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Diagnostic Laparoscopy for Early Detection of Acute Mesenteric Ischaemia in Patients with Aortic Dissection

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WHAT THIS PAPER ADDS

- Our study reports the largest series of diagnostic laparoscopy in patients with aortic dissection, and the results show that it is feasible and safe. Even though further investigation is needed, we believe that diagnostic laparoscopy represents a valuable diagnostic tool in these complex patients and helps to avoid more invasive procedure, such as exploratory laparotomy.

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ABSTRACT

Introduction: Recognition of acute mesenteric ischaemia (AMesI) in patients with aortic dissection (AoD) may be a challenge and exploratory laparotomy is often performed.
Methods: We retrospectively analysed our experience with the use of diagnostic laparoscopy (DL) for the early detection of AMesI in patients with AoD, either undergoing medical treatment or after open/endovascular interventions.
Results: Between 2004 and 2011, 202 consecutive AoDs were treated in our centre (71 acute type A AoD; 131 acute and chronic type B AoD). Among the 17 (8.4%) patients in which AMesI was suspected, nine (52.9%) were selected for DL. Three DLs were performed during medical treatment of patients with acute type B AoD, six after treatment of AoD (both surgical and endovascular). Three second-look DLs were also performed.
Eight DLs were negative, three showed AMesI and the patients underwent successful emergent revascularisation. One DL was not conclusive and laparotomy was required. Among the eight patients not submitted to DL, one case of bowel infarction was recorded.
Conclusions: In our series DL was feasible and safe. The low invasiveness and repeatability were the main advantages. Although additional experience is mandatory, DL seems a promising technique for the detection of AMesI in patients with AoD.

Acute mesenteric ischaemia (AMesI) is the most severe gastrointestinal complication of acute aortic dissections (AoDs),[1] with a reported mortality rate of 45–87%.[2–4] Mesenteric ischaemia is also a recognised complication of treatment of type B AoDs, both with open or endovascular techniques.[5]

Despite the importance of a timely diagnosis for treatment of AMesI, its recognition often occurs too late due to its unspecific symptoms and lack of reliable exams.[1,6]

At present high-resolution computed tomography angiography (CTA) is regarded as the gold standard for the diagnosis of AMesI, although, considering the risk of delayed recognition, many patients will still undergo exploratory laparotomy if CTA is not conclusive.[7,8]

In the last 20 years, diagnostic laparoscopy (DL) has evolved as a less invasive alternative to laparotomy for the diagnosis of AMesI in the critical setting.[9] Since 2004, we have started a diagnostic protocol based on the use of DL for the early detection of visceral complications in selected AoD patients.

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Methods

We retrospectively analysed the results of a diagnostic protocol for the early detection of AMesI in AoD patients based on DL.

The protocol started in January 2004 and patients were selected for DL if they:

1) had imaging suggesting impairment of flow to the visceral vessels. This included:
   a. CTA: documenting static or dynamic obstruction of the superior mesenteric artery (SMA), coeliac trunk or both.
   b. Intraoperative angiography: documenting reduced opacification of the SMA, coeliac trunk or both.
2) had clinical signs and symptoms suggesting AMesI. These included abdominal pain, peritoneal irritation, nausea, vomiting and diarrhoea.
3) had lab tests suggesting AMesI. These included:
   a. Persistent arterial blood pH < 7.34;
   b. Plasmatic lactate level > 2.1 mmol/L; and
   c. White blood cell count (WBC) $> 12{,}000$/mL.

Low pH was considered the main parameter, while plasmatic lactate and WBC were used as additional tests.

Either conditions $1 + 2$, conditions $1 + 3$ or all of them had to be present to take DL into consideration.

After evaluation of the case by on-call general surgeon, DL was performed if:

a. The patient could not be rapidly transferred to the radiology suite. This was the case of AMesI suspected after repair of AoD. The rationale for DL was that it would have saved time for the diagnosis and, in that case, it would have allowed us to proceed directly to treatment.
b. Previous CTA not conclusive, with lack of signs of severe ischaemia (i.e., changes in bowel wall thickness, bowel wall enhancement and solid organ infarction). The rationale of DL in these cases was to avoid the risks of delayed diagnosis and to spare a critical patient a possible unnecessary laparotomy.

