presumed mechanism of SMA dissection is intimal or vasa vasorum tear leading to hemorrhage in the medial and adventitial layers which can extend over a variable distance.[6][9-12] Segmental arterial mediolysis, congenital connective tissue disorders, arteriosclerosis, cystic medial necrosis, vasculitis and fibromuscular dysplasia have been reported as potential causes of SMA dissection (**Table 1**).[13-15] Interestingly, many patients who initially presented with a sudden onset of abdominal pain and had ultrasound and X-ray were diagnosed as having gastroenteritis, gastric or nonspecific pain, and had to return within a week to be correctly diagnosed with having SMA dissection.[15]

Sakamoto et al.[3] for the first time classified SMA dissection into four types based on the findings on contrast-enhanced CT scanning and described its management as reported in **Table 1** and illustrated in **Figure 1**. However this observation was only based on a study of 12 patients and large-scale studies are required to validate this data.

Table 1. Sakamoto classification of SMA dissection based on CT scan findings and its management

Type	Angiographic findings	Management
Type I	Both true and false lumen patent showing entry and re-entry sites	Conservatively, regular follow up
Type II	False lumen patent with entry but no re-entry flow (Cul-de-sac)	Revascularization
Type III	False lumen thrombosed. True lumen has ulcer like projections	Urgent revascularization
Type IV	Thrombosed false lumen but has no ulcer like projections	Resolves on its own, no follow up needed

CT = computed tomography; SMA = superior mesenteric artery.

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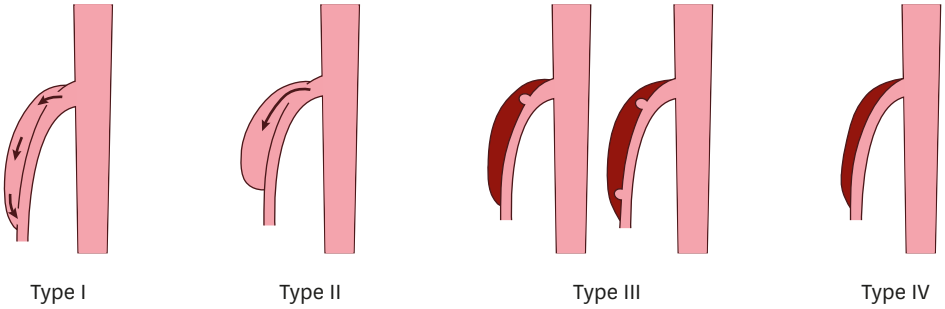

Figure 1. Type I: Patent false lumen; Type II: False lumen without re-entry; Type III: thrombosed false lumen with an ulcer-like projection; Type IV: completely thrombosed false lumen with no ulcer like projection.

An increasing number of patients with SMA dissection who are hemodynamically stable are treated conservatively. Along with anticoagulation therapy (heparin drip or warfarin), conservative management includes antiplatelets like cilostazol and ticlopidine, bowel rest and control of risk factors like hypertension. Anticoagulation does not revert or halt the progression of dissection but prevents thrombus formation and its distal embolization. It is recommended to have complete bowel rest and administer intravenous heparin until the abdominal pain settles. Oral anticoagulants and antiplatelet medications are continued until resolution of radiological images.[16]

Hemodynamically unstable patients having signs and symptoms of ischemia or those with radiological evidence of progression or worsening SMA dissection, such as formation of thrombus, narrowing or saccular aneurysm formation, should have urgent revascularization, as they are at high risk of rupture. The two main revascularization techniques are endovascular or surgical repair. A surgical procedure is inevitable in cases of bowel infarction or SMA rupture.[3] The extent and type of surgery depends on the viability of gut, type of dissection and the reversibility of circulation. Sisteron and Viveville[17] in 1975 performed the first SMA surgical revascularization using a saphenous vein graft.

Endovascular management includes intralesional thrombolytic therapy, stent placement, embolotherapy and balloon angioplasty. Leung et al.[18] first described percutaneous stent placement for SMA dissection. Endovascular technique is a minimally invasive procedure, prevents progression of dissection and provides instant relief from ischemia with shorter hospital stays.

METHODS

Search strategy

A literature search for relevant articles was performed by 2 authors independently on May 25, 2018, using MEDLINE (PubMed, Ovid), Embase, Scopus and Cochrane databases. There was no language or time restriction placed on the search. We were specifically looking for articles on SMA that described the three treatment modalities used for the management of SMA. These included conservative, surgical and endovascular management. The search strategies included various combinations of text-words and medical subject headings (MeSH) to generate two subsets of citations: one for SMA, using the MeSH and terms like “SMA”, “SMA dissection”, “superior mesenteric artery”, “superior mesenteric artery dissection”, “mesenteric artery dissection”, “intestinal artery dissection”, “spontaneous dissection of SMA”, and “spontaneous dissection of superior mesenteric artery” and the other for its management using terms and MeSH like

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"conservative", "heparin", "coumadin", "antiplatelet", "graft", "stent", "surgery", "patch", "resection". The terms from the 2 subsets were combined in 1:1 combination using the Boolean operators "AND" and "OR". Results from all the possible combinations were downloaded into an EndNote library. Based on our research question, a third author manually searched the references in all known articles to identify studies that were missed by the initial search.

