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MINIREVIEWS

Operative terminology and post-operative management approaches applied to hepatic surgery: Trainee perspectives

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Abstract

Outcomes in hepatic resectional surgery (HRS) have improved as a result of advances in the understanding of hepatic anatomy, improved surgical techniques, and enhanced peri-operative management. Patients are generally cared for in specialist higher-level ward settings with multidisciplinary input during the initial post-operative period, however, greater acceptance and understanding of HRS has meant that care is transferred, usually after 24-48 h, to a standard ward environment. Surgical trainees will be presented with such patients either electively as part of a hepatobiliary firm or whilst covering the service on-call, and it is therefore important to acknowledge the key points in managing HRS patients. Understanding the applied anatomy of the liver is the key to determining the extent of resection to be undertaken. Increasingly, enhanced patient pathways exist in the post-operative setting requiring focus on the delivery of high quality analgesia, careful fluid balance, nutrition and thromboprophlaxis. Complications can occur including liver, renal and respiratory failure, hemorrhage, and sepsis, all of which require prompt recognition and management. We provide an overview of the relevant terminology applied to hepatic surgery, an approach to the post-operative management, and an aid to developing an awareness of complications so as to facilitate better confidence in this complex subgroup of general surgical patients.

Key words: Hepatic surgery; Terminology postoperative management; Complications; Training

Core tip: Applied anatomy as used in hepatic surgery is different to the traditional morphological teaching. Applied hepatic anatomy is complex but trainees require an understanding of the basic principles to allow an appreciation of the operations performed. Complications require a low threshold of suspicion as they often have important consequences in relation to patient outcome. Recognition of such with rapid alerting of senior staff can facilitate timely and effective management. To date, no universal protocol exists for management of the post-operative period and varies from centre to centre. We provide a practical overview of the terminology, post-operative management, and complications associated with hepatic surgery.

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INTRODUCTION

The structural design and unique innate property of the liver to regenerate functioning parenchyma after tissue loss forms an important basis of hepatic resection sur-

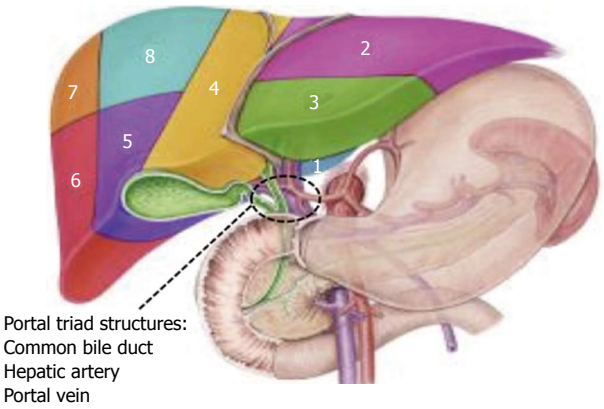

Figure 1 Couinaud classification of hepatic segmental anatomy. The liver is made up of 8 segments: Segment 1 is the caudate lobe and is closely related in position to the inferior vena cava posteriorly; Segments 1-4 make up the left hemi-liver; Segments 5-8 make up the right hemi-liver. Couinaud divided the liver into functional left and right hemi-livers, and the plane between the two runs in Cantlie's line. This line runs from the middle of the gallbladder fossa anteriorly to the IVC posteriorly.

gery (HRS). Early experience was associated with significant mortality and morbidity but these are now reported at 1%-4% and 15%-35% respectively in high volume centres[1-5].

Outcomes have improved as a result of advances in the understanding of hepatic anatomy, improved surgical techniques, and enhanced peri-operative management. Patients are generally cared for in specialist higher-level ward settings with multidisciplinary input during the initial post-operative period but greater acceptance and understanding of HRS has meant that care is transferred, usually after 24-48 h to a standard ward environment. The surgical trainee will be presented with such patients either electively as part of a hepatobiliary firm or whilst on-call, and it is therefore important to understand the key points in managing HRS patients.

