REVIEW / Gastrointestinal imaging

Diagnosis and radiological treatment of digestive haemorrhage following supramesocolic surgery

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Abstract
Digestive haemorrhage following supramesocolic abdominal surgery (cephalic duodenopancreatectomy, cholecystectomy, total oesogastrectomy) is a rare but serious complication, which can be life-threatening. Improvement in scanning techniques has made it possible to modify the diagnostic strategy and improve the therapeutic management of the patients. The aim of this iconographic review is to recall the causes of digestive haemorrhage following supramesocolic surgery and to illustrate the dominant role of tomodensitometry in diagnosing it and in planning and controlling the efficacy of endovascular treatment.

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Surgery of the supramesocolic abdomen is major surgery, with the resulting morbidity and mortality varying between 0 and 40% and 0 and 5%, respectively. The variations are related to the type of surgery and to the experience of the surgical teams [1–5]. Supramesocolic abdominal procedures are at risk of post-operative haemorrhage because of the nearness of the arteries coming from the coeliac trunk or of the superior mesenteric artery. Post-operative digestive haemorrhage following abdominal surgery can be due to a per-operative injury, arterial erosion (secondary to a pancreatic fistula or to leakage of digestive liquid), or to a ruptured false arterial aneurysm [6–9]. An emergency abdominal CT scan must be performed to look for the origin and cause of the bleeding and guide treatment, which in some cases has to be endovascular. The aim of this iconographic review is to recall the causes of digestive haemorrhage following supramesocolic surgery and to illustrate the dominant role of tomodensitometry in diagnosing it and in planning and controlling the efficacy of endovascular treatment.

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Imaging

Digestive haemorrhage in the early post-operative period is rare but serious, and must be dealt with as an emergency. The abdominopelvic CT scan with injection of a contrast agent is the standard examination and must be undertaken without delay. A recent prospective study demonstrated its superiority over endoscopy in detecting the site and aetiology of upper and lower digestive haemorrhage in 29 patients [10]. Indeed, with multidetector scanners, images can be rapidly acquired with excellent spatial resolution, with thin submillimetre slices (for 64-detector scanners, or higher). The use of multiplanar reconstructions, 3D images or reformatting in maximum intensity projection (MIP) (Figs. 1 and 2) is currently essential for locating the origin of the bleeding [11,12]. The use of MIP images is a help in detecting the site of the haemorrhage, but must in no case replace basic analysis of the thin slices in the three spatial planes, particularly the axial plane.

Injection of the contrast agent in the arterial phase is essential for objectifying active leakage of contrast agent or extravasation from the vessel or vessels involved

Figure 1. Fifty-year-old female patient operated for adenocarcinoma of the head of the pancreas 11 days previously. The procedure undertaken was a cephalic duodenumpancreatectomy. A post-operative fistula had appeared on D8 causing erosion of the hepatic artery proper, then a false arterial aneurysm, which ruptured and was revealed by haematemesis. Abdominal CT had revealed a false aneurysm of the hepatic artery proper requiring urgent treatment with endovascular implantation of a 3 mm diameter GraftMaster covered stent (OTW 3 × 19 Abbott): a: abdominal CT maximum intensity projection (MIP) coronal slice in the arterial phase showing extravasation of contrast agent into the Roux-en-Y jejunal loop (dotted arrow) from a false aneurysm (arrow) of the middle hepatic artery; b: abdominal CT MIP axial slice in the arterial phase showing the hepatic artery (dotted arrow) and extravasation of contrast agent (arrow); c: abdominal CT axial slice in the arterial phase showing extravasation of contrast agent (dotted arrow) and blood clots in the stomach (arrow); d: abdominal CT axial slice without injection showing several intragastric spontaneous hyperdensities (stars), corresponding to clots of blood; e: selective arteriography of the common hepatic artery: e1: extravasation of contrast agent from the hepatic artery proper (arrows), e2: covered stent mounted on monorail guide (arrows), e3: check following implantation of the covered stent, showing that the extravasation of contrast agent has ceased (white circle), e4: final check: No leakage of contrast agent (arrow) around the stent (circle); f: abdominal CT MIP coronal slice. Check-up 2 years after implantation of the covered stent (dotted arrow). The artery is permeable above and below the covered stent (arrows).
(Figs. 1c and 2a), so that the origin of the bleeding can be located [13,14]. Certain haemorrhages are only revealed in the portal, or even delayed phase, so that a second helical scan needs to be done in the portal phase or even in the delayed phase, at the request of the radiologist at the acquisition console after reading the initial images directly.