Selection criteria

The selection criteria for the included studies was all reported case reports, case series and review articles on SMA dissection describing its presentation, diagnosis, management and/or post management follow up. Studies with insufficient data, discussing only the mechanism or histology and conference papers were excluded, as were studies with not enough description of its subjects.

Study selection

The titles and abstracts of the selected articles were reviewed independently by three authors and the articles which met inclusion criteria were reviewed by a fourth author. Full-text articles that were potentially relevant to the study were also reviewed by all the four authors to confirm the eligibility. Disagreements were resolved by mutual consensus and after a detailed group discussion.

RESULTS

Initially, we retrieved a total of 261 articles after removing duplicates, out of which 111 articles were relevant to our case. Interestingly, the timeline of the articles included was very broad, ranging from articles published in 1975 all the way to 2017. It is important to note that the number of published articles on SMA dissection has seen a steep increase in the last couple of decades due to the increasingly widespread use of CT scan and the resultant increase in the number of diagnosed cases."

SMA dissection occurred in 80.6% males (n=117/145), and 17.2% females (n=25/145). The age of individuals ranged from 33 to 87 years with a mean age of 55.7 years (standard deviation, 9.7; 33–87). Data extraction from the review articles revealed that 41.3% cases (n=60/145) managed SMA dissection by conservative approach using anticoagulants, antiplatelets and antihypertensives. Endovascular approach (stenting, embolotherapy and thrombolysis) was employed in about 29.6% (n=43/145) whereas open surgical repair was done in 28.9% (n=42/145) (**Figure 2**).

The overall results were satisfactory after treatment as 91.7% (n=133/145) patients survived without complications. Only 5 cases resulted in death. Others developed acute diverticulitis, acute mesenteric ischemia, ligament of Treitz abscess and bilateral lower limb paralysis each. Poor recovery was observed in the case of bilateral lower limb paralysis, whereas the rest fully recovered from their complications.

DISCUSSION

Etiology

The exact etiology of isolated SMA dissection remains unknown, though many conditions have been found to be associated with SMA dissection. In our study, 22.7% (n=33/145) of the

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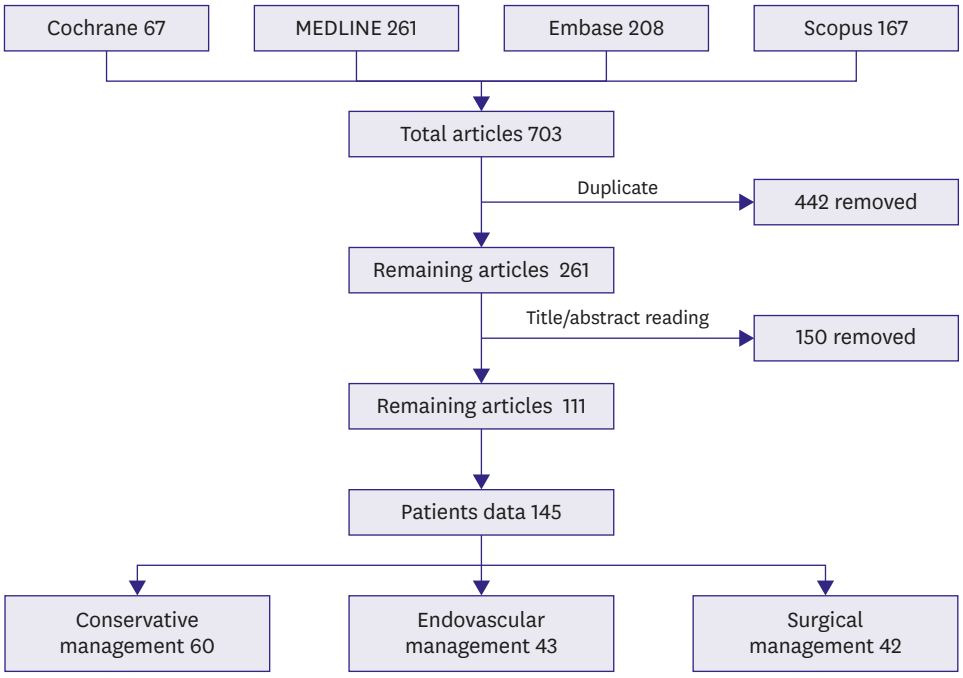

Figure 2. Prisma flow sheet showing the search strategy on isolated SMA dissection.
SMA = superior mesenteric artery.

patients were known hypertensives or presented with markedly high blood pressures (above 160/100 mmHg). Cigarette smoking was found in 18.6% of the cases (n=27/145).[19-21] A history of trauma was found to be associated with four or 2.7% (n=4/145). One patient had a seat belt trauma associated SMA dissection due to low-velocity motor vehicle accident, while another had trauma related SMA aneurysm, leading to presumed dissection.[22][23] Only a few iatrogenic SMA dissection cases were reported, following translumbar aortography with the use of balloon catheter, or due to mesenteric angioplasty in the treatment of chronic mesenteric ischemia.[24-26]