Herein we provide an overview of the relevant terminology of hepatic surgery, an approach to the post-operative management, and provide hints to highten awareness of complications so as to facilitate better confidence in this complex subgroup of general surgical patients.

INDICATIONS FOR HRS

In the United Kingdom and Europe the commonest indication for HRS remains colorectal liver metastasis (CRLM). Resection is also performed for other benign and primary malignant hepatobiliary tumours [cholangiocarcinoma (CCA) and hepatocellular carcinoma (HCC)], donation for transplantation and trauma[6-8]. Most resections performed for CRLM are on liver with otherwise normal or mildly diseased parenchyma such as post-chemotherapy fatty livers. Less frequently in the United Kingdom, HRS is performed for HCCs arising in cirrhotic patients, and such resections are associated with a higher complication rate[9,10].

LIVER ANATOMY AND SURGICAL TERMINOLOGY

Unlike other general surgical operations where the nature of the procedure is readily grasped, HRS requires some knowledge of hepatic anatomy, and specific nomenclature is applied to such resections[11]. The surgically applied anatomy of the liver is different to the traditional (morphological) teaching in undergraduate medical school. The core principle relates to the Couinaud classification of liver anatomy[12].

In this system the liver is divided into eight functionally independent segments (Figure 1). Each segment has its own vascular inflow, outflow and biliary drainage. In the centre of each segment there is a branch of the portal vein, hepatic artery and bile duct. In the periphery of each segment is the vascular outflow *via* the hepatic veins which link to form the right, middle and left hepatic veins. These in turn drain into the inferior vena cava. Crucially, the segmental portal and hepatic blood supply, together with the biliary drainage are unique, and allow for contiguous segments to be resected without compromising the vascular supply to the adjacent tissue.

In addition, the liver is separated into four sectors by the hepatic veins (Figure 2). Briefly, the right hepatic vein divides the right lobe into anterior and posterior segments; the middle hepatic vein divides the liver into right and left lobes (hemi-livers) and the left hepatic vein divides the left lobe into medial and lateral sectors.

This knowledge forms the basis of the consensus nomenclature outlined in the Brisbane 2000 terminology guidelines for hepatic resections[13]. In Table 1 the operation titles and number of segments are illustrated. While complex, it is more important perhaps for the trainee to be aware as to what constitutes a minor and major hepatic resection, as the extent of resection is associated with mortality and morbidity. A major resection was traditionally defined as $\geqslant$ 3 segments but more recently established as $\geqslant$ 4 segments[14].

DETERMINING THE LIMITS OF SAFE RESECTION

In the case of CRLM, the extent of resection that can be safely performed is now governed by two factors: the ability to resect all malignant tissue, and an adequate predicted volume of hepatic tissue remaining, the so-called functional liver remnant (FLR)[15,16]. As such during the pre-operative work-up it is important that surgeons work as part of a multi-disciplinary team with radiologists, oncologists and gastroenterologists to plan HRS to assess these factors[17].

The primary investigations used in determining the extent of resection are cross-sectional imaging studies with computed tomography (CT) ± magnetic resonance imaging (MRI) and if there is concern regards extra-hepatic disease, positron emission tomography (PET) scans

Table 1 Brisbane consensus nomenclature 2000 for describing hepatic resectional surgery based on liver segmental and sectorial anatomy

Anatomical term	Couinaud segments	Term for HRS	Major or minor resection
Right hemi liver	5, 6, 7, 8	Right hemihepatectomy or right hemihepatectomy	Major
Left hemi liver	2, 3, 4 ($^{+/-}$ 1)	Left hemihepatectomy or left hemihepatectomy	Major
Right anterior section	5, 8	Right anterior sectionectomy	Minor
Right posterior section	6, 7	Right posterior sectionectomy	Minor
Left medial section	4	Left medial sectionectomy or resection segment 4 or segmentectomy 4	Minor
Left lateral section	2, 3	Left lateral sectionectomy or bisegmentectomy 2, 3	Minor
-	4, 5, 6, 7, 8 , ($^{+/-}$ 1)	Right trisectionectomy or extended right hemihepatectomy or extended right hepatectomy	Major
-	2, 3, 4, 5, 8 , ($^{+/-}$ 1)	Left trisectionectomy or extended left hemihepatectomy or extended left hepatectomy	Major

