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Postoperative Evaluation of Hepatic Surgery with CT and MRI

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Abstract **Review Article**

Introduction**:* Hepatic surgery is associated with significant high rates of morbidity. CT scan is the optimal method for the detection of postoperative complications. In this context, MRI is increasingly used to detect certain complications, particularly biliary and pancreatic. This didactic article aims to illustrate the normal and pathological postoperative aspects of these surgeries in imaging. ***Recent data: First, we will describe the normal postoperative aspects of the surgical approach. Secondly, we will discuss the acute complications. The CT scan allows us to describe vascular complications such as: hemorrhages, ischemia and thrombosis. Relevant to add that biliary fistulas can be studied in both CT and MRI. ***Conclusion***: The knowledge of the surgical techniques and procedures performed as well as the normal aspect in postoperative imaging is a primordial step in order to know how to identify a complication requiring a secondary laparotomy, a radiological drainage or a conservative treatment.

Keywords: MRI - CT- liver - Surgery – tumor.

INTRODUCTION

Liver surgery is traditionally difficult. The liver is a voluminous organ, highly vascularized and located under the right costal margin. The risk, which can be fatal, is due to a very rich intrahepatic vascularization, constituted by a triple portal, arterial and suprahepatic network which flows into the inferior vena cava embedded in the posterior aspect of the liver.

After hepatectomy, there is a risk of hemorrhage (due to persistent bleeding in the slice) but also septic choc (favored by a biliary leak) in addition to liver failure when the volume and/or quality of the remaining parenchyma do not allow sufficient metabolic functions.

The prevalence of primary liver tumors, hepatocellular carcinoma and cholangiocarcinoma, is increasing and growing number of patients with metastases can be operated on. Surgical removal of these primary and secondary tumors remains the best treatment for these types of cancers. The management of these tumors has greatly benefited from combined approaches (chemotherapy, interventional radiology), allowing the operation of a larger number of patients who were until recently considered inoperable.

CT and MRI with contrast injection are currently the two most commonly used imaging modalities for monitoring and assessing the postoperative response. The appearance of the operated liver is specific to the type of surgical treatment performed [1].

It is important for the radiologist to be familiar with the different surgical techniques used, in order to better analyze the normal and complicated postoperative appearance of the liver.

Surgical techniques

Hepatic surgery is based on the segmentation of the liver parenchyma; it is said to be regulated (or typical) when it respects the anatomical criteria, in other terms, when it is limited to the entire liver parenchyma located downstream of a glissonian pedicle, and it is said to be unregulated (or atypical) when it leaves in place parenchyma that is partially devascularized or lacking biliary drainage [2]. The regulated nature of a liver resection is characterized by the fact that it decreases the risk of intraoperative hemorrhage and postoperative biliary fistula. For this reason, unregulated resections are usually small, roughly wedge-shaped with a peripheral base (wedge-resections).

A ruled hepatectomy will be named according to the number of contiguous segments it removes (Image 1) [3]:

- A right hepatectomy is performed when segments V-VI-VII and VIII are removed
- The right lobectomy corresponds to the resection of segments IV-VII and VIII.
- The left hepatectomy removes segments II - III and IV.
- And the left lobectomy corresponds to the resection of segments II and III.

A hepatic resection is said to be minor or limited if it removes no more than two segments, such as a sub-segmentectomy, a segmentectomy or a bi-segmentectomy. It is said to be major if it removes three or four segments, enlarged if it removes five segments and superlarged if it removes six segments.

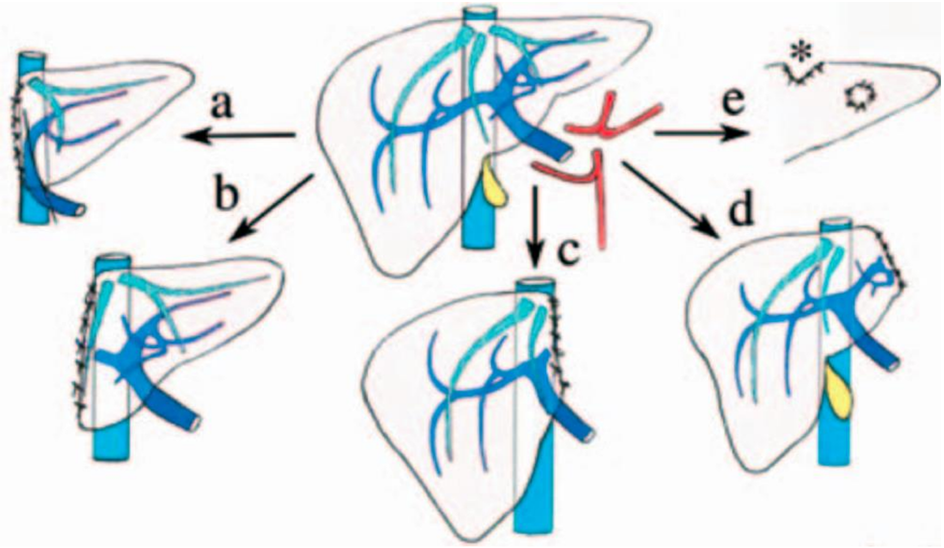

Image 1: Diagrams of the main types of hepatectomy. a) Right lobectomy. b) Right hepatectomy. c) Left hepatectomy. d) Left lobectomy. e) Lumpectomy wedge resection