All the patients with suspected AMesI, but not matching the aforementioned criteria, underwent watch-full waiting. Conversely, patients with frank sign of bowel infarction at CTA (pneumatosis and perforation) underwent emergent exploratory laparotomy.

The flow diagram of the protocol is presented in Fig. 1.

Techniques of DL

No patients had contraindications to laparoscopy (previous major abdominal surgery, inability to tolerate pneumoperitoneum, $pCO_2 > 50$ mmHg).

All DLs were performed in the operating room (OR). An 8 mmHg low-pressure CO_2-pneumoperitoneum was established using Hasson's technique (Wolf 2232 Laparo CO_2-PNEU, Richard Wolfe Endoskope, Germany) to avoid possible impairment of visceral perfusion due to high intra-abdominal pressure. A 10-mm port was inserted in the periumbilical region and the telescope introduced (Wolf 5550 HDTV Endocam – HD 1080p + Wolf 5131 AUTO LP, Richard Wolfe Endoskope, Germany). An initial exploration of the abdominal cavity was conducted for conditions that required emergent laparotomy (perforation and haemoperitoneum). Two

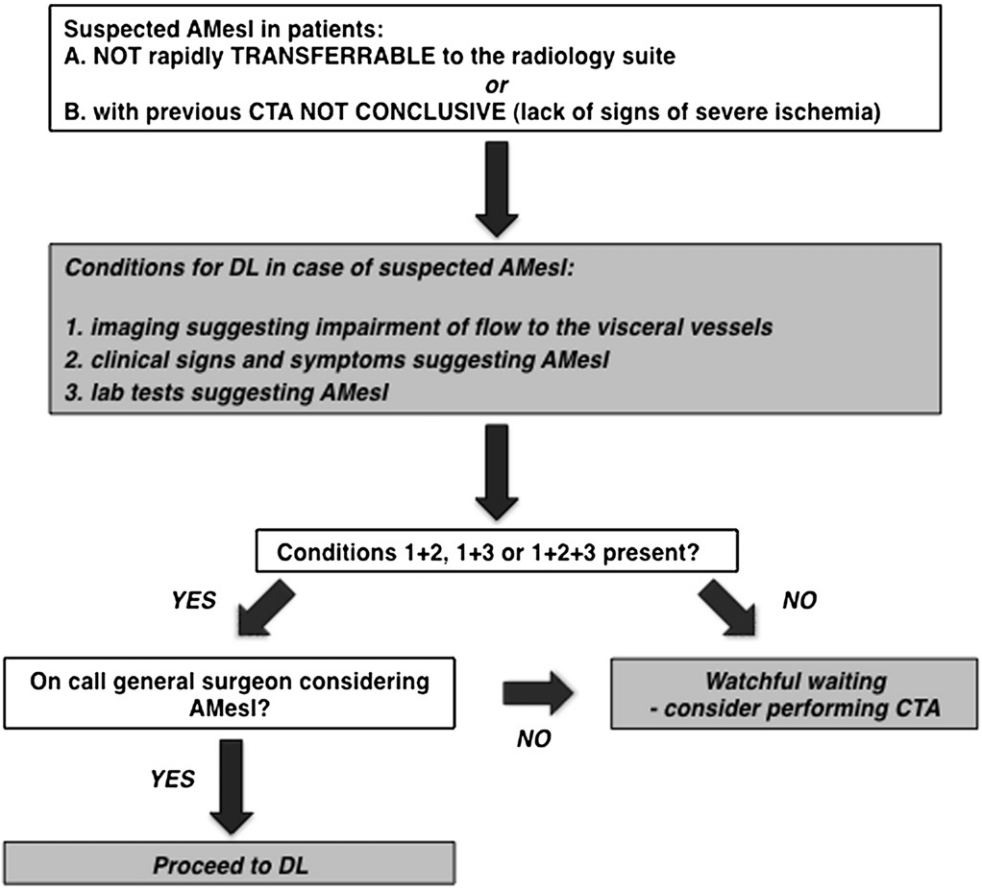

Figure 1. Flow chart of the protocol for diagnostic laparoscopy. DL = diagnostic laparoscopy; CTA = computed tomography angiography; AMesI = acute mesenteric ischaemia.

