

1998 Distinguished Academician Lecture: Hepatic Resection— A Western Perspective

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Abstract

During the past two decades, resection of the liver has progressed from a rarely to a commonly performed operation with a low morbidity and mortality. The description of the functional anatomy of the liver was instrumental in the change from non-anatomic to anatomic resections. Major hepatectomies dominated the early experience but segment orientated resections now play a more prominent role. Resections may be performed for a variety of malignant or benign lesions or as an emergency for trauma or other catastrophic event.

In the author's institution, 923 liver resections have been performed. The indications for the 825 elective resections were: metastases (46%), primary malignancy (30%) and non-malignant disease (24%). Two-thirds of the 98 emergency hepatectomies were for severe liver trauma. The 30-day mortality was 3.6% for the total series; 2.9% for elective resection, 1.6% for the non-jaundiced patients. In the last 300 elective resections, there has been one postoperative death and the median blood transfusion was zero.

The development of innovative graft reduction techniques has made a major contribution to liver transplantation. The lack of suitable whole liver grafts for paediatric recipients was addressed by volume of reduction of adult donor livers so that the left lateral segment could be implanted safely in an infant's abdomen. This technique was the forerunner of split-liver transplantation, auxiliary partial orthotopic transplantation and living-related liver transplantation.

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Introduction

Although debridement of portions of liver that prolapsed through war wounds was recorded from distant times, attempts at resection of a solid liver tumour were first reported in the latter part of the 19th century.¹ When one considers the enormous challenges faced by surgeons of the time, without the benefits of liver imaging, blood bank facilities and sophisticated anaesthesia, it is not surprising that concerted efforts towards elective surgical intervention were not made until the last half of the 20th century. Obstacles, such as difficult access due to a high position under the costal margin, enormous vascularity, no avascular planes and a soft friable structure that defied easy suture ligation, combined to delay the development of liver surgery.

Liver resections blossomed in the 1950s. This surge in activity resulted from experience of managing liver injuries in World War II, together with a better understanding of metabolic and haemodynamic support, improved anaesthesia and careful attention to vascular anatomy. Pioneering operations were reported from the USA and Asia. While this flurry of activity established

the fact that the liver could be successfully resected, it was recognised that it was fraught with danger.

The evolution of radiological imaging with ultrasound (US), computerised axial tomography (CT), endoscopic retrograde cholangiography (ERCP) and more recently, magnetic resonance imaging (MRI) has allowed preoperative diagnosis and planning of operative procedures to be made with more certainty. They have allowed earlier diagnosis with increased resectability rates which was not possible when only clinical observation was available.

The development of appropriate retractors which are fixed to the operating table has allowed virtually all liver resections to be performed through an abdominal incision without the need for a thoracic extension. Thoraco-abdominal incisions are associated with an increase in morbidity and mortality. The armamentaria available to transect the liver parenchyma has changed from scalpel with cautery and mattress sutures; finger fracture; blunt end of the scalpel; blunt haemostat fracture; blunt tip of the sucker; specially designed clamps, to the more recent innovations of the ultrasonic dissector, water-jet dissec-

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tor and harmonic scalpel. There is no doubt that in due course, these will be replaced by more sophisticated technological advances.

Types of Resection

The early experience of liver resection consisted of removal of a portion of parenchyma containing the lesion, without regard to the anatomic structure. These non-anatomic or atypical hepatectomies were replaced by anatomic resections, based on the description of the functional anatomy of the liver, by Couinaud² and Goldsmith and Woodburne.³ This was the foundation of modern liver surgery.

The so called "classic" anatomic resections are the right and left hemihepatectomy, extended right hepatectomy and left lateral segment resection (Fig. 1). These constitute the bulk of resections performed in the non-cirrhotic. The resection chosen depends on the pathologic process, the position and size of the lesion and especially its proximity to major structures such as the portal triad, hepatic veins and inferior vena cava. These major resections are appropriate for large hepatic lesions. However, patients with small lesions would suffer the loss of large volumes of normal liver tissue when subjected to such a procedure. This is even more important in the cirrhotic patient in whom the regenerative capacity is limited and the functional reserve is minimal. An appreciation of the segmental anatomy enunciated by Couinaud (Fig. 2) formed the basis for the introduction of segment orientated resections, allowing maximal preservation of parenchyma. In Europe this was championed by Scheele in Germany⁴ and Bismuth in France⁵ and in Asia, Japanese surgeons have been in the forefront with its development.

Segmental resection may be in the form of a monosegmentectomy, with complete removal of a single segment, bi- and polysegmentectomy with removal of interconnecting individual segments and multiple

segmentectomies, whereby simultaneous segmentectomies are carried out on different areas of the liver. In addition, a segmentectomy may be combined with a classic major resection-for example, a left hemi-hepatectomy plus segmentectomy VII. For these resections, both adequate preoperative imaging and intra-operative ultrasound are important. The number, size and position, as well as pathology of the lesion or lesions, will determine the type of procedure that is necessary. It has been stated that a segmental resection is between a wedge excision and a major anatomic resection but this is a fallacy. In general, segmentectomies are more complex and require precision. In many cases the surface of transected parenchyma is greater than with a major hepatectomy.