"Non-anatomical" resections are also performed either as the main index procedure or in combination with the above anatomical hepatic resectional surgery. A non-anatomical resection refers to a situation in which there is a small tumour that is excised with a negative margin but leaving a remnant segment – a so-called "chip-shot" or metastectomy.

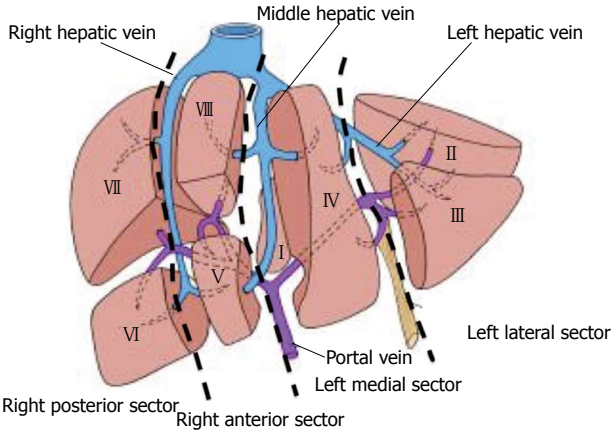

Figure 2 Sectorial anatomy of the liver based on the hepatic veins. The liver is divided into a right and left hemi-liver by the middle hepatic vein (lies in Cantlie's line). The right hemi-liver is divided into anterior and posterior sections by the course of the right hepatic vein; The left hemi-liver is divided into lateral and medial sections by the left hepatic vein.

are useful[18]. If there is concern regards the FLR then portal vein embolization of the diseased portion of the liver can be performed to induce hypertrophy of the remaining parenchyma. For otherwise normal parenchyma the ratio of FLR to total estimated liver volume should be in the order of 25% but 40% may be required in the presence of cirrhosis or other liver disease[19-24].

When proposing operating on cirrhotic livers it is also useful to perform a quantitative assessment of liver function, and in the Far East where HRS is more frequently performed for HCC, indocyanine green clearance (ICG) is carried out in all such patients to confirm the presence of an adequate volume of functioning parenchyma[25-30]. In the setting of CRLM, most patients have traditionally been observed to have normal parenchyma. However the widespread use of chemotherapy and its associated risk of liver injury such as steatohepatitis and sinusoidal obstruction syndrome may increase morbidity and potentially mortality associated with resection[31-33]. As a consequence such parenchyma may no longer be considered "normal" in this subgroup.

Biopsies of CRLM are not performed pre-operatively if a curative resection is planned because of concerns of needle track seeding[34]. In cases of HCC, biopsies are sometimes performed if imaging is inconclusive and may be indicated to assess the surrounding parenchyma[35].

INTRA-OPERATIVE STRATEGIES

There are now a wide range of devices and pharmaceutical agents available to the hepatic surgeon. Their collective aim is to reduce blood loss during surgery as blood loss and the need for blood transfusion are regarded as important prognostic indicators for outcome[36-38]. The most widely used device is the cavitron ultrasonic surgical aspirator (CUSA) that dissects liver tissue utilizing ultrasound.

A number of clamping maneuvers can also be employed to reduced bleeding during the phase in which the liver parenchyma is transected[39,40]. The most commonly performed procedure is the Pringle maneuver in which inflow to the liver is controlled by compressing the hepatic artery and portal vein at the level of the hepatic pedicle. A number of different protocols exist in which the vessels are intermittently clamped and released, usually at 15 min intervals.