The length of time between the intravenous injection of contrast agent and optimal opacification of the digestive arteries in the arterial phase depends on the age, the haemodynamic status or the left ventricular function of the patient being examined. With the use of automatic systems, with time synchronisation, for triggering acquisition at maximum arterial enhancement, the arterial opacification obtained can be of high quality, particularly of the digestive arteries, enabling detailed analysis of these vessels and thus allowing the site of the haemorrhage to be precisely detected.

Certain radiology teams undertake the first acquisition before intravenous injection of the iodinated contrast
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agent. The main aims of this are to exclude any other origin giving rise to hyperdensity (particularly surgical clips or calculi) and to pinpoint hyperdense haematomas (Fig. 1d). No study published to date has demonstrated that the helical scan without injection contributes in any other way to detecting active digestive haemorrhages [13]. We do not systematically include this helical scan without injection in our protocol.

Causes

The three major causes of early post-operative haemorrhage are injury or arterial trauma, arterial erosion due to a digestive or pancreatic fistula and rupture of a false arterial aneurysm. The cause is related to the type of surgical procedure. Pancreatic fistulas indeed occur following cephalic duodenopancreatectomy, whereas arterial wounds

Figure 2. Sixty-three-year-old male patient operated for an adenocarcinoma of the head of the pancreas. The procedure undertaken was a cephalic duodenopancreatectomy. Abdominal CT was conducted because of haematemesis on D7 post-operatively. The diagnosis was of extravasation of contrast agent due to a fistula of the stump of the gastroduodenal artery. The treatment consisted of embolisation of the stump of the gastroduodenal artery using two coils: a: abdominal CT axial slice in the arterial phase, showing extravasation of contrast agent (arrow), a post-operative pneumoperitoneum (dotted arrows) and an abdominal collection (star); b: abdominal CT maximum intensity projection (MIP) coronal slice in the arterial phase. With reconstructions it is possible to see the exact location of the arterial leakage (circle); c: abdominal CT MIP sagittal slice in the arterial phase. With reconstructions, it is possible to see the exact location of the arterial leakage (circle); d: selective arteriography frontal view. The catheter is positioned at the coeliac ostium. Amputation of the gastroduodenal artery (arrows); e: selective arteriography frontal view. Catheterisation at the origin of the gastroduodenal artery: extravasation of contrast agent (stars) in the region operated (circle); f: selective arteriography frontal view. Check-up after embolisation with two coils (Tornado—Cook 4/3 and 3/2 mm) at the origin of the gastroduodenal artery (arrows).
may arise after any form of abdominal surgery, even after cholecystectomy performed by coelioscopy.

Following cephalic duodenopancreatectomy

Rare, but potentially fatal post-pancreatectomy haemorrhage occurs in 2 to 12% of cases, with a mortality rate of 18 to 38%. Post-pancreatectomy haemorrhages are divided into two groups: early post-pancreatectomy haemorrhages (<5 days) are due to a peri-operative technical complication, whereas delayed post-pancreatectomy haemorrhages (>5 days) are associated with a pancreatic fistula or local infection [9]. The site of the intra-abdominal haemorrhage is generally the stump of the gastroduodenal artery (Fig. 2d and e), but the hepatic, splenic, and superior mesenteric arteries, or their branches, may also be involved.

If sentinel bleeding is observed, defined as loss of blood via the abdominal drains, a fall in haemoglobin greater than 1.5 g/dL or recurrence of bleeding following a free interval of at least 12 hours, an emergency search for post-pancreatectomy haemorrhage must be undertaken, because mortality rises to 57% in these patients [9].