Symptoms

The most common presentation in our study was sudden onset of pain, either abdominal 55.8% (n=81/145), epigastric 22.7% (n=33/145), periumbilical 4.8% (n=7/145), back pain 4.8% (n=7/145), or chest 2.0% (n=3/145). Most of these patients presented acutely within 4 weeks of the onset of symptoms possibly due to bowel ischemia and/or infarct.[15][27] Only 2.0% patients presented with shock along with abdominal pain (n=2/145) due to rupture of the dissecting SMA and eventually died.[7][11] Approximately 2.7% presented with melena (n=4/145). Besides these, patients commonly presented with nausea, vomiting and abdominal distension. We believe that physicians should follow the American Gastroenterological Association guidelines and should consider diagnostic work-up in an appropriate clinical setting for acute mesenteric ischemia in every patient with a history of unexplained abdominal pain for more than 2–3 hours.[28]

In our study about twelve patients or 8.2% had chronic symptoms lasting for more than a month, which included nausea, vomiting, diarrhea, melena, postprandial pain, and weight loss.[19] This suggests that SMA dissection can have a subacute or chronic course and physicians should have a high index of suspicion in an appropriate setting. Seven patients or

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4.8% had SMA dissection discovered either on autopsy or as an incidental finding on CT scan performed for pancreatitis or other reasons.[27][29-31]

Diagnosis

SMA dissection should be suspected in all patients presenting with intractable abdominal pain, and having one or more risk factors for vascular atherosclerotic disease.[21]

Our review showed that contrast enhanced abdominal CT scan and plain CT scan were used almost equally in 35.8% and 36.5% (n=52/145 and n=53/145) of cases. In 42.1% cases (n=61/145) CT angiogram was used, while very few patients had arteriography for the diagnosis of SMA dissection. The accuracy of CT angiogram is almost the same as conventional arteriography with the benefits of decreased morbidity and lower radiation exposure. It also provides a three-dimensional view of luminal borders and extraluminal organs and can be performed more quickly compared to conventional arteriography.[12][14][21][32][33]

Eight cases (5.5%, n=8/145) used digital subtraction angiography (DSA) as a diagnostic tool, which has the luxury of doing therapeutic intervention like thrombolysis and stenting if required with very little additional contrast. But we believe it should be reserved for patients with worsening symptoms, who requires endovascular treatment or surgical intervention as it is a very invasive procedure.[3]

A number of other imaging and surgical modalities were used to diagnose SMA dissection. Magnetic resonance angiography (MRA) and diagnostic laparoscopy were used in one case each 0.6% (n=1/145) while 2 patients or 1.3% were diagnosed on laparotomy.[34][35] Platelet scintigraphy was useful to determine the patency and thrombosis of false lumen (e.g., type IV Sakamoto CT classification).[3][29] Ultrasound was successfully used in making the diagnosis of seven patients or 4.8% of the patients, demonstrating the intimal flap while it missed SMA dissection in nine patients or 6.2% of the patients[36][37] This flap is sometime hidden behind the thrombus of the false lumen of SMA; contrast-enhanced CT is a better alternative in such cases.[38] Doppler ultrasound helped in the diagnosis of only seven patients or 4.8% of the patients but was very useful in the operating room for the assessment of bowel viability. It also helped to decide about the type of vascular intervention and for the post intervention surveillance of patients.[39] Of note, there was no role for blood tests or abdominal X-rays in the diagnosis of SMA dissection.

Moreover, this review also showed that the extent and type of diagnostic modality can direct towards appropriate management. Based on the review of the literature we suggest that symptomatology and clinical features of the patient should direct physicians for appropriate diagnostic testing as illustrated in **Figure 3**.

MANAGEMENT

Conservative

Our systematic review showed that the most common treatment modality utilized was conservative treatment in about 41.3% (n=60/145). These patients were hemodynamically stable and had no clinical or imaging evidence of ruptured SMA dissection.[9] They had successful resolution of symptoms during their mean follow up of 16.4 month (0.5–83 month) with no mortality, even in cases of 90% SMA involvement (**Table 2**). Hence, we deduce that a trial of