Imaging Protocols

CT scans can be used to complement ultrasound data, since it acquisitions can now be repeated at the different hepatic vascular times, particularly the arterial and portal times, which are essential for optimal exploration of the liver.

The arterial phase lasts about ten seconds (15 to 25 seconds after the start of the injection); it includes an early phase corresponding to the pure vascular time and a later parenchymal phase, around 25 seconds, during which hypervascular nodules are detected.

The portal phase takes place approximately 60 seconds after the start of the injection. The reference contrast acquisition is generally that of the aorta at the level of the celiac trunk. When the predefined enhancement threshold within this structure is reached, the acquisition is launched according to a protocol adapted to coincide with the desired times. Other parameters influencing the quality of CT imaging are the injection rate (optimal at 4 ml/s) and the concentration of the contrast medium. They allow the improvement of the density gradient between a tumor or a vascular structure and the liver. The acquired sections are examined in the native axial plane, but can also be reconstructed using multiplanar reformation (MPR), maximum projection intensity (MIP) (Figure 1) and 3D volume-rendered technique (VRT). The reconstruction planes are most often axial or coronal, but can be adapted according to the anatomy of each patient and the anomalies identified on the native sections. MIP and VRT reconstructions thus allow preferential visualization of vessels over adjacent tissue structures, giving images that are close to those obtained in arteriography. Specific post-processing software allows the realization of volumetrics after delimitation by an operator of the contours of the liver and its segments [4].

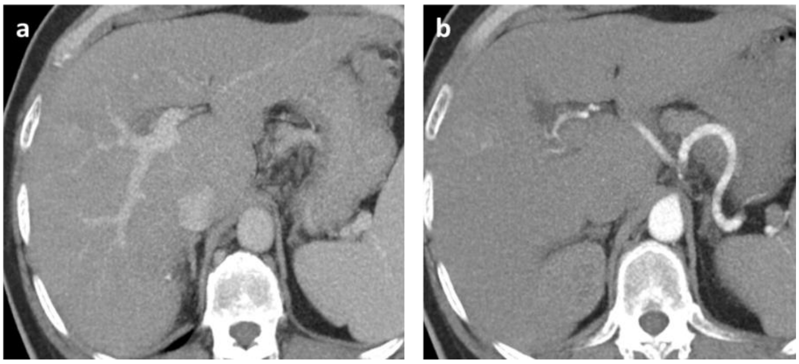

Figure 1: MIP reconstruction from CT scans showing portal (a) and arterial (b) vascularization of the liver in a living donor before harvesting

In practice, CT allows better characterization of a fluid collection and localization of any active bleeding.

The protocol must therefore include an acquisition in spontaneous contrast (search for a hematoma or hemoperitoneum) as well as an acquisition after injection of contrast medium, at arterial (search for active bleeding) and portal (search for abscesses and venous thrombosis) times [1].

MRI is still little used, if at all, because it is difficult to access for a patient hospitalized in the ICU, offers a less good spatial resolution, and the examination is artifacted by surgical drains and clips, as well as by the patient's respiratory movements [4].

- T1-weighted sequences with spectral saturation of the fat signal (in-phase and anti-phase sequences using the differences in precession frequency between water and fat)
- Conventional T2-weighted spin echo sequences of the FSE (Fast Spin Echo) or TSE (Turbo Spin Echo) type are specific in that they allow the distinction between liquid and solid lesions.
- Angio-MRI sequences are fast (in one breath) 3D T1 gradient echo sequences performed after injection of gadolinium, acquired in coronal sections and reconstructed in the different planes of space (most often in MIP);
- Cholangio-MRI, or bili-MRI, is a noninvasive method that represents a good alternative to endoscopic retrograde cholangiopancreatography to explore the biliary tree [5, 6]. Conventional bili-MRI sequences are T2-weighted sequences.
- More recently, T1 gradient echo weighted sequences with intravenous injection of biliary eliminating contrast medium such as mangafodipir, showing the bile ducts in hypersignal, have been added to biliary exploration; these sequences appear to some authors to be superior to conventional sequences [7].