APPROACH TO POST-OPERATIVE MANAGEMENT

Many units are now incorporating HRS patients into enhanced recovery programs with early targets for introduction of enteral diet, mobilization, prompt removal of invasive monitoring devices, reduction in the use of opiate analgesia, and judicious use of intravenous fluids[41-43]. These measures mean that most patients will expect to stay less than a week following their surgery. The increasing use of laparoscopic techniques has also contributed to the reduction in hospital stay especially for minor resections[44-46].

ASSESSMENT OF LIVER FUNCTION

Liver enzymes

Perhaps one of the most challenging aspects for the junior trainee in the post-operative period is making sense of liver function tests. A transient early rise in serum hepatic

transaminase levels as a result of hepatocellular damage is common, usually peaking at 24-48 h with the extent of derangement being related to the extent of resection[47]. A persistent rise should alert the surgeon to the presence of ongoing hepatic ischeamia. Such a problem is more likely in those in whom a vascular reconstruction has been performed or if there has been prolonged clamping of the hepatic pedicle. This is an indication for urgent notification of senior staff and a Doppler study is useful in looking at the patency of the hepatic artery and portal veins. Early intervention by means of re-operation or interventional radiological techniques may be appropriate.

An isolated rise in alkaline phosphatase or an elevation of this enzyme in association with gamma-glutamyltransferase may indicate normal hepatic regeneration rather than a pathological process, with levels of the enzyme peaking at around 14 d[48].

A sustained rise in bilirubin coupled with elevation in alkaline phosphatase should prompt a search for a cause of biliary obstruction. This is uncommon after a minor liver resection and is usually seen after a major resection in which a biliary reconstruction has been performed[49-52]. An ultrasound scan is the first line investigation to look for evidence of dilated biliary radicles. Further investigations and management can be arranged depending upon the findings of initial studies.

Synthetic function

Changes in platelet count, prothrombin International normalized ratio (INR) and activated partial thromboplastin times (aPPT), which are markers of coagulation status, may be deranged and reflect the magnitude of resection. Specifically, a post-operative rise in INR between days 1-5 as well as a decrease in platelet count and fibrinogen levels are common and thought to be due to a combination of decreased synthetic function of the remnant liver and a consumptive coagulopathy[53-55]. This is usually self-limiting particularly in the setting of normal liver parenchyma and does not need correction with fresh frozen plasma (FFP) or platelet infusions. While there are no established guidelines for the use of FFP to prevent coagulopathy, some centers do use prophylactic FFP if the INR is > 2, in particular in cirrhotic patients[56]. This can be administered in combination with other products including vitamin K and human recombinant factor VIIa to treat clinically significant coagulopathy.

FLUID AND ELECTROLYTES

Changes in liver function are coupled with fluid and electrolytes imbalances in the post-operative setting. The principles of goal-directed therapy in maintaining adequate fluid balance, haemodynamics and renal function (urine output > 0.5 mL/kg per hour) as outlined in the British Consensus Guidelines on intravenous fluid therapy for adult surgical patients should be followed (www.bapen.org.uk/pdfs/bapen_pubs/giftasup.pdf). However, there are some important caveats following HRS. In the setting of cirrhosis, colloids or human albumin solutions are preferred rather than crystalloids. In addition, sodium restriction, judicious use of diuretics, and selective paracentesis are additional important measures to be considered. Under normal circumstances liver gluconeogenesis consumes a large proportion of body lactate but in the post HRS setting serum lactate can rise, as it is not efficiently metabolised. There are a number of reports implicating the negative impact of elevated lactate and base excess on outcomes after HRS, and some centers advocate the use of non-lactate containing solutions[57].