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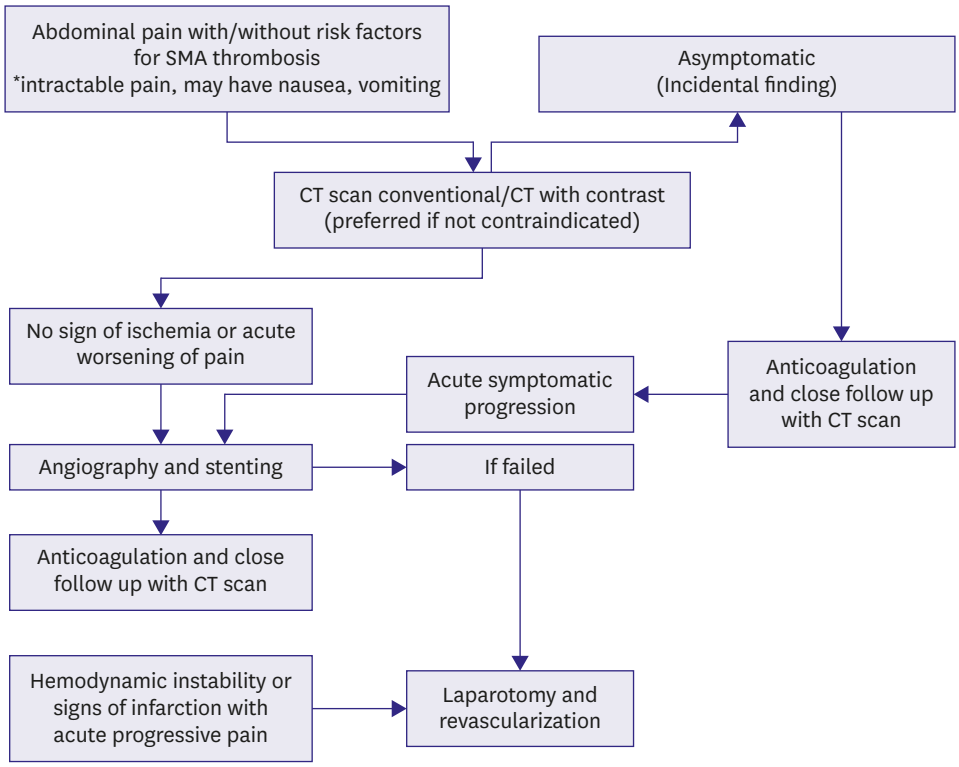

Figure 3. Flow sheet for diagnostic testing for SMA dissection based on symptomatology.
CT = computed tomography; SMA = superior mesenteric artery.

Table 2. Characteristics of conservatively managed isolated SMA dissection

No.	Year	Author	Age/Sex	Conservative management	Outcome	Follow up
1	2017	Léonard et al.[41]	57/M	Conservative	Good	N/A
2	2016	Spence et al.[42]	33/F	Conservative	Good	18 months
3	2016	Hoek et al.[43]	48/M	Conservative	Good	N/A
4	2016	Funahashi et al.[44]	58/M	Conservative	Good	12 months
5	2016	Funahashi et al.[44]	67/M	Conservative	Good	60 months
6	2016	Nath et al.[45]	68/F	Conservative	Good	0.5 months
7	2015	Jia et al.[46]	70/M	Antihypertensives, anticoagulants	Good	10 months
8	2015	de l'Escalopier et al.[47]	51/M	Bowel rest, antiplatelets, anticholesterol agents	Good	12 months
9	2015	Daghfous et al.[48]	40/M	Antiplatelets, antihypertensives	Good	N/A
10	2015	Zink et al.[49]	55/M	Antihypertensives	Paralysis of lower extremities, Decreased renal function	N/A
11	2015	Akuzawa et al.[8]	38/M	Heparin/Warfarin	Good	11 months
12	2015	Akuzawa et al.[8]	62/M	Heparin	Poor	Death
13	2015	Akuzawa et al.[8]	38/M	Heparin/warfarin	Good	11 months
14	2014	Moreno-Machuca et al.[50]	46/M	Anticoagulant (bemiparine), antihypertensives, analgesics	Good	24 months
15	2014	Ogul et al.[51]	40/M	N/A	N/A	N/A
16	2014	Zinsser et al.[52]	61/M	Antihypertensives, antiplatelets, heparin, statins	Good	1 month
17	2014	Ham et al.[53]	56/M	Conservative	Good	N/A
18	2014	Corral et al.[54]	42/M	Antiplatelets	Good	14 months
19	2014	Corral et al.[54]	85/M	Anticoagulants	Good	N/A
20	2013	Davis and Kendall[55]	46/M	Intravenous labetalol and nitroprusside	N/A	N/A
21	2012	Yoo et al.[56]	56/M	Conservative	Good	17 months
22	2012	Shimizu and Tokuda[57]	61/M	Conservative	Good	6 months

(continued to the next page)

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Table 2. (Continued) Characteristics of conservatively managed isolated SMA dissection