Table 1
Patients' characteristics and indication to diagnostic laparoscopy. Classification of aortic dissections according to the Stanford Group. AMesI: acute mesenteric ischaemia; CTA: computed tomography angiography; SMA: superior mesenteric artery; CT: coeliac trunk; WBC: white blood cell count; TEVAR: thoracic endovascular aortic repair.

Group	*N*	Sex	Age	Type of aortic dissection	Dissection related complications other than AMesI	Suspicion of AMesI	Criteria for DL				Treatment of aortic dissection
							1. Imaging		2. Abdominal symptoms	3. Lab tests	
							CTA	Intraoperative angiography			
A	1	M	41	Acute type B	None	At admission (DL performed after 18 h)	Dynamic obstruction of the SMA and CT	Collapsed true lumen	Diffuse abdominal pain, nausea	pH 7.34 (BE − 4), WBC 13,000/mL, plasma lactate 2.1 mmol/L	TEVAR (Petticoat technique)
	2	F	22	Acute type B	None	At admission (DL performed after 12 h)	Dynamic obstruction of the SMA–CT	Collapsed true lumen	Diffuse abdominal pain	pH 7.31, plasma lactate 2.6 mmol/L	TEVAR (Petticoat technique), stenting of the left renal artery
	3	M	33	Acute type B	None	At admission (DL performed after 48 h)	Static obstruction of the SMA (dissection of the SMA)	Not performed	Pain, nausea	WBC 16,000/mL, pH 7.33. Serum creatinine 2.1 mg/dL	Medical treatment
B	4	M	70	Acute type B	Lower limbs ischaemia	At admission	Dynamic obstruction of the CT and SMA	Reduced opacification of SMA and CT	Pain, nausea	pH 7.31, plasma lactate 2.3 mmol/L, WBC 15,000/mL	TEVAR
	5	M	69	Acute type B	False lumen expansion, persistent thoracic pain	At admission	Static obstruction of the SMA, oedema of the jejunal loops	Reduced opacification of SMA	Pain, nausea, mild peritonismus	WBC 14,000/mL, pH 7.34, base excess − 7 mEq/L	TEVAR
	6	M	73	Acute type A (post aortic valve surgery)	Lower limbs ischaemia, oliguria	After aortic valve surgery	Not performed	Type A dissection with collapsed true lumen of the visceral aorta	Patient under general anaesthesia	pH 7.30	Repair of the ascending aorta, right axillo-femoral bypass
	7	M	72	Acute type A	None	At admission	Dynamic obstruction of the SMA; bowel oedema	Not performed	Frank abdominal pain, nausea, vomit	pH 7.32, plasma lactate 2.3 mmol/L	Repair of the ascending aorta
	8	M	71	Chronic type B	Aneurysm of the false lumen	After TEVAR (deliberate coverage of the CT)	Not performed (patent CT and SMA at preoperative CTA)	Reduced opacification of SMA. CT not visible	Patient under general anaesthesia	pH 7.32, plasma lactate 2.2 mmol/L	TEVAR
	9	M	71	Chronic type B	None	After open repair, with incomplete fenestration of the visceral aorta	Not performed (patent CT and SMA at preoperative CTA)	Reduced opacification of SMA; patent CT	Patient under general anaesthesia	pH 7.33	Open repair, with incomplete fenestration of the visceral aorta

5-mm trocars were then inserted in the lower right and lower left abdominal quadrant. Laparoscopy was conducted with a two-hand technique with atraumatic clamps. The position of the operating table was tilted according to the explored area. Whenever possible, inspection started at the ligament of Treitz and the bowel was run segment by segment until the rectum.

Diagnosis of visceral ischaemia was made by direct inspection of the gut by a general surgeon with expertise in laparoscopy. Laparoscopy was considered positive when showing:

a. diffuse spasm or oedema of the intestines, associated with
b. mild duskiness/pallor;
c. frank bowel discolouration (severe duskiness);
d. subserosal haemorrhage;
e. gangrene or infarction.

Criteria a and b, typical of early stages of AMesI (<5 h from onset), were considered as signs of ongoing ischaemia also in patients with possible advanced AMesI (time from onset >8 h) due to the fact that end organ ischaemia in AoD might be fluctuating because of dynamic obstruction.

