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Review

Anaesthesia for elective liver resection: some points should be revisited

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Summary

Improvement in surgical techniques, technology and perioperative assessment has dramatically simplified the anaesthetic care for elective liver resection. Patients with a non-tumorous healthy liver should only need the usual preoperative assessment. Patients with pre-existing parenchymal liver disease should be specifically assessed for gas exchange impairment, alcoholic or nutritional-associated cardiomyopathy, infection, cirrhosis decompensation, acute alcoholic hepatitis, and kidney impairment. The type of anaesthetic management does not influence the intra- and postoperative courses. Intermittent clamping of the portal vascular triad is better tolerated than prolonged continuous periods of ischaemia – especially in patients with abnormal liver parenchyma. Intraoperative antibiotic prophylaxis must be administered to prevent translocation of intestinal enterobacteria to the systemic circulation in patients with both healthy and diseased livers. Blood-salvage techniques have limited indications in liver resection. Systematic invasive haemodynamic monitoring is no longer warranted. An arterial cannula should only be considered in procedures of long duration and in selected situations likely to cause anticipated circulatory impairment: total liver vascular occlusion, repeat surgery, combined organ resection, and surgery conducted on tumours >10 cm in size or in connection with the vena cava. In a recent large series of liver resections, 60% of patients did not need a blood transfusion, only 2% of transfused patients received >10 units of blood and cirrhosis was not predictive of increased intraoperative bleeding. Postoperative ascites, which always develops at the expense of circulating fluid, is a frequent occurrence in patients with healthy or diseased livers. Intra- and postoperative fluid limitation does not prevent postoperative ascites. Volume expansion, diuretics and vasopressor therapy should be initiated early to prevent kidney failure.

Keywords: ANAESTHESIA, GENERAL; LIVER DISEASES, liver failure; LIVER TRANSPLANTATION; SURGERY.

Introduction

It has been accepted for some time that there is a considerable risk of massive bleeding during surgery for elective liver resection [1]. At present, improvements in surgical techniques, technology and preoperative assessment – in conjunction with a better understanding of the functional anatomy of the liver – have dramatically reduced the risk of adverse haemodynamic changes associated with elective liver resection. This includes the risk of bleeding. Therefore, anaesthetic care for elective liver resection has become simpler, even though the limits of liver resection have been extended [2–7].

Preanaesthetic assessment

Routine preoperative assessment is all that is needed in healthy non-tumorous liver patients [2,8]. Patients with pre-existing underlying liver disease must be

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assessed for specifically associated organ dysfunction. Should respiratory or circulatory failure be suspected, arterial blood-gas measurements while breathing room air and Doppler echocardiography must be performed to assess cardiomyopathy, either from alcohol toxicity (low flow circulation) or vitamin deficiency (hyperdynamic circulation) [8–11]. The ejection fraction will give an indication of left ventricular function in these cases [10].

Increased pulmonary artery pressure

Echocardiographic findings consistent with pulmonary hypertension include tricuspid regurgitation, a dilated right atrium and a dilated right ventricle. Right heart catheterization allows the measurement of the pulmonary arterial and pulmonary capillary wedge pressures. Patients with increased pulmonary vascular resistance can be separated from those with a high flow state associated with low or normal pulmonary vascular resistance [9].

Arterial hypoxaemia is caused by pleural effusions, usually associated with clinical ascites, or by intrapulmonary vascular dilatation [8,10,11]. The improvement from hypoxaemia on administration of 100% inspired oxygen should be measured to estimate the degree of the shunt and whether weaning from mechanical ventilation of the lungs postoperation will be possible. Patients with severe hypoxaemia ($PaO_2 < 8.0$–9.3 kPa) and a poor response to 100% inspired oxygen must be investigated using contrast echocardiography or perfusion lung scanning with technetium-labelled macroaggregated albumin [9].

Patients with a diseased liver must also be systematically assessed for kidney impairment, which is consistently associated with chronic liver disease. The serum creatinine concentration should also be measured [11].

Abnormalities suggesting decompensation caused by cirrhosis

Abnormalities suggesting decompensation caused by cirrhosis are an increase in the serum concentration of bilirubin, a decrease in plasma albumin and Factor V, the presence of ascites and the presence of neurological signs and symptoms. Both an infectious disease (which needs to be adequately controlled preoperatively) and acute alcoholic hepatitis may account for cirrhosis decompensation [8,10,11].