No.	Year	Author	Age/Sex	Conservative management	Outcome	Follow up
23	2012	Kokai et al.[58]	56/M	Antihypertensives, anticoagulants, antiplatelets	Good	47 months
24	2011	Namikawa et al.[59]	59/M	Conservative	Good	4 months
25	2011	Kang et al.[60]	46/M	Heparin, steroids	Good	1 month
26	2010	Saba et al.[61]	49/M	Prostaglandin E1	Good	3 months
27	2010	Bair et al.[62]	72/M	Antihypertensives	Good	N/A
28	2009	Subhas et al.[63]	56/F	Heparin	Acute diverticulitis after 2 months (treated with antiobiotics)	2 months
29	2009	Mousa et al.[64]	57/M	Heparin, warfarin	Good	18 months
30	2009	Totsugawa et al.[65]	51/M	Prostaglandin E1	Good	N/A
31	2009	Totsugawa et al.[65]	56/M	Prostaglandin E1	Good	10 months
32	2009	Jang et al.[66]	58/M	Proton pump inhibitors	Good	2 months
33	2008	Tsai et al.[21]	49/M	Antihypertensives	Good	N/A
34	2008	Ghuysen et al.[67]	38/M	Heparin, antiplatelets	Good	3 months
35	2008	Morris et al.[68]	56/M	Heparin, warfarin	Good	5 months
36	2008	Morris et al.[68]	62/F	Conservative	Good	5 months
37	2008	Takayama et al.[69]	58/M	Conservative	Good	83 months
38	2007	Sakamoto et al.[3]	58/M	Conservative	Good	7 months
39	2007	Sakamoto et al.[3]	43/M	Conservative	Good	38 months
40	2007	Sakamoto et al.[3]	60/M	Conservative	Good	60 months
41	2007	Sakamoto et al.[3]	52/M	Conservative	Good	72 months
42	2007	Sakamoto et al.[3]	48/M	Conservative	Good	36 months
43	2006	Chang et al.[20]	49/M	Conservative	Good	3 months
44	2006	Lee et al.[70]	57/M	Conservative	Good	24 months
45	2004	Nagai et al.[16]	59/M	Heparin, ticlopidine	Good	12 months
46	2004	Nagai et al.[16]	56/M	Heparin, warfarin, ticlopidine	Good	5 months
47	2004	Nagai et al.[16]	49/M	Heparin, warfarin, ticlopidine	Good	4 months
48	2004	Nozu et al.[71]	55/M	Anticoagulation	Good	8 months
49	2004	Suzuki et al.[39]	54/F	Anticoagulation	Good	4 months
50	2004	Suzuki et al.[39]	50/M	Conservative	Good	4 months
51	2004	Suzuki et al.[39]	60/M	Conservative	Good	5 months
52	2004	Suzuki et al.[39]	50/M	Conservative	Good	2 months
53	2003	Sartelet et al.[7]	44/M	Fluid resuscitation	Death	N/A
54	2002	Furukawa et al.[33]	52/M	Conservative	Good	12 months
55	2002	Takayama et al.[72]	63/M	Warfarin	Good	6 months
56	2001	Sheldon et al.[14]	41/M	Coumadin	Good	22 months
57	2000	Matsou et al.[73]	58/M	Conservative	Good	N/A
58	1998	Yasuhara et al.[19]	45/M	Conservative	Good	24 months
59	1998	Yasuhara et al.[19]	55/M	Conservative	Good	12 months
60	1998	Dushnitsky et al.[74]	58/M	Conservative	Good	16 months

F = females; M = males; N/A = not available; SMA = superior mesenteric artery.

anticoagulation therapy as a conservative approach is warranted in all cases of uncomplicated SMA dissection.[40] This is especially true for Sakamoto type I and IV dissection.

Surgical revascularization

We found that about 28.9% (n=42/145) patients underwent surgical management and that bypass grafting was the commonest procedure. Bypass grafting was performed in 57.1% (n=24/42) patients, in which a saphenous vein graft was used in 12 cases. Infrarenal aortoiliac bypass, superior aortomesenteric prosthetic bypass, radial artery bypass and right gastroepiploic bypass were used in one case each. Other grafts used in our review included superficial femoral artery, radial artery and prosthetic grafts. SMA was directly anastomosed to the infrarenal artery in a few cases to avoid graft-related complications. Thrombectomy was performed in 16.6% cases (n=7/42) whereas arteriotomy and intimectomy were performed in 9.5% cases each (n=4/42). Ligation of a branch of SMA was carried out in one case (**Table 3**).

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Table 3. Characteristics of surgically managed isolated SMA dissection