Normal postoperative aspects

The sectioned area is often identified by the presence of multiple hyperechoic spots that correspond to the small clips left on the sectioned vascular and biliary pedicles. The surgical clips are hyperdense on CT and show no signal on MRI (Fig 2) [1].

In cases where the surgeon has used only wire, its punctuations are absent.

Figure 2: Axial CT section after contrast injection illustrating the scannographic appearance after left lumpectomy. The surgical clips generate hyperdense metallic artifacts (arrows) [1]

Within the remaining liver parenchyma, a T2 hypersignal band may appear along the resection margin in 20% of cases on MRI [8]. It corresponds to an accumulation of bile and blood, fibrous infiltration and fatty transformation related to the local trauma. This band will regress spontaneously with time [9].

In the periphery of the remaining liver, a right pleural effusion, a pneumoperitoneum, a small liquid collection limited to the resected area, more or less associated with postoperative air bubbles, is almost always observed immediately postoperatively, without any pathological character until the second postoperative month, in the absence of fever (Fig 3) [10].

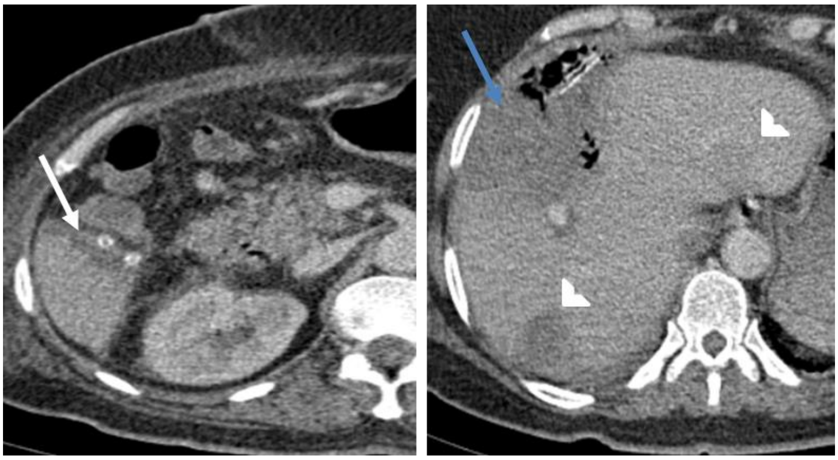

Figure 3: CT axial sections after injection of contrast medium in portal time, showing in early postoperative, a liquid collection (white arrow) and another mixed one; liquid and gas (blue arrow), limited to the resection area with drainage probes opposite, in a patient operated for liver metastases

Note two secondary hepatic lesions (arrowhead): sub capsular of segment V and straddling segments II and III.

Hepatic regeneration allows restoration of hepatocellular function in 2 to 3 weeks if the liver is healthy. Morphologically, hepatic hypertrophy is noticeable a few days after the operation and continues for several months (Fig 4). Pathologically, signs of cell regeneration are seen as early as the seventh day, namely mitotic figures, vascular and bile duct neogenesis (11). In the early days, hepatocyte proliferation may be more rapid than vascular neogenesis, resulting in portal poverty on imaging.

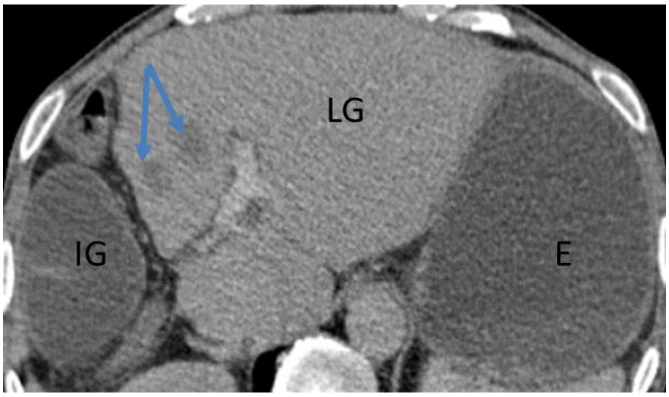

Figure 4: Aspect tomodensitométrique postopératoire tardif après hépatectomie droite, coupe axiale. Note the appearance of two hypodense nodular lesions of segment IV related to liver metastases (arrows)

After right lobectomy, the morphologic changes are identical to those seen after right hepatectomy, but segment IV has disappeared and the portal branch of segment IV downstream of the Rex recess is bound [1].

After left hepatectomy, the section slice passes in the plane of the medial VH, which is usually preserved. The left portal branch is bound at its origin. The right liver is usually enlarged if the underlying liver is healthy.

Its contours become rounder and it takes on a round shape, with elongation in the transverse and craniocaudal directions. There is also moderate hypertrophy of segment I (Fig 5) [1].