Acute alcoholic hepatitis

Should a severe acute alcoholic hepatitis be suspected on biochemical or clinical grounds, elective surgery should be postponed and the patient referred to a specialist for a liver biopsy and possible preoperative corticosteroid therapy in selected cases [10].

Operative risk

The ASA classification of physical status does not take into account the clinical features resulting from chronic liver disease. On the contrary, the Child and Pugh scoring systems consider the serum bilirubin and albumin concentrations, prothrombin time, the presence of ascites, and encephalopathy and clinically assessed nutritional impairment (Tables 1 and 2). Both scoring systems have been reliably correlated with postoperative mortality rate in cirrhotic patients undergoing portocaval shunt and general surgery, and the scoring systems distinguish three operative risk levels, which are summarized in Tables 1 and 2 [8,10].

Recently, multivariate analysis has identified variables independently associated with perioperative complications and mortality in cirrhotic patients undergoing general surgery: the male gender, a high Child–Pugh score, the presence of ascites, a diagnosis of cirrhosis – other than primary biliary cirrhosis (especially cryptogenetic cirrhosis) – an elevated creatinine plasma concentration, the diagnosis of chronic

Table 1. Pugh score. It distinguishes three risk levels in general surgery.

	Score		
Variables	1	2	3
Encephalopathy	0	Grade I, II	Grade III, IV
Ascites	0	Moderate	Important
Total serum bilirubin concentration (mmol L^{-1})	<34.2	34.2–51.3	>51.3
Serum albumin concentration (g L^{-1})	>35	30–35	<30
Prothrombin time (%)	>65	50–65	<50

	Score		
	5–6	7–9	10–15
Surgical risk	Good	Moderate	High
Mortality rate (%)	5	10	>50

Table 2. Child score.

	Score		
Variables	A	B	C
Encephalopathy	0	Grade I, II	Grade III, IV
Ascites	0	Moderate	
Total serum bilirubin concentration (mmol L^{-1})	<34.2	34.2–51.3	Important
Serum albumin concentration (g L^{-1})	>35	30–35	>51.3
Nutritional assessment	Excellent	Good	<30 weak

In the child scoring system, the prothrombin time is replaced by a clinically assessed nutritional state. Child scoring system distinguishes three risk levels following general surgery: A: low risk; B: middle risk; C: high risk.

obstructive pulmonary disease, preoperative infection, preoperative upper gastrointestinal bleeding, a high ASA physical status, a high surgical severity score, surgery on the respiratory system and the presence of intraoperative hypotension (Table 3). In this analysis, the risk factors were additive. Blood transfusion was associated with a poor prognosis [12]. In contrast, cirrhotic patients with no ascites, no hepatocellular insufficiency, no acute alcoholic hepatitis and a normal prothrombin time underwent major surgery with a prognosis similar to that of patients with no underlying liver disease undergoing identical surgery [3,12]. The type of anaesthetic management did not influence the postoperative course [12].

Technical improvements

Before surgery, the relationships of tumours with liver vessels, mainly branches of the vena cava, the portal vein, the suprahepatic veins and the hepatic artery, are localized by Doppler ultrasonography and abdominal computed tomography. Additionally, selective coeliomesenteric angiography and magnetic resonance imaging are performed whenever required. Consequently, resectability and the situations likely to prolong surgery and/or increase intraoperative bleeding can often be anticipated [2]. Such circumstances are encountered in the case of pre-existing adhesions resulting from previous surgery and when additional organ removal, cava or portal vein resection, or recanalization are necessary [2,13].

During surgery, ultrasonography allows the exact localization of vascular and biliary structures and facilitates liver parenchyma sectioning either with hepatic vascular occlusion (total liver vascular exclusion or portal vascular triad clamping) or without hepatic inflow occlusion [2,14]. Thus, intraparenchymal vessels and biliary tracts will not be injured during parenchyma transection using an ultrasonic dissector. Finally, before wound closure, surgical haemostasis is completed using biological glue or an argon dissector, or both [2].

Table 3. Multivariate associations with the presence of complications in Ziser and colleagues' study [12].