Hypo/hyperglycemia, hypocalcaemia and hypophoshataemia particularly after major resection should not be ignored and require correction. Strict control of glucose levels has been shown to improve outcomes using a variety of techniques and most intensive/high dependency care units have dedicated protocols. Phosphate is an important component of efficient cell energy metabolism. A decreased level can affect many systems and functions including respiratory failure, cardiac and neurological dysfunction, and insulin resistance[58]. Replacement can be with phosphate infusions, potassium phosphate solutions and oral and paraenteral replacement. The exact mechanism behind the pathogenesis of hypophosphataemia is likely to be increased renal excretion[59]. Hypocalcaemia should be corrected with calcium gluconate or calcium chloride to optimize coagulation status since calcium is critically important in the coagulation cascade and in liver regeneration[60].

THROMBOPROPHYLAXIS

The prevalence of venous thromboembolism (VTE) after surgery particularly in oncological patients cannot be overemphasised. In HRS there has been reluctance in the past to prescribe pharmacologic thrombo-prophylaxis due to concerns regarding bleeding and so-called 'auto-anticoagulation'. However, VTE can still occur even in the presence of elevated INR and aPPT following HRS[61]. Indeed, evidence now confirms patients are more hypercoagulable and the use of pharmacologic thromboprophylaxis lowers the incidence of symptomatic VTE after major HRS without increasing the rate of blood transfusion[62,63]. The majority of patients undergoing HRS will undergo placement of an epidural catheter and so low molecular weight heparins should be started on the day of surgery unless explicit instructions from the operating team regarding increased risk of bleeding. During the surgery, pneumatic compression devices are employed to reduce the risk of thrombosis and mechanical should be continued with compression stockings post-operatively.

ANALGESIA

It is crucial for the junior doctor reviewing a patient to insure they have adequate analgesia as poor pain control leads to prolonged recovery time, inefficient respiratory effort,

a poor appetite and a general slowing down of recovery. There are many options available that and can be tailored to the patient, the two most commonly used being patient-controlled analgesia with intravenous agents (opioids or paracetamol), and epidural analgesia[64]. Local anaesthetic techniques such as transversus abdominis plane (TAP) blocks and infusion catheters are also useful techniques to spare the use of opioids[65,66]. Patients can then be switched to regular and as required oral analgesics according to the world health organization analgesic ladder[67].

As the liver is an important organ for drug metabolism and detoxification it is important to realise potential risks of each modality in the context of liver parenchyma status, magnitude of resection, and concomitant liver or renal failure. Opiates have traditionally been the main stay of analgesia but can be associated with respiratory depression, excessive sedation, and exacerbation of hepatic encephalopathy[68]. As such patients on opiates require close observation in particular after major resections, HRS carried out in the presence of cirrhosis or renal impairment. Better alternatives to simple morphine in cirrhotics include hydromorphone and fentanyl as they are less affected by renal impairment, and are better secreted by the kidney[69]. Intramuscular routes should be avoided, as bioavailability is variable. Non-steroidal anti-inflammatory agents are generally avoided post hepatectomy due to concerns in relation to coagulation and renal impairment[69].

DRAINS

Unit guidelines will dictate when drains are used and when they should be removed, as there are no published guidelines. In reality, the decision to remove drains is dependent on the reason the drain was inserted, the type of fluid draining and the volume of that fluid. If bile is observed then senior colleagues should be informed as imaging studies may be indicated especially if drainage persists or volume increases. Some have advocated the "3× 3" rule (drain-fluid bilirubin level below 3 mg/dL on day 3 after operation) as criterion for removal of prophylactically placed abdominal drains after hepatic resection[70]. Interestingly, a Cochrane review has shown that routine abdominal drainage for uncomplicated liver resection is not needed and if used a closed drain system is associated with less infectious complication and hospital stay than open systems[71].

NUTRITION

Following major HRS, patients enter a catabolic state and so require early nutritional support to optimise liver regeneration, prevent infections, and promote general recovery. Those undergoing minor resection with normal parenchyma will often only require re-introduction of normal diet the first post-opertaive day. A systematic review of nutrition following HRS confirmed that early nutrition by enteral route is associated with a lower incidence of wound infections and complications as compared to parenteral, and therefore remains the favoured route of nutritional support[72].