After left lobectomy, segment IV remains present and the left portal branch remains visible along the sectional slice. The branches of segments II and III are linked. With time, the left portal branch becomes small, as it perfuses only segment IV [1].

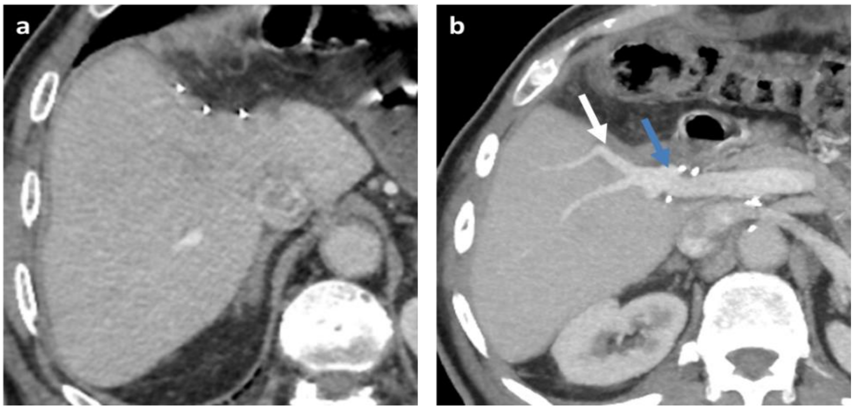

Figure 5: Late postoperative CT appearance after enlarged left hepatectomy, axial slices (a, b) with MIP (b): The left portal branch is bound at its origin (blue arrow) with conservation of the medial portal branch (white arrow)

After unregulated hepatic resection (which may be the case of hepatic transections from outside to inside, without primary vascular control), a portion of the remaining parenchyma is likely to experience disorders of portal perfusion, venous drainage or biliary drainage [1].

After sub-segmentectomy (or wedge-resection), a peripheral scar retraction may be observed, corresponding to the resection margin; sometimes, the surgical metal clips visible on the surface of the liver are the only post-operative stigma.

Complications

Imaging in the early postoperative period is indicated in cases of unexplained fever, abdominal pain, jaundice, or low levels of hemoglobin.

When on the fifth postoperative day, the prothrombin level is less than 50% and the plasma bilirubin level is greater than 50 micromoles per liter, the postoperative mortality rate may exceed 50% [12], which should lead to a search for an infectious, functional or vascular cause on an echo-Doppler and/or an abdominal CT scan.

The role of imaging consists, mainly, in the detection and management of postoperative collections, as well as vascular complications [10, 13].

CT is used to complement ultrasound data; it allows better characterization of a fluid collection and localization of possible active bleeding.

MRI is rarely used, especially in severe patients hospitalized in the ICU [1]. Imaging allows us to detect the various complications of this type of surgery, namely:

1.1 Hemorrhagic complications

Postoperatively, hemorrhage is most often due to bleeding from the section slice and can therefore be prevented during surgery by anatomical resection, careful hemostasis, ligatures mounted on the vascular pedicles rather than simple ligatures or coagulation. This is all the more important when the patient has cirrhosis. These phenomena may be aggravated by coagulation disorders after hepatectomy.

Bleeding disorders related to a state of hepatocellular insufficiency are dreadful and always of poor prognosis. The incidence of postoperative hemorrhage is around 2% in the literature [14].

CT or MRI can be helpful by showing spontaneous hyperdensity or T1 hypersignal in cases of hematic collections (Fig 6 and 7) [1].

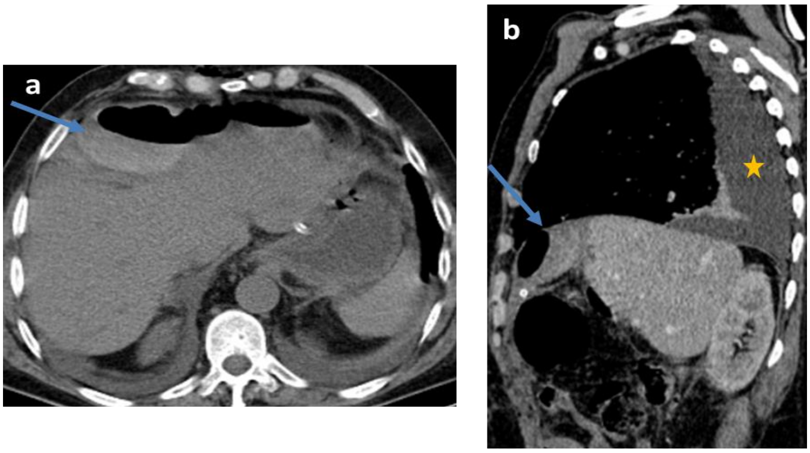

Figure 6: Axial section CT scan in spontaneous contrast (a) and sagittal section after injection of PCI (b) at D10 post-segmentectomy on segment IV, showing a spontaneously hyperdense collection enclosing a NHA, adjacent to the section slice (arrow) without any significant contrast, indicating a hematoma. A pleural effusion is associated (star)