Second-look laparoscopy was performed 24–48 h from the index DL to evaluate the results of visceral revascularisation and the need for resection.

Analysis

The following conditions were used to evaluate the results of DL:

- True positives: patients with a positive DL and AMesI either that was confirmed at laparotomy or that, after treatment, showed amelioration of intestinal perfusion at second-look laparoscopy.
- True negatives: patients with a negative DL who did not develop complications related to mesenteric ischaemia.
- False positives: patients with a positive DL who did not show the presence of AMesI at the ensuing laparotomy or who did not require treatment of AMesI.
- False negatives: patients with a negative DL who developed AMesI-related complications.

A 2 × 2 contingency table was created and analysed using the Fisher exact test. Statistical analysis was performed with GraphPad Prism (GraphPad Software Inc., La Jolla, CA, USA).

Results

Between January 2004 and January 2011, 202 patients with AoD were treated in our Institution. Seventy-one had acute type A AoD while type B AoD was present in 131 cases. There were 31 cases of acute type B AoDs, of which eight were treated medically, 17 were treated with either thoracic endovascular aortic repair (TEVAR) or hybrid endovascular procedures and six with open aortic surgery or other surgical revascularisation. One hundred cases of chronic type B AoD were also treated (42 with open repair and 58 with endovascular/hybrid repair).

From an analysis of the medical records, 17 cases of suspected AMesI were identified among patients with AoD:

- six patients with acute type A AoD;
- seven patients with acute type B AoD; and
- four patients who underwent intervention for chronic type B AoD.

Watch-full waiting was chosen in eight cases not meeting the criteria for DL and, among these patients, one underwent late laparotomy due to mesenteric infarction. There were also three cases (two after open surgery of type A AoD and one after TEVAR for an acute type B AoD) that were submitted to emergent laparotomy due to CTA signs (pneumatosis and splenic infarction), lab tests (pH < 7.31) and clinical findings clearly suggesting mesenteric infarction.

The remaining nine patients underwent DL for suspected AMesI. The group included two type A and seven type B AoDs. Among the patients with type B AoD, two had chronic type B AoDs with aneurysmal evolution while five were admitted for acute type B AoD.

In three patients with acute type B AoD, DL was performed to confirm the presence of AMesI and decide if treatment was warranted (group A, Table 1). All these cases initially underwent medical treatment in the intensive care unit (ICU). Two patients in group A had a positive DL and both underwent emergent TEVAR with Petticoat technique; in the first patient (patient 1, Figs. 2 and 3) an adequate visceral flow was confirmed at second-look DL at 48 h; in the second patient (patient 2, Figs. 4 and 5), second-look DL after 24 h showed amelioration of perfusion although with an area of possible persistent ischaemia. The patient was sent to exploratory laparotomy which resulted negative.

Six patients underwent DL at the end of treatment for AoD, both endovascular and surgical (group B, Table 1). All aortic procedures

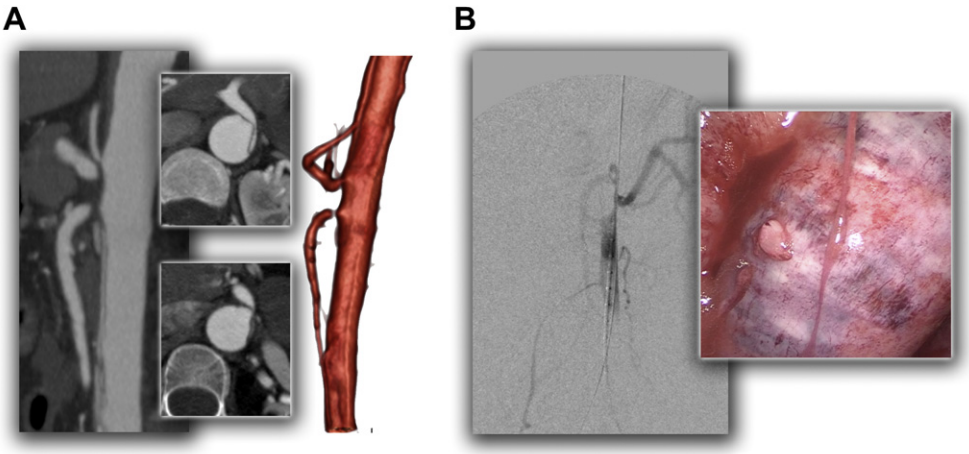

Figure 2. (A) Preoperative CTA of patient 1 showing dynamic malperfusion of both coeliac trunk and SMA. (B) Intraoperative angiogram showing complete collapse of the true lumen with exclusive perfusion of the left renal artery. Diagnostic laparoscopy demonstrates small bowel ischaemia with subserosal haemorrhage and pallor.