In addition to early feeding, data is now emerging to encourage the use of pre- and pro-biotics (known as symbiotic therapy) in an attempt to address gut barrier dysfunction and microbial flora to reduce the gut-mediated systemic inflammatory response syndrome and encourage liver regeneration[73,74]. This therapy is yet to be validated in large randomised controlled trials and not used routinely in current United Kingdom clinical practice.

RECOGNISING POST-OPERATIVE COMPLICATIONS

The mortality rates in the majority of published series are now in the order of 0%-2%, however, with reported morbidity rates of 25% to 45% it is important to be alert to potential complications following HRS in all patients. Risk factors for complications include: age > 65 years; ASA score ⩾ 3; larger extent of resection (multiple tumours, bilobar disease); requirement for blood transfusion; and involved resection margins[75]. Up to 30% can suffer "major" complications; specifically bleeding, liver/kidney/respiratory failure and sepsis and account for the majority of deaths post surgery[75]. In an attempt to allow comparison across series, the Clavien-Dindo classification of post-operative complication is now frequently reported[76].

HEPATIC FAILURE

Around 3%-5% of patients may develop liver failure following their resection and will usually show signs and symptoms from 48-72 h after their surgery[2]. These are usually patients undergoing major resections, or resections carried out in the presence of cirrhosis. The International Study Group of Liver Surgery recently developed a consensus definition for post-hepatectomy liver failure namely 'the impaired ability of the liver to maintain its synthetic, excretory, and detoxifying functions, which are characterized by an increased international normalized ratio and concomitant hyperbilirubinemia (according to the normal limits of the local laboratory) on or after postoperative day 5[77]. They graded the severity of post-hepatectomy liver failure on the basis to its impact on clinical management: Grade A post-hepatectomy liver failure requires no change of the patient's clinical management. The clinical management of patients with grade B post-hepatectomy liver failure deviates from the regular course but does not require invasive therapy. The need for invasive treatment defines grade C post-hepatectomy liver failure.

In our own practice, the following indices are used in the monitoring of hepatic function and identifying dysfunction: (1) persistent hyperbilirubinemia [serum bilirubin level > 4.1 mg/dL (to convert to micromoles per liter, multiply by 17.104)]; (2) coagulopathy with anINR > 2.5,

Table 2 Abridged version of West Haven criteria

HE grade	Mental state
1	Mild confusion, slowing of ability to do mental tasks, *e.g.*, serial 7's
2	Drowsiness, inappropriate behaviour
3	Somnolent but rousable, marked confusion
4	Coma

Reproduced with permission from reference Ferenci *et al*[79].

despite early attempted correction with clotting factors; (3) abdominal ascites (drainage volumes > 500 mL/d); and (4) encephalopathy with hyperbilirubinemia and exclusion of other acute confusional states[36].

Another practical definition of post-hepatectomy liver failure is indicated by a prothrombin time < 50% and serum bilirubin > 50 mmol/L (the "50-50" criteria) and been shown to predictive factor of mortality when measured at days 3 and 5[78].

Patients with significantly impaired hepatic function may exhibit hepatic encephalopathy (HE). The West Haven criteria (Table 2) grades HE from I to IV according to severity and is widely used[79]. It is based on changes of consciousness, intellectual function, behavior, and is useful in monitoring patient progress. Ammonia levels should be measured if HE is suspected and lactulose and systemic antibiotcs prescribed to alter gut flora and reduce the production and absorption of ammonia[80].

A number of risk factors have been identified for the development of post-hepatectomy liver failure and have been summarised in a recent review[81]. When confronted with a picture of liver failure, it is important to attempt to determine the underlying cause, as some elements are correctable. Causes of liver failure are usually multifactorial and include: bleeding; sepsis; hepatic ischeamia; portal vein thrombosis; venous outflow obstruction; and a poorly functioning liver remnant. There hepatotoxic effects of pre-operative chemotherapy on the parenchyma, and the presence of steatosis may also contribute to insufficiency.