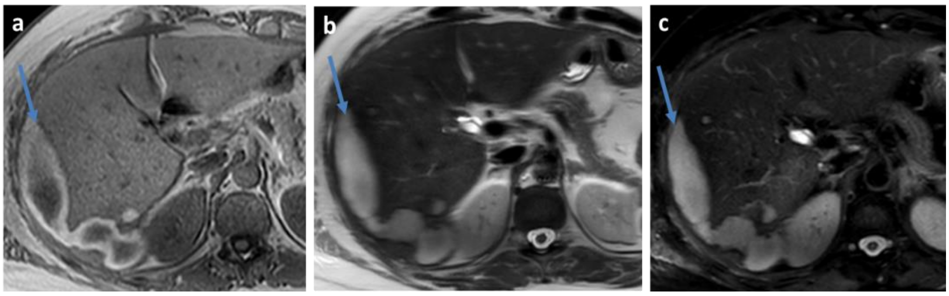

Figure 7: Axial T1 (a), T2 (b) and T2 Fatsat (c) weighted MRI slices after right liver metastasectomy showing a sub capsular collection with scalloped wall continuing with logettes that fuse intrahepatically in heterogeneous T1 and T2 hypersignal that does not fade after fat saturation (arrow) related to a hematoma

1.2 Biliary complications: (15-16-17)

Despite technical advances, biliary complications of liver resections remain a major postoperative problem. The rates of biliary complications in the series published in the last 10 years vary between 3% and 10%.

The biliary fistula corresponds to the exit of bile on the hepatic section. Most often, it is the absence of ligation of the orifice of a small bile duct, located at the level of the sectional slice, which was not identified during the operation. Sometimes the leak is a symptom of an underlying stenosis due to inappropriate ligation, and it may also be the section of a larger bile duct draining the remaining liver or a leak at the level of a hepatico-jejunal anastomosis. Finally, it can be a secondary necrosis of a bile duct by devascularization after a too aggressive dissection. The increase in pressure in the bile duct in the immediate postoperative period favors biliary leakage (Fig 8).

Central hepatic resections are said to cause more postoperative biliary fistulas, as they create a large Hepatectomy slices with a large surface area and exposing the convergence. Finally, performing a cholangio-MRI before the hepatic resection to detect an anatomical variation and performing a bile duct leakage test at the end of the operation are considered , by some authors , as effective means to prevent biliary fistulas.

Most often, the fistula will dry up spontaneously if there is no obstacle in the downstream bile duct and if the fistula is not downstream biliary tract and if there is no intermediate pocket likely to perpetuate suppuration along the suppuration along the drainage. If there is no obstruction, the treatment of the biliary fistula must be only a good drainage. This drainage must be as direct as possible, without intermediate pockets. The drain orifice should be as close as possible to the biliary orifice.

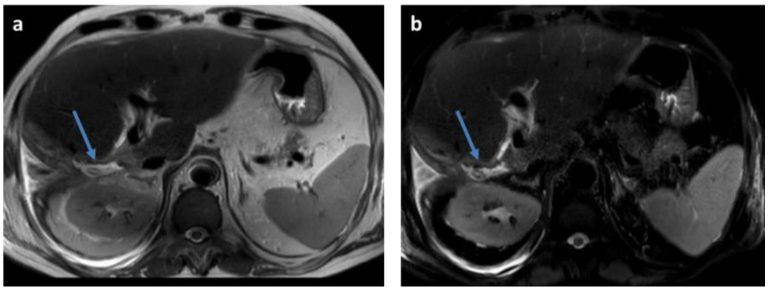

Figure 8: Axial T2-weighted (a) and T2 Fatsat (b) MRI sections at D8 after right hepatectomy showing a fluid collection opposite the stump of the cystic duct in T2 frank hypersignal, extending perihepatically along the section slice (arrow) in connection with a biliary fistula

The pathogenesis of Biloma is the same as that of a biliary fistula, but in this case, the bile flow is not drained to the outside, resulting in the formation of a collection containing bile and blood in contact with the hepatic section (Fig 9). The initial management of this complication is based on radiological drainage, using a drain of sufficient calibre, taking the most direct route possible. Then, the biliary fistula must be treated if it exists.