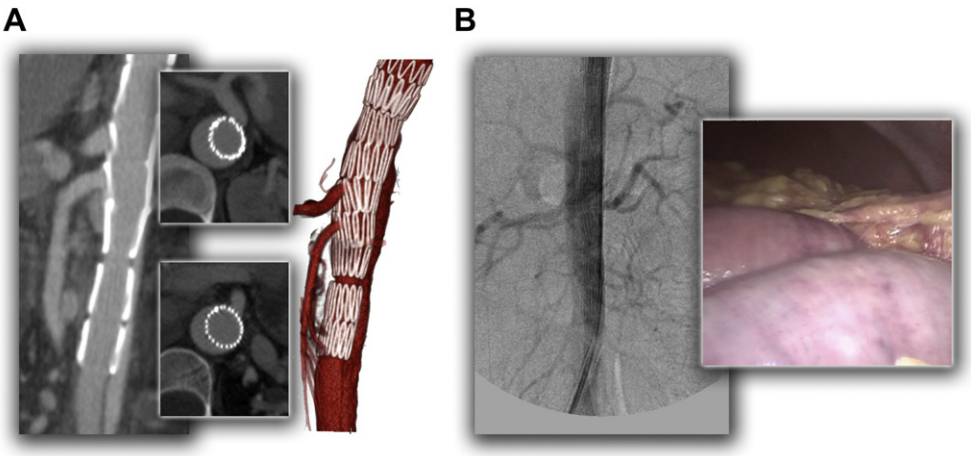

Figure 3. (A) Postoperative CTA after the deployment of the Cook Zenith Dissection System (William Cook Europe, Bjaeverskov, Denmark). CTA shows resolution of distal dynamic malperfusion and patency of both the coeliac trunk and SMA. (B) Intraoperative angiogram shows good perfusion of renal and visceral vessels. Second-look laparoscopy demonstrates the absence of necrosis.

were performed under general anaesthesia and DL took place before awakening. One patient in group B had a positive DL (patient 6). He suffered from acute type A AoD during aortic valve surgery with severe lower limb ischaemia and possible AMesI. He underwent emergent revascularisation of the lower torso with an axillo-femoral bypass. DL was performed at the end of the operation and showed ischaemic suffering of the bowel. After 24 h, second-look DL demonstrated normal visceral appearance, without areas of necrosis.

Clinical data and criteria for DL for each patient are presented in Table 1 while the total number of patients involved with the results of DL are presented in Fig. 6.

There were no laparoscopy-related complications during the study period. Second-look DL was performed in all the three positive cases at index DL. The average time required for DL was 37 ± 8 min. Results of DLs and clinical outcome for each patient are presented in Table 2.

Overall DL was negative in eight cases and these patients did not develop any complication related to AMesI. In four cases, DL (three first-look DLs, one second-look DL) was positive for AMesI, with one false positive (patient 2 did not have visceral ischaemia at laparotomy).

The contingency table is shown in Table 3. The calculated sensitivity of DL in the setting of AoD was 100% and the specificity was 88.9%. The positive predictive value was 75% while the negative predictive value was 100%. The calculated two-tailed *P* for the Fisher exact test was 0.0182.

Discussion

Our preliminary results show that DL is feasible and safe and portends specific advantages for patients with AoD.