In the event of a pancreatic fistula, apart from arterial erosion, the appearance of false aneurysms is not exceptional. There again, the most frequently affected site is the stump of the gastroduodenal artery, but the other splanchnic arteries can also be involved. A false aneurysm can occur, for example, due to erosion of an artery in contact with a pseudocyst that occurred several weeks after a cephalic duodenopancreatectomy (Fig. 3a). Pseudocysts can cause haemorrhagic complications (false aneurysms), but can also become infected (Fig. 3b).

Following cholecystectomy

Coelioscopy is the standard technique for performing a cholecystectomy. However, the incidence of post-operative complications is estimated to be between 0.3 and 1% of cases [15]. Cholecystectomy complications fall into two groups, once complications related to the approach have been excluded (injury when inserting cholecystectomy trocars, for example). Per-operative complications include the gall bladder opening, with the biliary contents being distributed into the peritoneal cavity, injury to the viscera (the duodenum, transverse colon and liver, in particular), haemorrhage, particularly from the cystic artery, and injuries to the main biliary tract. A bile leak, a haemorrhage or, in the longer term, stenosis of the main biliary tract are the late-developing complications most frequently reported.

The appearance of false arterial aneurysms following cholecystectomy, manifesting sometimes several months after the surgery, is rare (with less than 500 cases published in the literature), but serious (up to 50% mortality in some series) complication of coelioscopy [7,8]. Haemobilia is related to an arteriobiliary fistula between a false aneurysm and the biliary pathways, most often the bile duct (Fig. 4). The development of false aneurysms can be related either to an inflammatory reaction of the arterial wall if there is cholecystitis, or to direct trauma to the cystic, hepatic or gastroduodenal arteries that occurred during the cholecystectomy and appearing some considerable time after the surgical procedure.

Following total oesogastrectomy

Total oesogastrectomy for cancer of the cardia or the lower oesophagus is major surgery due to the surgical techniques and partly to the high rate of morbidity/mortality. There are two different surgical techniques: a single abdominal approach or surgery via both a thoracic and abdominal approach. The advantages of the dual approach for cleaning the mediastinum are counterbalanced by the higher rate of complications (9% mortality in the thoracotomy group as against 0% in the abdominal approach group in this study published in 2010) [2]. Digestive haemorrhage can occur due to arterial erosion secondary to a digestive fistula or a false arterial aneurysm, for example, of an artery of the duodenopancreatic arcades (Fig. 5).
Treatment

Of an injury or arterial erosion

Following cephalic duodenopancreatectomy

The treatment of post-pancreatectomy haemorrhage consists in controlling the bleeding and the haemorrhagic shock. There is a variety of information in the literature concerning management. No statistical difference has been demonstrated in terms of mortality between interventional management and surgery. Nevertheless, it is difficult to repair an artery after recent pancreatic resection because of the inflammation, necrosis and fragile nature of the surrounding tissues and the anastomosis. In addition, haemorrhage from an arterial wound presents two major hazards arguing against surgery: the difficulty of surgical exposure due to the active bleeding and the risk of causing increased bleeding, at present contained, due to the adjacent haematoma.

Until recently, the radiological procedure of choice was embolisation of the artery implicated using coils (Fig. 3c). However, complications such as infarction or hepatic abscesses can occur, with up to 11% in certain series [16–19]. A more recent approach, arising in the 2000s, is the implantation of a covered stent into the vessel in question, to cover the arterial wound and seal the leakage (Fig. 1e); this could become the standard technique in the future, but long-term monitoring is as yet still inadequate [20].
If the bleeding is from the stump of the gastroduodenal artery, a coil introduced into this stump is sometimes sufficient (Fig. 2f).

Digestive haemorrhage can be treated using other embolisation methods, particularly by injecting resorbable (porcine gelatin) or non-resorbable particles (particles in polyvinyl acetate or microbeads) [21–24]. However, these embolisation methods, validated for a great many indications (post-trauma, tumours, haemorrhoids, malformation, inflammation), have not been validated for post-operative haemorrhage (injuries or arterial erosion). In addition, the use of small size resorbable particles produces a risk of distal necrosis of the digestive wall [22,25].

**Following total oesogastrectomy**

Repairing a wound or arterial erosion very soon after performing total oesogastrectomy cannot be contemplated because of the risks related to the difficulties of surgical exposure during haemorrhage and the risks of the arterial lesion healing poorly in a context of inflammation. Here again, coil embolisation (Fig. 6) or endovascular implantation of a covered stent are the prime treatments.