Once the drainage is in place, the management of biliary fistulas and biliomas are identical. Most often, the fistula will dry up spontaneously in less than seven days, without any consequences on the postoperative follow-up. If the fistula persists, without a decrease in flow and becomes chronic despite good drainage (no intermediate pocket).

Additional examinations are necessary to understand the exact mechanism of the biliary leak by magnetic resonance imaging (bili MRI). The resulting management is complex and not standardized.

Drainage alone, left in place until the fistula has dried up spontaneously, is sometimes the best solution. However, the practitioner has different therapeutic tools at his disposal, the use of which differs according to the team such as; Endoscopic sphincteromy associated with the installation of a stent, which is still widely used by some. It allows a retrograde cholangiography to be carried out for diagnostic purposes and a therapeutic procedure (prosthesis); it is of interest in the case of stenosis downstream of the fistula or in fistulas caused by a wound at the convergence. Either the trans-parieto-hepatic drainage of the bile ducts feeding the fistula allows to "dry" the fistulous path and to favour its healing; its difficulty of use is due to the fact that the bile ducts are not dilated and therefore difficult to puncture.

The surgical reintervention must be considered in case of failure of the two previous treatments or immediately in case of fistula in a patient with ascites or in the case of a fistula originating from the fistula originating from the main bile duct or its bifurcation.

In case of fistula concerning a peripheral bile duct, treatments by injection of biological glue, ethanol or by obturation with a balloon have been proposed and proved to be effective.

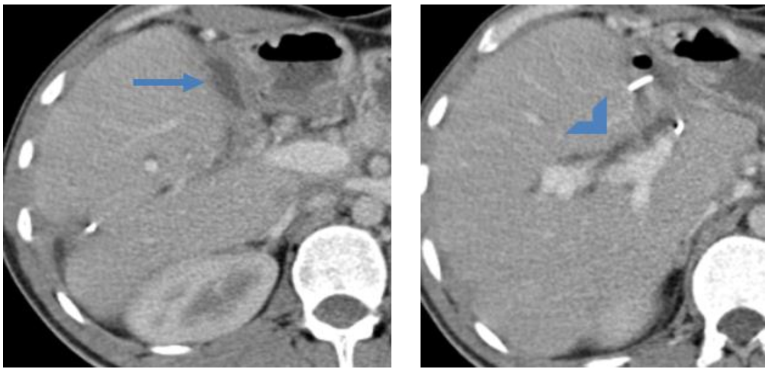

Figure 9: Axial slice CT scan at D8 post metastasectomy showing a fluid collection adjacent to the section slice (arrow) in communication with the adjacent bile ducts (arrowhead) in relation to a biloma

Choleperitoneum

This is a serious complication of these biliary leaks and may present as biliary ascites (choleperitoneum without infection). It is serious because of the fluid sequestration it causes by transudation due to the concentration of bile salts and the associated inflammatory reaction. The initial symptomatology is often insidious, marked by pain and moderate distension of the abdomen, sometimes with tenderness on palpation. At the slightest doubt, an exploratory puncture should be performed, possibly with guided ultrasound. The aggressiveness of the bile towards the peritoneum and the risk of superinfection rapidly lead to the stage of biliary peritonitis with a vital risk (mortality 40 to 50%). A second operation to locate and drain the fistula is essential.

1.3. Hepatic necrosis [18]

***Diffuse hepatic necrosis**

Diffuse lesions are due to excessive duration of clamping of the hepatic pedicle aggravated by possibly repeated collapses. It may be related to problems of vascularization of the residual segments by thrombosis of the portal artery or vein (Fig 10), or by folding of the suprahepatic vein or veins due to torsion of the remaining liver. The finding of very high transaminase and GGT levels should raise the suspicion of hepatic necrosis and lead to the performance of a Doppler ultrasound or arteriography. Depending on the findings, a specific treatment will be started (heparin therapy, reoperation).

Localized necrosis

It corresponds to the ischemic tissue along the hepatic section slice. It is exceptional if the resection is anatomical, but the realization of blind spots used for hemostasis can lead to such lesions. These necrotic areas may evolve towards progressive atrophy or abscessation.