First, it is an additional diagnostic tool in a setting where symptoms and lab tests of AMesI can be disguised by concomitant conditions. In patients 4 and 6, acidosis could have been entirely explained by lower limb ischaemia, while patient 6 had also mesenteric ischaemia. Similarly, abdominal pain in all acute dissections (patients 1–3, 4, 5, 7) could have been interpreted as a symptom of aortic disease, while patients 1 and 2 had ongoing mesenteric ischaemia. Moreover, patients with AoD are often sedated to treat pain and control haemodynamic parameters; thus, abdominal symptoms are even more unreliable.[7]

Second, a diagnostic protocol that includes DL can reduce the number of laparotomies, which have a high morbidity rate (5–22%)

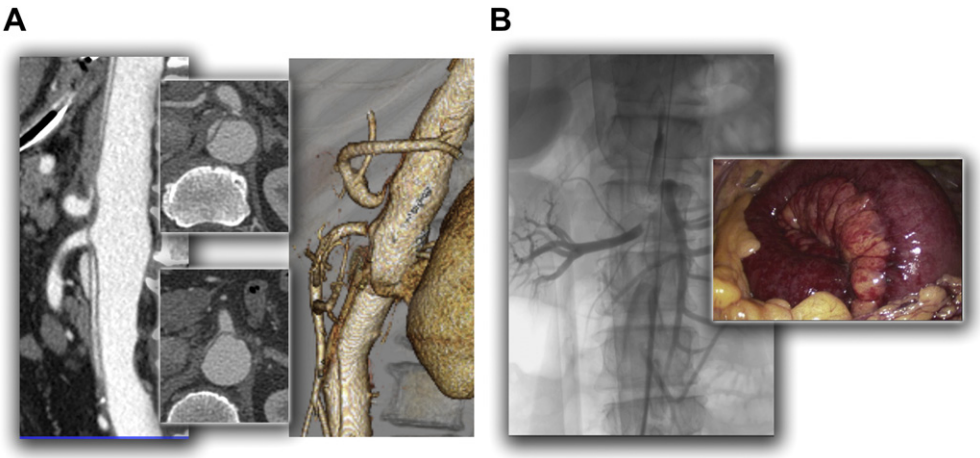

Figure 4. (A) Preoperative CTA scan of patient 2 showing dynamic malperfusion of coeliac trunk and SMA due to true lumen collapse. (B) Intraoperative angiogram shows a completely collapsed true lumen with reduced perfusion of the SMA and coeliac trunk and no flow to the left renal artery. Intraoperative laparoscopy shows clinical evident ischaemia of the small bowel, with severe subserosal haemorrhage and duskiness.

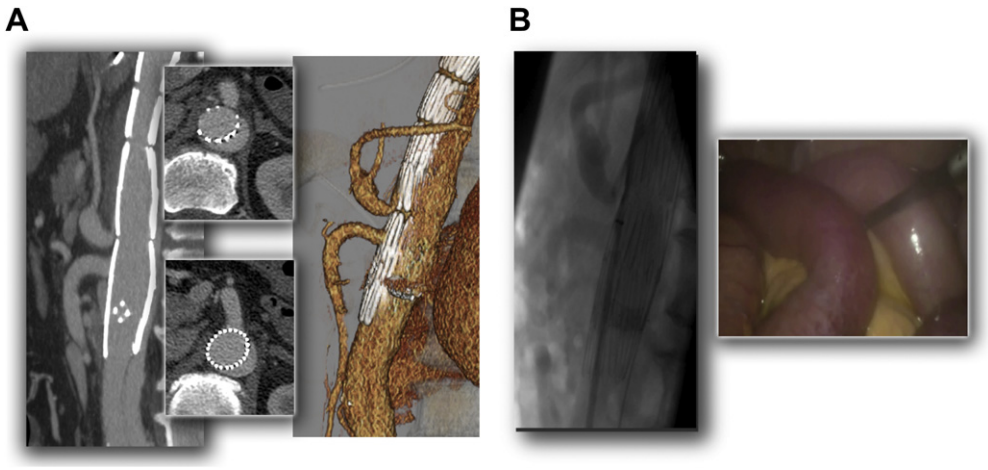

Figure 5. (A) Postoperative CTA scan after the deployment of the Zenith Dissection System (William Cook Europe, Bjaeverskov, Denmark) and stenting of the left renal artery. CTA shows resolution of distal malperfusion and patency of both coeliac trunk and SMA. (B) Intraoperative angiogram after the deployment of stent-graft shows reperfusion of splanchnic vessels. Second-look laparoscopy shows frank amelioration of perfusion but with possible areas of persistent ischaemia.

in critically ill patients.[9] In our series two patients with AMesI (patients 1 and 6) avoided laparotomy, thanks to the use of DL and second-look DL to monitor the evolution of mesenteric ischaemia.