Intensivists, senior surgeons and hepatologists lead the management of this most feared complication. The mainstay of treatment is supportive with blood products administered to support synthetic function, aggressive investigation and treatment of infection, and radiological investigation to ensure patency of major vascular and biliary structures. The use of exogenous antioxidants such as N-acetylcysteine (Parvolex®) has been used by some including our own unit in attempting to reduce the damage by oxygen free radical associated ischaemic reperfusion injury of the liver[82]. However this remains to be accepted as universal practice and currently lacks a strong evidence base[83,84].

BLEEDING AND TRANSFUSION REQUIREMENTS

Intra- and post-operative bleeding, and the requirement for blood transfusion are associated with increased morbidity, mortality and poorer long-term disease-specific outcomes in CRLM and HCC[85,86]. Kooby *et al*[37] in a study of 1351 liver resections noted a variation in operative mortality between 1.2% for no transfusion to 11.1% when more than 2 units of blood were transfused. A recent review by Dixon *et al*[38] highlighted the negative effects of blood loss on outcome in surgical oncology patients, and suggested that the need for transfusion may be an indicator of the quality of surgery performed.

The operating surgeon and anaesthetist incorporate multiple techniques including: low intra-operative central venous pressure; dynamic intra-operative coagulation monitoring; drugs (aprotinin, tranexamic acid); and haemostatic products on the cut surface of the liver to reduce the occurrence of this complication. As a result median blood loss in overall HRS has significantly reduced and reported to be less than 700-800 mL[87]. Indeed, the median transfusion rate in the majority of contemporary series is zero.

Blood loss during surgery should be clearly documented on the operative note. Unit protocols drive the specific haemoglobin criteria for transfusion and should be referred to when assessing the patient in this early stage. During the post-operative phase, patients will have haemoglobin and haematocrit measurements determined regularly. It would be expected that patients would stabilise during the initial 24-48 h and any deterioration following this should trigger referral to senior colleagues and a request for imaging studies. Patients actively haemorrhaging may require re-exploration or radiological embolisation of bleeding vessels.

POST-OPERATIVE SEPSIS

As evidence grows implicating post-operative complications, in particular infection, in poorer disease-free survival, an important aim must be to pro-actively attempt to minimise infections, and when present to identify and implement treatment in an expedient manner[75]. Risk factors known to be associated with infection include: obesity; major resections requiring blood transfusions; presence of co-morbidities (diabetes, chronic obstructive pulmonary disease); and post-operative bile leaks[88]. Standard effective interventions to minimise infections include ensuring adequate chest physiotherapy, early patient mobilisation, prompt removal of indwelling devices, and institution of broad-spectrum antibiotics therapy where indicated.

BILE LEAKS

Bile leakage is an important complication occurring after liver surgery and its reported incidence ranges between 4.8%-7.6% in large series[89-95] and is less common in surgery for CRLM than for HCC or CCA. The International Study Group of Liver Surgery has recently proposed a uniform definition of bile leakage and a grading system according to severity, which is based on drain fluid bilirubin concentration of greater than three times the serum

bilirubin concentration on day 3 after surgery or the need for additional interventions[96]. Management of bile leaks includes treatment of associated infection, defining the location of leak, externalizing the bile with a radiologically placed drain, and the consideration of insertion of biliary stents and/or reconstructive surgery[97].

SUMMARY AND FUTURE DIRECTIONS

No consensus protocol exists for the post-operative management of HRS, as each centre will have different guidelines reflecting preferences of senior staff with regards to the finer points of management. It is important to deliver early nutrition, effective analgesia, and promote good respiratory function. Furthermore close observation in the early post-operative period is required to identify and aggressively manage bleeding, infection and prevent the development of liver failure. The surgical trainee is required to have a basic grounding and have the ability to appreciate exactly what resection has been performed in a patient to allow for meaningful assessment. Such knowledge will provide insight into being able to alert senior staff appropriately and expediently in this challenging dynamic subgroup of patients.

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