**Of rupture of a false aneurysm**

The standard treatment of pseudoaneurysms is arterial embolisation, which controls the haemorrhage in 67 to 100% of cases. The act consists of excluding the pseudoaneurysm by creating an occlusion on either side of it (Fig. 5b and c), to avoid an arterial supply being restored by reverse flow or via anastomoses. Sometimes coils are introduced into the pseudoaneurysm, but this embolisation technique, with the risk of iatrogenic rupture of the aneurysm sac, is not performed as a first course of action. If there are several false aneurysms or a large false aneurysm, it is possible to associate embolisation with coils introduced into the false

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**Figure 4.** Eighty-four-year-old female patient who underwent a cholecystectomy 5 months before the appearance of haematemesis. The endoscopy performed produced the diagnosis of haemobilia. Abdominal CT was then conducted and found four false arterial aneurysms of the hepatic artery proper and its branches, at least one of which had ruptured into the main biliary tract. Emergency coil embolisation was undertaken of the hepatic artery proper: a: abdominal CT axial slice in the delayed phase: spontaneous hyperdensity in the main biliary tract (arrow) related to the haemobilia; b: aortography showing several false aneurysms of the middle hepatic artery and its branches (arrows); c: final check-up after coil embolisation of the four false aneurysms and of the hepatic artery (stars).
Figure 5. Seventy-year-old male patient who underwent total oesogastrectomy 6 weeks previously due to cancer of the cardia. A fistula of the anastomotic loop, then high digestive haemorrhage had appeared post-operatively. Emergency CT was conducted which detected a false aneurysm of a pancreaticoduodenal artery: this underwent emergency treatment by coil embolisation: a: abdominal CT axial slice in the arterial phase showing a voluminous false aneurysm (black star) of a pancreaticoduodenal artery, explaining the digestive haemorrhage, and an abdominal collection of the left hypochondrium (white star); b: selective arteriography showing a false aneurysm of a duodenopancreatic arcade. Selective catheterisation of a branch of the superior mesenteric artery (arrows in b1, b2 and b3) and coil embolisation (arrow in b4); c: selective catheterisation of the gastroduodenal artery then coil embolisation. This example illustrates the “sandwich” technique,
where arterial embolisation has been produced on each side of a false aneurysm to avoid any reverse blood flow supply and any risk of new digestive haemorrhage; d: abdominal CT axial slice in the portal phase. Check-up a few months after coil embolisation of a false aneurysm of a duodenopancreatic arcade (white arrow).

Figure 5. (Continued).
an aneurysm(s) with additional embolisation of the artery concerned (Fig. 4b and c).

If there is no access to an interventional radiology room and as a second line of treatment, a false aneurysm can be treated by surgical ligation.

**Post-therapeutic imaging**

Early and long-term post-therapeutic monitoring of digestive haemorrhage that has occurred following abdominal surgery must be by CT scanning.

For coil embolisation, short-term monitoring must be carried out to check that occlusion of the artery has not provoked infarction of the respective organ (the spleen, for the splenic artery, for example, Fig. 7) or to check the permeability of the vessel in which a stent has been inserted (the hepatic artery proper for example, Fig. 1f).

Later monitoring is also by CT scanning as part of following up the initial pathology, for example when looking for recurrence of a tumour such as an adenocarcinoma of the head of the pancreas following cephalic duodenopancreatectomy. The metal artifacts created by coils should be known to any radiologist, producing tiny arciform images in one or more arteries (Fig. 5d).

**Conclusion**

Digestive haemorrhage in the early post-operative period following digestive surgery requires emergency and multidisciplinary management, in which anaesthetists, surgeons and radiologists must cooperate rapidly and effectively. The radiologist has a central role in detecting the site of origin and cause of the haemorrhage (a false aneurysm, a fistula or a wound) from reading the multidetector CT scan, including at least an arterial phase, and in treating it by an endovascular approach, the standard treatment.

**Disclosure of interest**

The authors declare that they have no conflicts of interest concerning this article.
References