Diagnostic laparoscopy was also a useful diagnostic adjunct during monitoring of medically treated acute type B AoDs (group A), with two patients (patients 1 and 2) emergently treated for AMesI after a positive DL. This seems even more important when considering that, during the study period, one patient with suspected AMesI who underwent watchful waiting developed intestinal infarction. It is reasonable to speculate that early DL could have avoided this late diagnosis, although some limitations of early DL need to be mentioned.

It is in fact well known that DL has a reduced sensitivity in the early stages of AMesI, due to the fact that the mucosa can be extensively ischaemic while the gut might still appear normal at external inspection. To solve this limit and permit reliable early recognition of AMesI, some authors have described the use of i.v. fluorescein and laparoscopic ultraviolet light.[10] In general, we think that performing a close second-look DL might also help in the detection of evolving ischaemia, thus reducing the risk of late mesenteric infarction.

Laparoscopy might as well result a possible alternative to CTA in patients with impaired renal function, as the decision to proceed directly to DL in patient 3 was also related to his elevated serum creatinine (2.1 mg dl^{-1}).

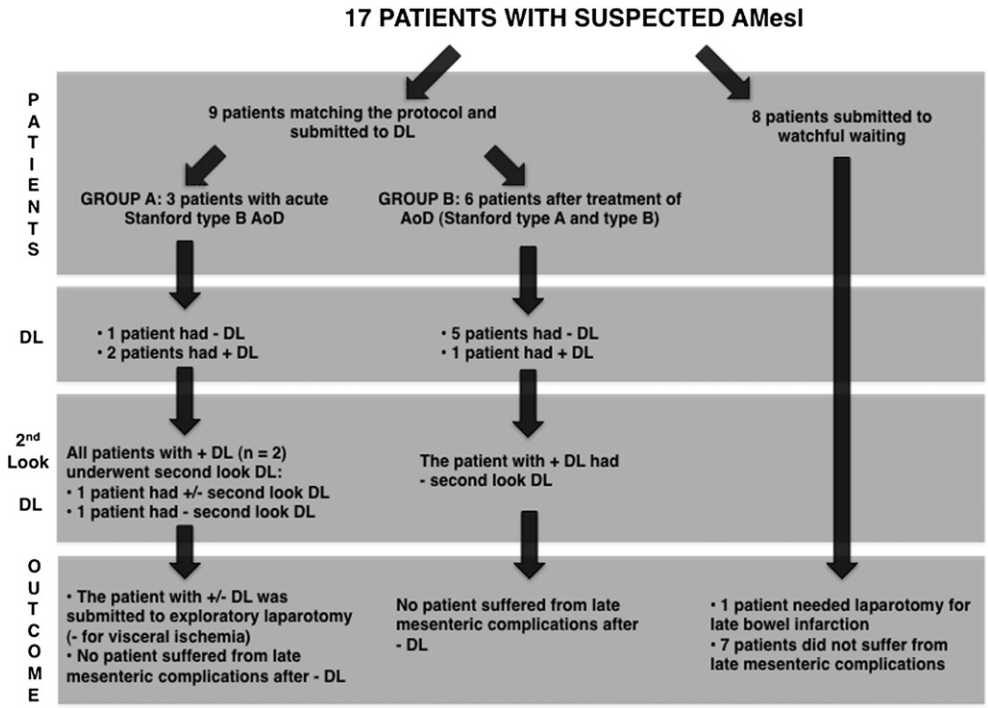

Figure 6. Flow chart of study with the total number of patients and the outcome for each group. AMesI = acute mesenteric ischaemia; DL = diagnostic laparoscopy; AoD = aortic dissection; − = negative; + = positive; +/− = uncertain.

Table 2
Classification of aortic dissections according to the Stanford Group; AMesI: acute mesenteric ischaemia; CTA: computed tomography angiography; SMA: superior mesenteric artery; CT: coeliac trunk.