Risk factors	Morbidity rate (%)	30 day mortality rate (%)	6 month mortality rate (%)
Pugh score: 7–10	42	15	31
Ascites	48	20	39
High creatinine concentration	42	21	36
Chronic pulmonary disease	41	18	29
Preoperative infection	74	49	60
Upper gastrointestinal bleeding	70	12	23
ASA IV–V	68	32	52
Major surgery	39	12	23
Intraoperative low blood pressure	45	15	26
Cryptogenetic cirrhosis	33	14	24

Anaesthetic care

Refinements in surgical techniques have helped to simplify anaesthesia care.

Anaesthesia

The influence of anaesthetic techniques and drugs on liver function following elective liver resection has never been investigated. Halothane, but not isoflurane, worsened previously altered liver function in laboratory animals and probably should not be administered [15,16]. Atracurium and cisatracurium have no hepatic metabolic pathway and should be favoured [17]. Should moderate liver impairment exist before surgery, alfentanil elimination may be delayed, but fentanyl and sufentanil pharmacokinetics are unlikely to be altered [18]; liver function is not involved in remifentanil elimination [19]. However, there is no evidence that any one anaesthetic agent should be preferred to another in elective liver resection [8,20]. Indeed, surgery is contraindicated in patients with a degree of hepatocellular impairment that would rule out the administration of anaesthetic agents metabolized by the liver [8,20]. All drug effects should be carefully titrated after the tumour has been removed [20]. Under these conditions, liver resection should be conducted under standard general anaesthesia. Two large-bore venous cannulae should be inserted to permit rapid fluid or blood infusion. Any intraoperative decrease in systemic arterial pressure must be rapidly treated to preserve liver blood flow and, therefore, minimize postoperative liver impairment. Infused fluids should be restricted – as tolerated by the haemodynamic status – until parenchyma sectioning is completed [8]. Indeed, intraoperative blood loss, mainly related to parenchymal venous bleeding in major liver resection, has been correlated with the central venous pressure [21].

Antibiotics

Antibiotic prophylaxis suitable for clean surgery (Altemeier Class 1) must be administered when the resection of a benign or a non-complicated malignant tumour, which has developed within a healthy or a diseased liver parenchyma, is scheduled. Intraoperative antibiotic prophylaxis is warranted because of the long operating times, large postsurgery deadspaces

and inevitable areas of devitalized tissue [22]. On the contrary, postoperative routine antibiotic administration has been shown to be unnecessary following liver resection. Translocation of intestinal enterobacteria to the systemic circulation is mainly responsible for peritoneum inoculation following major liver surgery [23]. Consequently, intravenous cefazoline (2 g before induction of general anaesthesia with 1 g every 4 h throughout surgery) is recommended [22,23]. Biliary obstruction, even when not associated with clinical infection, should be considered as a potential source of sepsis and it requires antibiotic therapy. In this case, piperacillin (with or without tazobactam) combined with an aminoglycoside or with a fluoroquinolone are adequate choices [4,8,22]. Further antibiotic administration depends on the results of bacteriological examination of intraoperative bile samples [22]. Pre-existing or intraoperatively diagnosed ascites in cirrhotic patients is likely to result in intraoperative bacterial inoculation by translocation of intestinal enterobacteria to the systemic circulation. A 24 h prophylaxis by a third generation cephalosporin or fluoroquinolone is warranted in cirrhotic patients with ascites [3,8,11,24].

Haemodynamic changes

Intraoperative events may still compromise haemodynamics during elective liver resection.

Intraoperative bleeding. Recently published series indicate that the transfusion rate has now markedly decreased in elective liver resections compared with previous reports [1,2,6]. Similar blood loss is reported in several recent large series of patients undergoing major liver resection [2,3,6,7,13]: 60% of patients did not need a blood transfusion, 80% of transfused patients received <6 units of red blood cell and 2% of transfused patients received >10 units of red blood cells. Owing to better patient selection, cirrhosis is no longer predictive of increased intraoperative bleeding [3,21]. Cirrhotic patients with no ascites, no hepatocellular insufficiency, no acute alcoholic hepatitis and a normal prothrombin time undergo major surgery with a prognosis similar to that of patients with no underlying liver disease undergoing identical surgery [3,12,25]. Selected patients, including cirrhotic patients, may undergo major liver resection without blood transfusion [6]. Intraoperative bleeding is life-threatening only in situations likely to be anticipated by careful preoperative assessment in repeat surgery, combined organ resection, tumours >10 cm, inferior vena cava or portal vein replacement, or recanalization and increased portal pressure [2,8,13].