The high incidence of hepatocellular cancer (HCC) in Asia has seen the refinement of techniques in performing resections in cirrhotic patients, using US-guided puncture of the respective portalvein, with dye injection to mark the area for removal.⁶ In the West, where cirrhosis is less common, the use of segment orientated resection is mainly performed for metastatic colorectal cancer and some benign lesions.

The resections performed at the Princess Alexandra Hospital by the author and his colleagues are outlined in Table I. Although the "classic" anatomic resections dominate the series, the performance of segment orientated resections has increased appreciably in recent years.

While it may be thought that the limits of resection has been reached, there have been efforts made for these to be extended. One method has been the removal of the whole liver or partial removal, perfusion with cold preservation solution, performing resection on the back table after total hepatectomy or *in situ* in the partially removed liver and then re-implanting the resected liver, maintaining haemodynamic stability by using venovenous bypass during the anhepatic phase.⁷ Most hepatic surgeons believe that the vast majority of tumours can be removed without the necessity for such a procedure and the method has not been widely practised. Many surgeons would use total vascular exclusion to

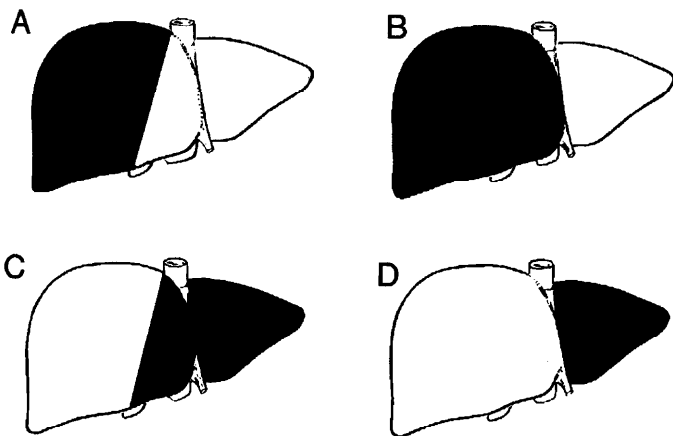


Fig. 1. The standard anatomic resection. A - right hemihepatectomy. B - extended right hepatectomy. C - left hemihepatectomy. D - left lateral segment resection. The black area is the portion of liver resected.

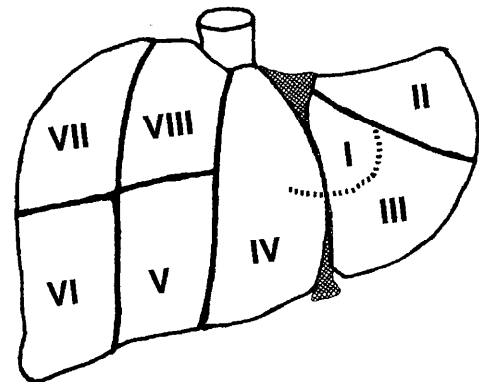


Fig. 2. The segments of the liver.

TABLE I: LIVER RESECTIONS PERFORMED AT THE PRINCESS ALEXANDRA HOSPITAL

Right hemihepatectomy	331
Left hemihepatectomy	156
Extended right hepatectomy	72
Extended left hepatectomy	24
Left lateral segment resection	83
Segmental resection	169
Non/anatomical resection	75
	910
Resection for transplantation	194
Total	1104

achieve comparable results.⁸ Tumours previously considered non-resectable because of involvement of all three major hepatic veins, have been successfully removed using a temporary hepatic vein to IVC shunt, followed by graft replacement of the hepatic vein that drains the preserved liver remnant.

The most important development to extend resectability is the stimulation of compensatory hypertrophy of the left side of the liver preoperatively by portal vein embolisation." This is performed two to three weeks prior to operation. It is used when the liver mass remaining after resection is small and allows a safe resection without the fear of post surgical liver failure which would have been inevitable without this intervention. Although originally and primarily used for hilar cholangiocarcinoma, it can be used for other tumours.

Indications for Liver Resection

Hepatectomies may be performed for a variety of malignant or benign lesions or as an emergency for trauma or other catastrophic event. In addition, its use in liver transplantation has accelerated over the past decade. The indications will vary from country to country and region to region, depending on the epidemiology of liver disease, but overall, malignancy, either primary or metastatic is the prime reason.