No.	Year	Author	Age/Sex	Surgical procedure	Outcome	Follow up
1	2016	Mitsuoka et al.[77]	45/M	Laparotomy, arteriotomy, stenting of SMA	Good	6 months
2	2015	Dzieciuchowicz et al.[78]	42/F	Thrombendarterectomy	Good	30 months
3	2014	Wall et al.[79]	65/M	Infrarenal aortoiliac grafting	Good	6 months
4	2011	Carter et al.[80]	57/F	Great saphenous vein grafting	Good	6 months
5	2011	Tameo et al.[81]	51/M	Ligation of a branch of SMA	Good	6 months
6	2011	Mei et al.[82]	58/F	Arteriotomy of the inferior mesenteric artery, thrombectomy, great saphenous vein grafting	Good	N/A
7	2010	Hwang et al.[83]	54/M	Intimectomy, great saphenous vein patch angioplasty	Thrombus formation (resolved with anticoagulation)	12 months
8	2009	Bruns et al.[84]	47/M	Thrombendarteriectomy	Good	5 months
9	2008	Morris et al.[31]	39/F	Enterectomy, hemicolectomy, small bowel transplant	Good	24 months
10	2007	Sakamoto et al.[3]	45/M	Surgery	Good	40 months
11	2006	Matsushima[76]	51/M	Laparotomy	Good	N/A
	2006	Armstrong and Franklin[85]	64/M	Laparotomy, resection of aneurysm, interposition vein grafting of pancreaticoduodenal artery	Good	24 months
12	2005	Picquet et al.[27]	53/F	Saphenofemoral grafting, cholecystectomy, percutaneous jejunostomy	Good	6 months
13	2005	Kochi et al.[86]	43/M	Bypass grafting	Good	6 months
14	2004	Tsuji et al.[87]	44/M	Endoaneurysmorraphy	Good	15 months
15	2003	Javerliat et al.[4]	68/M	Dissection of aneurysm	Good	6 months
16	2003	Javerliat et al.[4]	61/F	Closure of arteriotomy, thrombus removal	Good	5 months
17	2003	Javerliat et al.[4]	51/M	Small bowel resection, jejunostomy	Good	30 months
18	2002	Kugai and Chibana[88]	51/M	Resection, SMA interposition with SV	Good	N/A
19	2002	Hirai et al.[89]	42/M	Radial artery grafting	Good	N/A
20	2002	Yamashiro et al.[90]	67/M	Saphenous vein bypass grafting	Good	12 months
21	2002	Gouëffic et al.[36]	56/M	Superior aortomesenteric prosthetic bypass grafting, end to end distal anastomosis	Good	3 months
22	2001	Wadhwani et al.[91]	61/M	Resection of aneurysm	Good	N/A
	2000	Zimmerman-Klima et al.[23]	49/M	Resection of aneurysm, aorto-SMA bypass	Good	N/A
23	2000	Iha et al.[92]	46/M	Aortomesenteric bypass with Saphenous vein	Good	N/A
24	2000	Sparks et al.[93]	41/M	Resection of aneurysm	Good	12 months
25	1999	Common et al.[94]	69/M	Laparotomy	Good	132 months
26	1998	Barmier et al.[12]	48/F	SMA thrombectomy	Good	0.23 months
27	1997	Nakamura et al.[29]	44/M	Laparotomy, resection of transverse colon	Good	48 months
28	1995	Ando et al.[13]	47/M	Resection, SMA transposition	Good	48 months
29	1993	Solis et al.[22]	45/F	SMA thrombectomy, intimectomy, aneurysmorraphy	Good	6 months
30	1992	Vignati et al.[35]	50/M	Right gastroepiploic artery bypass grafting	Good	12 months
31	1992	Chaillou et al.[1]	64/F	Bypass grafting	Good	6 months
32	1992	Suzuki et al.[39]	57/F	Bypass grafting	Good	9 months
33	1992	Suzuki et al.[39]	78/M	Laparotomy	Good	3 months
34	1992	Cormier et al.[40]	50/M	Intimectomy, angioplasty	Good	6 months
35	1992	Cormier et al.[40]	52/M	Bypass grafting	Good	24 months
36	1992	Cormier et al.[40]	41/M	SMA angioplasty	Good	36 months
37	1992	Cormier et al.[40]	60/M	Bypass grafting	Good	48 months
38	1989	Corbetti et al.[95]	62/M	Resection	Good	N/A
39	1989	Corbetti et al.[95]	52/M	Arteriotomy, Fogarty procedure	Good	N/A
40	1989	Koto et al.[96]	53/M	Resection, SV aortomesenteric bypass	Good	N/A
41	1988	Takehara et al.[32]	50/M	Aortomesenteric bypass	Good	N/A
42	1985	Krupski et al.[97]	51/F	SMA thrombectomy, intimectomy, saphenous vein grafting	Good	48 months
43	1976	Rignault et al.[34]	50/M	SMA transposition	Good	N/A
44	1975	Sisteron et al.[17]	N/A	Saphenous vein graft	Good	N/A

F = females; M = males; N/A = not available; SMA = superior mesenteric artery; SV = splenic vein.

Some cases among the selected articles were complicated with aneurysms as well. In these cases, aneurysms were resected in 16.6% (n=7/42) and aneurysmorrhaphy was performed

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in 4.8% cases (n=2/42) along with grafting. In a review of 30 cases by Stanley et al.[75] simple ligation of communicating vessels with SMA aneurysm was successful (**Table 3**).

Only one patient had hemicolectomy and small bowel transplant while another had small bowel resection and jejunostomy due to bowel infarct because of the SMA dissection.[31] Cholecystectomy and percutaneous jejunostomy was executed in a solitary case, and in a single patient embolectomy with Fogarty procedure was carried out.

Modified surgical techniques such as endoaneurysmorrhaphy was adopted for extended dissections, as this helped to preserve the patent collateral circulation. Certain limited access procedures like patch angioplasty after intimectomy for small dissection was also beneficial. In some cases laparotomy was performed due to suspected bowel infarction but no intervention was done due to the absence of any ischemia or infarction.[76]

These surgical interventions for SMA dissection had successful resolution of symptoms on their mean follow up of 15.8 months where the follow up ranged from 0.23 to 48 months.