Surgical liver mobilization. It is possible that the inferior vena cava and portal vein may be compressed or twisted by surgical liver mobilization during operation. This occurrence should be considered intraoperatively in instances of the combined reduction in systemic arterial pressure and in expired PCO_2 [8]. It is life-threatening only in hypovolaemic patients [8,13,14].

Liver vessel occlusion. Liver inflow may have to be interrupted during surgery using portal vascular triad clamping (performed by the combined occlusion of the portal vein and hepatic artery) and total vascular exclusion of the liver (performed by portal triad and infra-hepatic and suprahepatic inferior vena cava clamping) [14].

Portal vascular triad clamping causes a 5–10% decrease in cardiac output associated with a 20–30% increase in both left ventricle afterload and arterial pressure; a noxious reflex elicited in the peritoneum accounts for this vasopressor response [14]. Afterload increase is likely to increase myocardial wall stress and, therefore, to compromise myocardial oxygen supply in patients with pre-existing coronary disease [8,14]. In these patients, left ventricle afterload should be lowered during portal vascular triad clamping, either by increasing halogenated anaesthetic agent delivery, if these agents are being used for intraoperative hypnosis, or by infusing titrated doses of vasodilators. Intravenous nicardipine is suitable for treating decreases in afterload during portal triad occlusion [8]. Recent clinically controlled and experimental studies demonstrated that intermittent 15 min clamping is better tolerated than continuous ischaemia, especially in patients with steatosis and chronic parenchymal liver disease [26].

Total liver vascular exclusion causes a 30–60% decrease in cardiac output [14]. Ideally, total liver vascular exclusion should be progressively established while volume expanders – 1000–2000 mL – are infused to increase left ventricle preload [8,14]. At present, since liver vascular exclusion is expected to be of short duration, it is usually performed before an efficient preload increase [8,14,18]. Consequently, pharmacological haemodynamic support should be considered to keep the mean systemic arterial pressure at 50–75 mmHg while vascular exclusion is performed [14]. Intravenous norepinephrine is usually chosen for haemodynamic support during total liver vascular exclusion because of its potent vasopressor and inotropic effects. On the contrary, the 30–60% increase in cardiac output resulting from reversal of total vascular exclusion – associated with volume expansion – is likely to cause left ventricular overload in patients with pre-existing heart disease. To prevent such cardiac impairment, intravenous dobutamine may be transiently infused, in association with diuretics, in patients with pre-existing heart disease while total vascular exclusion is reversed [8]. Similar blood loss has been reported following

total liver vascular exclusion and portal vascular triad clamping [14]. Therefore, total liver vascular exclusion is restricted to the resection of tumours with hepatocaval connection and as a last resort after an untoward intraoperative vascular wound [8,13,14].

Air embolism. Haemodynamically significant air embolism during operation has become an uncommon event during elective liver resection [27]. It is prevented by preoperative localization of parenchymal vessels, which therefore will not be injured during liver parenchyma sectioning, and by the immediate oversewing of any perforations in the hepatic veins during parenchymal dissection [2,27]. An abrupt fall in expired CO_2, perhaps associated with haemodynamic alteration, indicates an air embolism after causes such as hypovolaemia or any surgically related decrease in the venous return of blood to the heart have been considered [8,14,27]. Positive end-expiratory pressure has never been demonstrated to prevent this occurrence efficiently, although it has often been proposed for this purpose [8,27].

Intraoperative haemodynamic monitoring. Adequate preoperative assessment and improved surgical and anaesthetic management should dramatically reduce the need for invasive monitoring in elective liver resection.