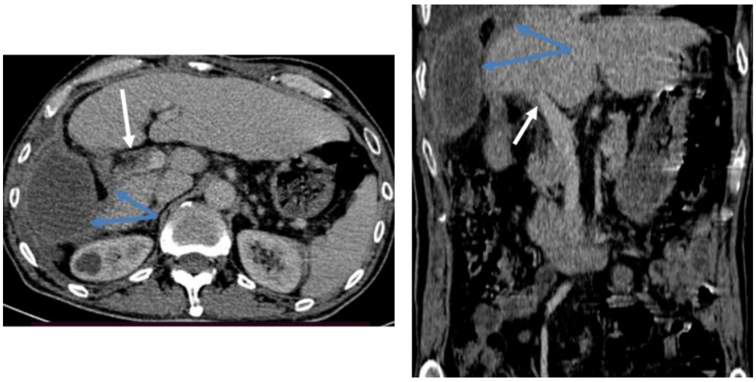

Figure 10: CT scan in axial and coronal section showing a thrombosis of the right portal branch (white arrow) responsible for diffuse necrosis of the right liver (blue arrow)

1.4. Abscess [19, 20]

It may occur in the absence of reabsorption of bile, blood or necrotic tissue. Bacterial organisms may reach the liver from the bile and arterial blood, or portal blood and thus colonize the surgical site. Very often, abscesses are associated with biliary fistulas that favor bacterial colonization. Normally, the germs are sequestered by the Kupffer cells in the liver, but the devitalized parenchyma loses its capacity to phagocytose, thus favoring the development and persistence of the infection. The diagnosis, clinically evoked in a septic context, is confirmed by imaging on peripheral contrast, sometimes associated with a significant amount of gas within the formation (Fig 11) [1].

If the abscess appears isolated or in the absence of associated necrosis, puncture-drainage under ultrasound or CT scan covered by appropriate antibiotic therapy is the treatment of treatment of choice, allowing a cure in nearly 80% of cases.

The factors favoring the occurrence of a postoperative abscess seem to be the type of surgery (right hepatectomy or extended right hepatectomy), the duration of the surgery greater than five hours and postoperative hemorrhage requiring a intervention. The use of passive drainage has been incriminated in the formation of abscesses as well as secondarily infected biliomas or hematomas.

The incidence of these abscesses could be reduced by systematic culture of drainage fluids and prophylactic antibiotic therapy with second generation cephalosporins.

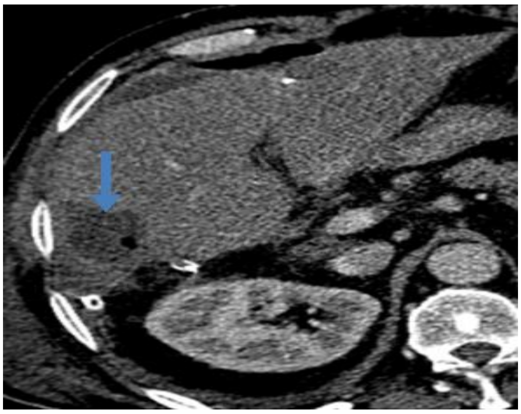

Figure 11: Axial section CT scan showing a fluid collection opposite the section slice containing an air bubble with peripheral contrast (blue arrow) corresponding to an abscess

1.5 Biliary tract obstruction [18]

The appearance of postoperative jaundice can have multiple origins; iatrogenic stenosis, reactive oditis or lithiasis migration. In all cases, dilatation of the intrahepatic bile ducts will evoke the diagnosis.

1.6 Ascites [21]

The early postoperative phase is often associated with extracellular water sequestration, both at the both peritoneal and pleural, the treatment of which requires adequate perfusion and The importance of ascites is correlated to the degree of hepatocellular insufficiency. Its appearance is favored by:

- A preoperative hypo albuminemia, a decrease in total proteins and a hydro sodium retention;
- Portal hypertension which appears immediately after a major resection
- Lymphatic hyper production of tissues at the surgical site;
- Changes in renal function;
- Postoperative paralysis, explained by the intraoperative traction on the diaphragm at the level of the incision;
- Peritoneal inflammatory phenomena which make it frequent after hepatectomy.

On the CT scan, ascites is seen as an effusion of liquid density (between 0 and approximately 30 Hounsfield units) that does not enhance after injection of contrast medium (Fig 12). On MRI, ascites is seen as a T2 hypersignal, T1 hyposignal effusion that does not enhance after injection.

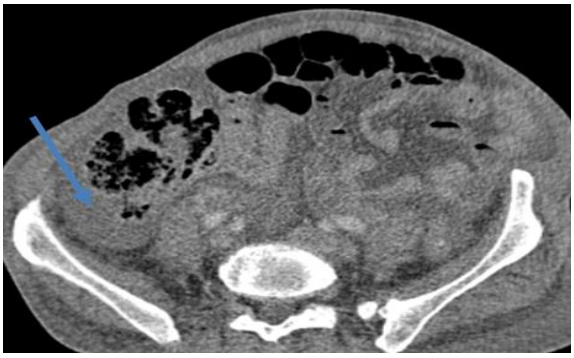

Figure 12: Axial CT section of the pelvic floor showing abundant ascites (arrow) within which the digestive tracts are visible

The risk of immediate parietal complications (infection, evisceration) or late complications (ventration). Prevention and treatment of this fluid retention requires adequate perfusion and maintenance of intravascular volume.