Group	Pts.	Sex	Age	Type of aortic dissection	Index diagnostic laparoscopy	Treatment of AMesI	Second-look laparoscopy	Laparotomy	Late visceral complication	Outcomes at 30 days
A	1	M	41	Acute type B	Duskiness, subserosal haemorrhage	TEVAR (Petticoat technique)	Amelioration, no area of necrosis	Not performed	None	Paraparesis
	2	F	22	Acute type B	Severe duskiness and diffuse subserosal haemorrhage	TEVAR (Petticoat technique + left renal stenting)	Pallor, reduced subserosal hyperaemia	Negative	Ileus	Late relaparotomy for ileus
	3	M	33	Acute type B	Negative	Not required	Not performed	Not performed	None	Uneventful
B	4	M	70	Acute type B	Negative	Not required	Not performed	Not performed	None	Uneventful
	5	M	69	Acute type B	Negative	Not required	Not performed	Not performed	None	Uneventful
	6	M	73	Acute type A (post aortic valve surgery)	Spasm associated to mild duskiness[a]	Right axillo-femoral bypass	Resolution	Not performed	None (at autopsy)	Death (heart failure on the 12th postoperative day)
	7	M	73	Acute type A	Negative[b]	Not required	Not performed	Not performed	None	Stroke
	8	M	71	Chronic type B	Negative	Not required	Not performed	Not performed	None	Type I endoleak l
	9	M	71	Chronic type B	Negative	Not required	Not performed	Not performed	None	Uneventful

[a] Performed after repair of the ascending aorta and after right axillo-femoral bypass grafting.
[b] Performed after repair of the ascending aorta.

Another aspect that warrants consideration is that DL could be safely performed immediately after aortic interventions (group B). We believe this a valuable option as it might permit early detection of AMesI and allow treatment right at the end of aortic repair. Moreover, this seems especially convenient in AoD patients in which visceral malperfusion syndrome is a well-known complication after both surgical and endovascular repair.

In particular, coeliac trunk malperfusion syndrome is not uncommon after TEVAR when coeliac trunk coverage is required to exclude distal aortic tears. Since the rate of ischaemic complications after coeliac trunk coverage can be as high as 20%,[11] this always mandates for a high level of alert, in particular for gallbladder ischaemia (due to lack of collaterals in its vascularisation). Interestingly, the specificity of DL in the evaluation of gallbladder has been well documented in the critical patient.[9]

Growing evidence has shown that DL can be conducted at bedside in ICU patients.[9,12] Due to the fact that in our Institution the ICU and the ORs are in the same facility, all our DLs were easily done in the OR. However, we regard bedside DL extremely valuable in AoDs, as it avoids transferring the patient,[12] and it does not require interruption of ICU therapies.

In spite of the theoretical value of DL, the evidence-based guidelines of the European Association for Endoscopic Surgery for Laparoscopy for Abdominal Emergencies states that conventional imaging is preferable over DL for the diagnosis of AMesI.[13] The limitations of DL are that serosal colour can be misjudged and segmental ischaemia can be missed because of the difficulty in 'running' the bowel.[6] It is to be noted however that this indication depends also on the fact that the prevalence of AMesI as a cause of acute abdomen is low (1%),[13] thus reducing the positive predictive value of DL. Conversely, the incidence of AMesI in AoD patients is at least 5 times greater;[4] thus DL may actually result more reliable in this high-risk subgroup.

Our study entails several limitations. We presented a retrospective analysis of a small group of patients (even if the largest in literature to our knowledge) and this strongly limits the power of statistics. Furthermore, the large number of negative DLs (67%) might imply that the criteria to indicate DL were too loose and this, associated with the fact that most patients with AoD did not undergo DL, cannot exclude a type I statistical error. Nevertheless, although the use of statistics in our analyses has only a descriptive aim, we could correctly diagnose AMesI in three cases and correctly exclude it in eight, with a $P < 0.05$ at the Fisher exact test. Moreover, the false-positive rate was 8% (1/12), which is in line with published studies of DL in critically ill patients.[9,12,14,15]

Although larger experience is needed to better define the indication, our study shows that DL is a valuable option for patients with AoD and warrants further consideration.

Table 3
Contingency table showing the results of diagnostic laparoscopy. AMesI: acute mesenteric ischaemia; DL: diagnostic laparoscopy.

	AMesI+	AMesI−	Total
DL+	3	1	4
DL−	0	8	8
Total	3	9	12

Conflict of Interest/Funding

None declared.

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