Central venous line pressure monitoring. Central venous pressure (CVP) measurement does not reliably account for haemodynamic changes in ICU patients with circulatory impairment [28]. Central venous pressure monitoring is much less reliable during liver resection. During liver resection, the pressure of surgical retractors on the diaphragm increases the intrathoracic pressure and, consequently, increases the CVP [8,29]. Clamping of liver vessels reduces the venous return of blood to the heart and therefore decreases the CVP [14,29]. Intraoperative liver mobilization is likely to twist the vena cava and portal vein and therefore decrease venous return to the heart [8,14]. A liver compressed during surgery is likely to release a significant amount of blood into the systemic circulation and therefore increase CVP [8,29]. In addition, central venous catheters are longer than peripheral venous cannulae and cause a higher resistance to fluid flow. Consequently, blood transfusion is more easily performed through a peripheral cannula than through a central venous catheter [28]. Moreover, measurement of CVP is not needed to guide intraoperative fluid infusion or to keep the systemic arterial pressure as low as haemodynamically tolerated and therefore to limit blood loss during parenchymal sectioning [16,29]. Finally, should massive bleeding occur, the major criteria for blood volume expansion are the adequacy of systemic arterial pressure and expired CO_2 plus the adequacy of the waveform of the peripheral pulse oximetry curve [29].

Pulmonary artery catheterization. Indications for pulmonary artery catheterization in ICU patients are becoming increasingly more ill-defined for patients with intricate circulatory impairment [29]. Whether a pulmonary artery catheter will contribute to quantifying intraoperative bleeding is questionable [28]. This should be anticipated [8,13,29] and can be estimated by assessment of losses of blood into suction bottles. The need will usually be <6 units of red blood cells [2,8,13]. Furthermore, haemodynamic disturbances resulting from liver vascular occlusion or from an intraoperative bacteriaemia are reproducible and should be routinely managed by volume expanders with inotropic and vasopressor agents as necessary [14,29].

Transoesophageal echocardiography. Should an uncommon intraoperative multifactorial circulatory disturbance be anticipated, transoesophageal echocardiography will best assess the volume status, left ventricular function, kinetic abnormalities and afterload indices [30].

Oesophageal Doppler. Further studies are needed to assess whether oesophageal Doppler is of value during major abdominal surgery. Indeed, surgical abdominal manipulations and body position changes require frequent probe repositioning [30].

Arterial catheter. A peripheral arterial catheter allows frequent blood samples to be taken and displays the systemic arterial pressure continuously. A peripheral arterial catheter is a useful, albeit rather invasive, tool that should be inserted when long-lasting procedures or circulatory impairments, or both, are anticipated [29].

Blood-sparing techniques

The blood-sparing effect of isovolaemic haemodilution and autologous blood predonation is still being debated. Administration of erythropoietin is efficient for the rapid restoration of preoperative anaemia. However, administration of erythropoietin, which is approved for orthopaedic surgery, has not been validated as a blood-sparing procedure in elective liver resection. These techniques may be proposed in selected situations such as a rare blood group, a pre-existing anaemia or in the case of reluctance to receive blood transfusions related to the patient's religious concerns [31]. Intraoperative blood salvage is seldom used in major liver resection. Indeed, liver resection is often performed for cancer removal, a circumstance in which controversy exists about the use of intraoperative blood salvage, or for treatment of infectious diseases [2–4,6–8,31,32]. Aprotinin, when compared with placebo, significantly reduced transfusion requirements by 50% and the number of units of transfused red blood cells by 60% in elective liver

resections [33]; however, severe allergic reactions have been reported [31,33]. Prophylactic administration of aprotinin may be useful in selected situations when major blood loss is anticipated [8,13,14,33]. The haemoglobin concentration that allows safe postoperative metabolism is still under debate. However, tolerance of lower intra- and postoperative haemoglobin values than previously reported and the limitation of intraoperative fluids to reduce haemodilution have contributed to the reduction of intraoperative blood transfusions in several reports [31].

Postoperative care

Significant postoperative pain follows liver resection [34–37]. Several analgesic techniques have been investigated.

Spinal and epidural analgesia

The use of spinal or epidural analgesia has been shown to control efficient postoperative pain following elective liver resection. Various protocols have been proposed: boluses or continuous administration of opioids (fentanyl, sufentanil, morphine), combined or not with local anaesthetics (bupivacaine, ropivacaine) [35–37]. However, it may be argued that the incidence of catastrophic postpuncture bleeding complications – including epidural haematoma – could be increased following liver resection [37]. Indeed, liver resection results in measurable decreases in the concentration of various clotting factors due to consumption, to a transient insufficiency of the remnant liver to synthesize new factors and to increased intraoperative activation of fibrinolysis [33,37].