1.7 Pulmonary complications [22, 23]

***Pleural effusion* (Fig 13)**

Pleural effusion is very frequent, especially after right hepatic resection or resection near the diaphragm. Its mechanism of occurrence is multifactorial: decrease in postoperative diaphragmatic mobility, passage of intra-abdominal fluids into the pleural cavity through the costo-diaphragmatic hiatus, hydrops. If they are very important, their evacuation by puncture or pleural drainage is necessary for the improvement of the patient's clinical condition.

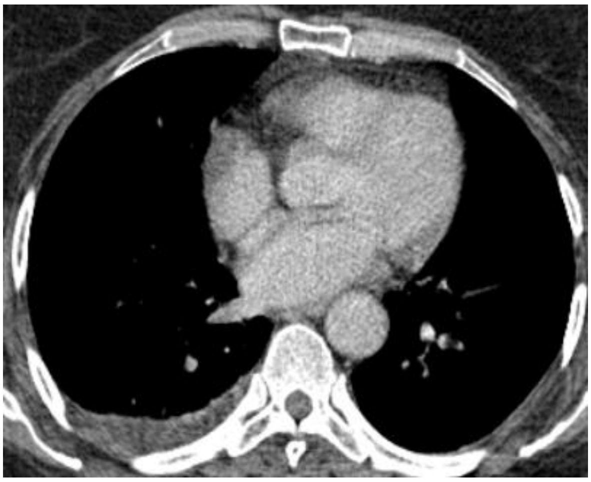

Figure 13: CT axial section in mediastinal window showing early right pleural effusion after right lobectomy

Atelectasis (Fig 14)

Atelectasis is favored by the subphrenic surgery and by the postoperative pain which reduces respiratory ampliation, they may require fibroaspiration. These pulmonary complications pulmonary complications can be prevented by early postoperative respiratory physiotherapy.

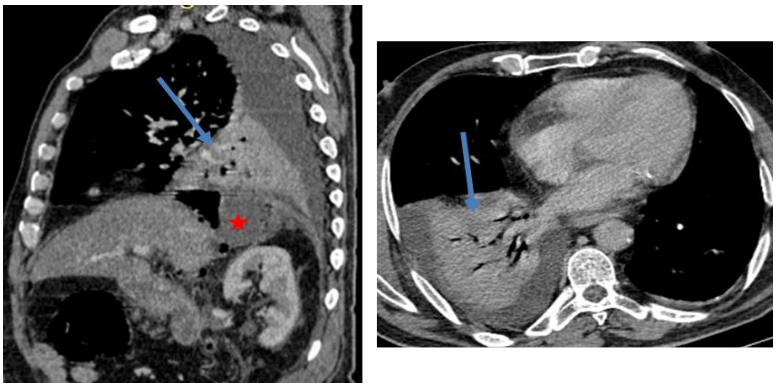

Figure 14: CT scan in coronal and axial section in the mediastinal window showing a pleural effusion with collapse of the LID (arrow) at D7 post right hepatectomy. There is also a mixed liquid and gas collection (star) in the perihepatic area opposite the section

1.8. Digestive hemorrhage [24]

The incidence of stress ulcers in the postoperative period is 5% and their mortality is about 50%. Systematic prophylaxis of this pathology after hepatic resection is therefore essential, based on the administration of proton pump inhibitors.

One third of cirrhotic patients have gastroesophageal varices. The mortality rate associated with the bleeding of these varices is 15 to 40%, which justifies checking for the absence of varicose veins preoperatively for hepatectomy in cirrhotic patients, or treating existing varicose veins.

1.9. Other vascular complications [13]

They are mainly represented by portal thrombosis and acute Budd Chiari syndrome. These complications often occur after right hepatectomy, by folding of the common trunk of the median and left VH, due to an excessive tilt of the remaining left liver towards the right. More rarely, they can occur following iatrogenic trauma (ligation, burn) of a glissonian pedicle (portal branch or artery).

The diagnosis of portal thrombosis is based on CT or MRI in the absence of enhancement of the vessels involved or of the downstream liver parenchyma (Fig 10) [1].

The diagnosis of Budd Chiari syndrome is also based on Doppler ultrasound data, which is indicated when there is an alteration in liver function and excessive production of ascites. Spectral demodulation of the remaining VH (which remain permeable in the acute stage, despite the plication) and a slowing of portal flow are then observed [1].

CONCLUSION

To enable postoperative management of liver surgery, it is essential for the radiologist to know the normal postoperative aspects and complications of these surgeries as well as the diagnostic pitfalls in CT and MRI.

Declaration of interest: The authors declare that they have no ties of interest.

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