Endovascular revascularization

The results of our systematic review showed that 29.6% patients (n=43/145) underwent endovascular repair of SMA dissection (**Table 4**). SMA stenting was used in 88.3% cases (n= 38/43). Other procedures executed were thrombolysis with urokinase in 18.6% (n=8/43) of patients. However, it was given as an intralesional infusion in only half of the patients (n=4/8), and most of these patients underwent subsequent stenting, while one patient had laparotomy due to ischemic bowel within 4 hours of infusion for pain. Therefore, the utility of urokinase cannot be established by this review and larger scale studies are required. 4.6% (n=2/43) had embolotherapy through a vascular procedure, but regular follow up of such patients is needed to determine its long-term effects. In one case a laparoscopic cholecystectomy was performed alongside stenting highlighting that other intraabdominal pathologies can also be addressed in conjunction with this technique.

In most cases, stents up to a diameter of 10 mm and lengths of 10 cm were used. There is not enough data on the types of stents to be used but self-expandable stents are popular among the gastroenterologists.[98][99] Kim et al.[100] in his study described the use of special types of covered stents on two patients due to its high flexibility, stability and minimal shortening. The number of stents varied in different studies ranging from a single up to three stents.[15][98][101][102]

In cases of complicated SMA dissection combined approach with endovascular arterial stenting and eventual bowel resection can be considered in unstable patients with a contaminated cavity.[99]

Iwase et al.[121] and Kutlu et al.[122] described the importance of balloon angioplasty in a patient with SMA dissection with complete narrowing of the true SMA lumen. Sakamoto et al.[3] used embolotherapy with microcoils in a patient presenting with a large mesenteric hematoma due to SMA rupture. The management protocol is illustrated in **Figure 4**.

The follow up in these patients who underwent endovascular revascularization ranged from 2 to 50 months, with an average follow up of 16 months. Longer follow ups are needed to determine the efficacy of endovascular management.

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Table 4. Characteristics of endovascularly managed isolated SMA dissection

No.	Year	Author	Age/Sex	Endovascular intervention	Outcome	Follow up
1	2017	Nishi et al.[103]	49/M	Antihypertensives, antiplatelets, stenting of SMA	N/A	N/A
2	2017	Gao et al.[104]	58/M	Antihypertensives, antiplatelets, stenting of SMA	Good	6 months
3	2016	Akpınar et al.[105]	53/M	Heparin, thrombolysis, stenting of SMA	Good	6 months
4	2015	Jia et al.[106]	49/M	Stenting of SMA, antiplatelets, antihypertensives	Good	24 months
5	2015	Sirignano et al.[107]	45/M	Stenting of SMA	Good	10 months
6	2014	Chang et al.[108]	56/M	Stenting of SMA	Good	3 months
7	2013	Saguchi et al.[30]	82/M	Stenting of SMA, heparin, antiplatelets	Death	24 months
8	2013	Lee et al.[109]	71/F	Stenting of SMA, antiplatelet therapy	Good	14 months
9	2012	Nakai et al.[110]	73/M	Stenting of SMA	Thrombosis of the SMA pseudoaneurysm after 1 week (treated with warfarin)	7 months
10	2011	van Uden et al.[111]	52/M	Stenting of SMA	Good	6 months
11	2011	Lim et al.[112]	46/M	Enoxaparin, aspirin, clopidogrel, stenting of SMA	Good	13 months
12	2011	Lim et al.[112]	48/M	Enoxaparin, aspirin, clopidogrel, stenting of SMA	Good	14 months
13	2011	Yang et al.[113]	43/M	Thrombolysis with urokinase, stenting of SMA	Good	24 months
14	2011	Nomura et al.[114]	70/F	Stenting of SMA	Good	18 months
15	2011	Carter et al.[115]	45/F	Heparin, stenting of SMA	Good	6 months
16	2010	Watring et al.[15]	44/F	Clopidogrel, stenting of SMA	Ligament of Treitz abscess (resolved with drainage and antibiotics)	N/A
17	2010	Kwak et al.[116]	52/M	Stenting of SMA	Good	4 months
18	2010	Patel et al.[117]	75/M	Stenting of SMA	Good	6 months
19	2009	Wu et al.[118]	53/M	Enoxaparin, clopidogrel, stenting of SMA	Good	9 months
20	2009	Wu et al.[118]	66/M	Stenting of SMA, aspirin, clopidogrel	Good	7 months
21	2009	Gobble et al.[119]	43/M	Anticoagulation, stenting of SMA	Good	19 months
22	2009	Gobble et al.[119]	48/M	Stenting of SMA	Good	12 months
23	2009	Gobble et al.[119]	78/F	Stenting of SMA	Good	11 months
24	2009	Baldi et al.[120]	50/M	Heparin, stenting of SMA	Good	12 months
25	2008	Casella et al.[99]	51/M	Stenting of SMA	Good	30 months
26	2007	Sakamoto et al.[3]	47/M	Embolotherapy	Good	50 months
27	2007	Sakamoto et al.[3]	51/M	Embolotherapy	Good	38 months
28	2007	Sakamoto et al.[3]	61/M	Thrombolysis	Good	48 months
29	2007	Sakamoto et al.[3]	49/M	Thrombolysis	Good	36 months
30	2007	Sakamoto et al.[3]	47/M	Thrombolysis	Good	12 months
31	2007	Sakamoto et al.[3]	44/M	Thrombolysis	Good	38 months
32	2007	Iwase et al.[121]	57/M	Stenting of SMA, anticoagulation	Good	N/A
33	2007	Kutlu et al.[122]	74/M	Stenting of SMA, heparin, aspirin	Good	12 months

F = females; M = males; N/A = not available; SMA = superior mesenteric artery.