Acetaminophen

Acetaminophen (paracetamol) significantly reduces morphine requirements following abdominal surgery [38]. It should be prescribed cautiously for a limited period following major liver surgery [8,20,39]. However, the elimination half-life of acetaminophen has not been studied following major liver resection [15,39]. Furthermore, non-specific clinical and biological features recorded in hepatitis associated with acetaminophen (nausea, vomiting, abdominal pain, jaundice, elevation of transaminase concentration, moderate kidney impairment, dizziness) may be unnoticed following major abdominal surgery [39].

Nefopam

Nefopam has no hepatic metabolism and has been suggested as a better analgesic than acetaminophen when controlling postoperative pain following liver resection [34]. Administration of nefopam, combined with subcutaneous or patient-controlled intravenous morphine, should therefore be favoured when treating postoperative pain after elective liver resection [34,36,40].

Non-steroidal anti-inflammatory drugs

Non-steroidal anti-inflammatory drugs (NSAIDs) should be avoided in cirrhotic patients [20]. They are likely to worsen the pre-existing renal dysfunction frequently associated with cirrhosis [8,10,11,20], and, more importantly, they also worsen functional renal dysfunction and fluid retention associated with cirrhosis and impair diuretic efficiency [10,20].

Postoperative course

Histological findings in the non-tumorous liver predominantly influence postoperative outcome following liver resection [2,8]. Following liver resection, the mortality rate is about 1% in patients without pre-existing underlying liver disease and about 10% in patients with a pre-existing underlying liver disease [2–4,6,7]. Specific liver-related adverse events are likely to complicate elective liver resection.

Healthy liver

Ascites. The incidence rate of transient exudative ascites is 50% following major liver resection performed on an underlying healthy liver [2,8]. In this case, ascites usually disappears within 2–5 days [2,8,11]. However, this ascites develops at the expense of intravascular circulating fluids and causes hypovolaemia [10,11]. Consequently, fluid and sodium intake restriction, or diuretic administration, or both, will not control this ascites. On the contrary, prescribed inappropriately, they will worsen the associated hypovolaemia and cause a decrease in renal perfusion and in the glomerular filtration rate. Volume expanders should therefore be infused – mainly plasma colloid substitutes – either as a preventative measure or as soon as any sign of hypovolaemia (oliguria, tachycardia, decrease in systemic arterial pressure) appears following liver resection in order to prevent renal impairment. Albumin infusion is not warranted in this situation [8,10].

Hepatocellular insufficiency. The incidence rate of hepatocellular insufficiency is 1–3% following major liver resection performed on an underlying healthy liver [2,8]. It requires the usual intensive-care support and that patients be checked for a triggering cause, mainly postoperative abdominal or systemic infection, or acute portal vein or hepatic artery thrombosis [8,10].

Diseased liver

Biliary tract obstruction. The in-hospital mortality rate of patients with obstructive jaundice secondary

to malignant biliary obstruction has been reported to be 5–20%. In these cases, the predominant cause of death is liver failure and/or associated postoperative abdominal or systemic sepsis [4]. Postoperative biliary leak is a frequent occurrence. Preoperative biliary drainage did not significantly influence mortality rate in this sub-group of patients [2,4].

Cirrhosis. The risks of major liver resection were retrospectively assessed in 50 patients with underlying parenchymal liver disease [3]. Findings were in accordance with main review articles on the mortality and morbidity in cirrhotic patients undergoing anaesthesia for various types of surgery [12]. Pathological examination of the non-tumorous liver showed various lesions graded from a normal liver to cirrhosis. In cirrhotic patients, intraoperative transfusion rates were not significantly correlated with fibrotic changes. The incidence rate of postoperative complications in the entire group was 70%. The most frequent complications were: ascites (56%), lung infection (38%), encephalopathy (20%), kidney failure (13%), portal vein thrombosis (7%) and upper gastrointestinal bleeding (4%). The incidence rate of death from liver failure was 32% in patients with cirrhosis compared with zero in patients with less severe or no fibrosis. Patients >60 yr old and with a preoperative serum aspartate transaminase concentration greater than twice the upper range were significantly more likely to die from liver failure. The incidence rate of postoperative death was significantly correlated to the degree of fibrosis: overall mortality rate (16.3%), cirrhosis (32%) and low-grade fibrosis (zero). The risk of postoperative ascites was correlated with the intensity of fibrosis. The risk of encephalopathy and of pulmonary complications was correlated with intraoperative transfusion. The risk of kidney impairment was correlated with preoperative serum aspartate transaminase concentrations greater than twice normal [3]. Should an adverse event occur following liver resection conducted in patients with pre-existing liver disease, a triggering surgical complication should be sought and specific intensive-care supports be provided [8,10].

Ascites warrants specific care. The pathophysiology of circulatory and renal dysfunction in cirrhosis and the treatment of ascites and related conditions (hepatorenal syndrome and bacterial peritonitis) are still areas of investigation. Following liver resection, ascites results from the deleterious combination of cirrhosis, high portal pressure and exudation associated with liver resection [8,10,11]. Ascites is associated with splanchnic arterial vasodilation and systemic (including renal) vasoconstriction. The treatment of ascites has recently improved [11]. Limiting intra- or postoperative fluid infusion, or both, has not been associated with a lower incidence rate of postoperative ascites in cirrhotic patients [8,10,11]. Should efficient renal perfusion not be restored, kidney function (frequently associated with cirrhosis) will worsen and cause hepatorenal syndrome with poor prognosis [11]. Therefore, the primary goal of intra- and postoperative care in cirrhotic patients is to maintain adequate kidney perfusion and diuresis [10,11]. There are three appropriate strategies: plasma substitutes, furosemide and vasoconstrictors.

Plasma substitutes or albumin infusion may be used, taking into account that higher plasma-expanding power has not been demonstrated with albumin compared with plasma substitutes [11]. Compared with plasma substitutes, treatment with albumin does not increase plasma oncotic pressure and does not significantly change haemodynamic or lung function following major surgery because infused albumin rapidly leaves the vessels and passes into the interstitial fluid [41]. Used as the sole therapy, volume expanders will mainly increase the splanchnic circulation and will seldom restore the associated decreases in renal perfusion and glomerular filtration rate [11].

Furosemide may be used and its administration titrated to the adequacy of the diuresis. Potent vasoconstrictors may be of value if oliguria or ascites, or both, persist, or if systemic arterial pressure decreases in spite of volume expansion and diuretic administration. The infusion of the vasopressin analogue, ornipressin, has been associated with circulatory improvement and a significant increase in glomerular perfusion rate in several studies [11].

Polycystic liver disease

Polycystic liver disease is sometimes associated with chronic symptoms linked to hepatomegaly or with acute complications such as haemorrhage or cyst infection. Partial hepatic resection may therefore be warranted. Chronic renal failure or high systemic blood pressure, or both, are often associated with liver disease and patients are often treated using major hypotensive drugs. Long-lasting ascites (>2 weeks) occurs postoperatively in 80% of patients as a consequence of an exudative process associated with multiple microcysts that remain gaping following parenchymal transection [42]. This postoperative ascites should be treated similarly to exudative ascites occurring in the healthy liver [8,10,11]. Haemodynamic functions should be checked carefully. Indeed, cumulative adverse effects of haemodynamic disturbances resulting from general anaesthesia, hypovolaemia or hypotensive drugs may rapidly result in postoperative circulatory and renal failure that is specifically deleterious in patients with frequent pre-existing kidney failure [42].

Recent approaches

Recent surgical approaches are under evaluation [5,43].

Laparoscopic surgery

Liver resections are feasible and safe using laparoscopic surgery in selected healthy or diseased liver patients, with left-sided and right-peripheral benign or malignant lesions requiring limited resection. The laparoscopic approach avoids a major abdominal incision. It allows liver resection for living-donor liver transplantation. Haemodynamic and respiratory changes associated with laparoscopic liver resection have no specificity. The surgical learning period is likely to prolong the duration of surgery and increase surgical hazards [43].

Radiofrequency ablation

Radiofrequency ablation is performed with thin electrodes placed in the centre of a small tumour under ultrasonographic guidance. Radiofrequency waves induce ionic agitation, which destroy neighbouring tissues by heat. The technique is minimally invasive and spares liver parenchyma tissue. Blocking intrahepatic blood flow, which spares the *in situ* released energy, enhances efficacy. The energy released within the liver causes a transient 1–2°C increase in body temperature [5]. However, a few complications specifically associated with radiofrequency treatment have been reported, including cholecystitis, intrahepatic abscess formation and haemolysis associated with prolonged procedures [44].

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