Follow up

There are no available guidelines for the interval of follow-up and imaging studies for SMA dissection patients. More studies are needed to determine the long-term benefits of each of the different management modalities. In our review, the cumulative follow up for all studies ranged from 1 week to 7.5 years. This longest follow up was observed in a patient who was managed conservatively and there were no further SMA dissection episodes reported. The longest follow-up for endovascular treatment was 4.1 years, and 11 years for surgical procedure in 3 patients.[3][93] We believe that repeat CT scans should be performed on follow up in all patients to monitor the progression/resolution of SMA dissection in cases of conservatively managed SMA dissection and to look for the patency of stenting in endovascularly managed cases. Similarly, CT scan, if performed on regular follow up, can

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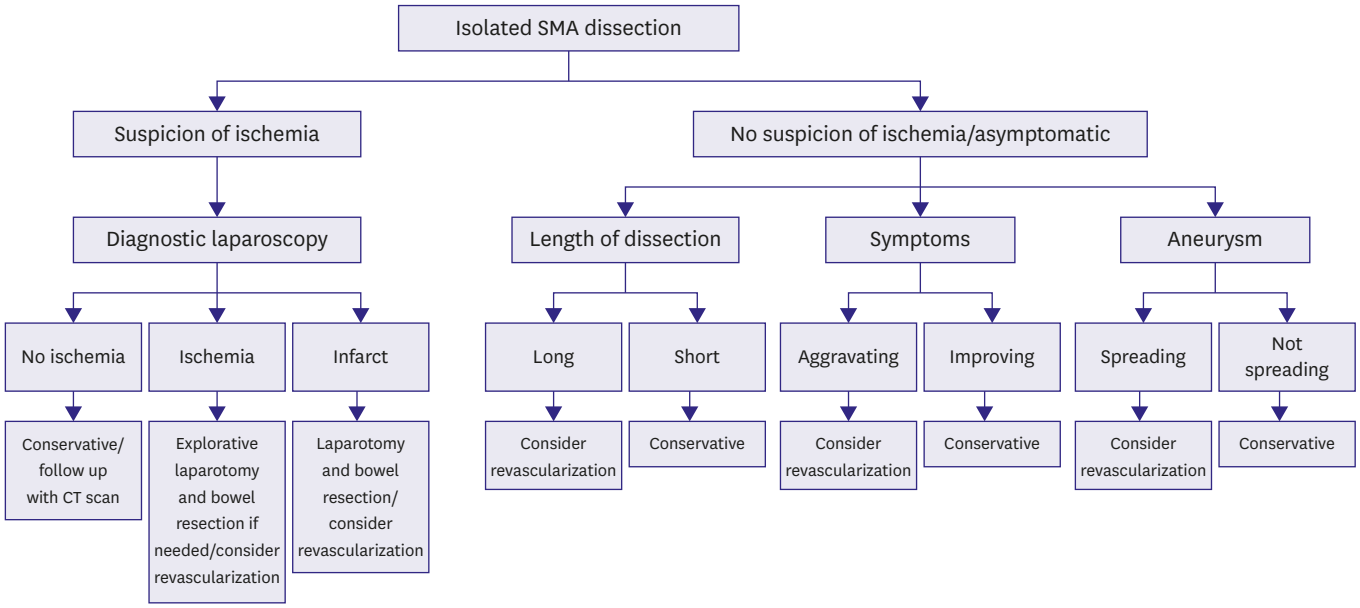

Figure 4. A flow diagram for management approach of isolated SMA dissection.
CT = computed tomography; SMA = superior mesenteric artery.

give an idea about post-surgical long-term complications in SMA dissection patients. Our review showed that the interval of follow up and hence the duration of post management imaging varied widely among all studies. In a study by Sakamoto et al.,[3] a CT scan was performed weekly initially for the first month and then only twice or thrice over the span of years thereafter. We advocate that there should be evidence-based recommendations for regular follow up imaging for each treatment modality of SMA dissection.

CONCLUSION

SMA dissection is strongly associated with hypertension and smoking, presents mostly with intractable acute abdominal pain but can also be picked up as an incidental finding on CT scan or angiography. The conservative and endovascular management approach could be used in most patients, which can reduce costs and surgery-related morbidity and mortality. Surgical management should be reserved for complicated cases where conservative or endovascular management has no role or when there are other compelling indications for surgery like vessel rupture or bowel infarction. Our study furthermore revealed that there was no concordance among the 145 cases when it came to follow up and imaging studies but serial CT scans for monitoring the progress or resolution of SMA dissection is of paramount importance in conservatively managed cases while CT angiography is beneficial as arteriography for monitoring stent patency in endovascularly managed cases and for monitoring post-surgical complications.

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