Elective

In Western countries, metastatic malignancy, particularly from colorectal cancer, has been the predominant indication for performing liver resection. In the selected group of patients who undergo resection, a five-year survival of 25% to 30% can be expected. Adverse outcomes are likely to occur when the size exceeds 5 cm; there are more than three metastases; there is a very high preoperative CEA level; and most importantly, there is a failure to obtain a clear margin of at least 1 cm of healthy tissue. The presence of extrahepatic disease, especially in the portal or coeliac nodes, is a contraindication to resection. If technically feasible, repeated resection after hepatectomy for metastatic disease should be

considered. The survival is similar to that of the first metastasis.¹⁰ Non-colorectal metastases may also be amenable to hepatic resection. An actuarial survival rate of 27% at 5 years has been reported for selected patients.¹¹

Patients with a single metastasis from neuroendocrine, melanoma and gynaecological primary tumours may well benefit from hepatectomy. On occasions, resection of a metastasis from a breast or renal primary may be indicated if extensive investigations fail to reveal evidence of other disease. It would be rare to consider surgery for liver metastases from primary tumours of the lung or adenocarcinomas arising from the stomach or pancreas.

Hepatocellular cancer is one of the most common cancers world-wide but is seen less frequently in Western populations. The high incidence associated with cirrhosis in Asian countries has been accompanied by incredible efforts towards earlier diagnosis. This, together with the development of surgical techniques and improved preoperative evaluation of hepatic functional reserve,¹² has permitted more limited resections and a reduction in postoperative liver failure. As a consequence, the operative mortality has been markedly reduced. Even so, only 20% of patients with HCC in Japan were treated by surgery. In the remaining patients, the disease and/or associated cirrhosis was too advanced. In 1992, the Liver Cancer Study Group in Japan reviewed more than 4000 patients with HCC who underwent hepatic resection and reported a cumulative 5-year survival rate of 35%. Significant prognostic indicators of tumour recurrence were tumour size; number of tumours growth pattern; capsular and portal vein involvement.¹³

The Western experience with HCC has been mainly in the non-cirrhotic. Characteristically, these have been large to very large tumours, which require extended resections. The increase in hepatitis C as well as Asian emigration has meant that Western surgeons are now experiencing similar challenges to those faced by Asian surgeons. In the present series, 85 patients have undergone resection for HCC with an actuarial 5-year survival of 45%.

Less common primary liver tumours such as intrahepatic cholangiocarcinoma and an assortment of mesenchymal tumours may be resected. The survival is variable, e.g. angiosarcoma has a dismal prognosis, with patients rarely surviving past one year, whereas embryonal sarcoma has a 75% survival at 10 years.¹⁴ The remarkable chemosensitivity of hepatoblastoma in the paediatric population has resulted in many non-operable children being converted to candidates for resection. Our experience with hepatoblastoma in 24 children who had pre and/or post resection chemotherapy, has shown an

actuarial 5-year survival of 100%.

One of the great challenges in hepatobiliary surgery has been the management of hilar cholangiocarcinoma. Surgical resection has been tempered by the extreme technical challenge of the procedure, often in the setting of compromised hepatic and renal function, a depressed immune system, poor nutritional status and hepatobiliary sepsis. In addition, the disease most frequently occurs in an older age group. The complexity of the procedure is an order of magnitude above most liver surgery. Our experience with radical surgery in 90 patients, 78 of whom required liver resection, showed an actuarial 5-year survival of 24%.

Not all non-malignant liver lesions are benign in nature and a number of these are amenable to hepatic resection. Table II lists the conditions where there may be an indication for resection. This does not mean that removal of all these lesions in every case is advocated. However, when symptomatic and affecting quality of or endangering life, resective surgery is the most appropriate treatment. In the author's series, 201 resections were performed for non-malignant conditions, with minimal morbidity and zero mortality. In the past, the morbidity and mortality of hepatic resection prompted less than optimal treatment of non-malignant lesions. What was defensible conservation then would be regressive today and is no longer acceptable.

The distribution of elective resections according to the indications is shown in Figure 3 — 46% for metastases, 30% for primary malignancy and 24% for non-malignant disease. Biliary reconstruction to a Roux-en-Y jejunal

loop was performed in 131 cases in view of the necessity to resect the confluence of the hepatic ducts due to cancer involvement such as hilar cholangiocarcinoma or non-malignant conditions such as primary sclerosing cholangitis or pyogenic hepatolithiasis.

In the authors last 300 elective resections, the median blood transfusion was zero (range 0 to 6 units). This has been made possible by the use of inflow occlusion during parenchymal transection, combined with the maintenance of a low central venous pressure by the anaesthetist. For routine hemihepatectomy, the patient has a blood group and serum saved but are not cross matched. Despite many patients requiring to travel hundreds of miles from Brisbane after discharge, the median hospital stay was eight days. The rapid recovery is probably a manifestation of the remarkable benefit gained from the routine use of postoperative epidural analgesia. There was one intraoperative death from air embolus in 1983. The 30-day operative mortality was 2.9% and for the non-jaundiced patients was 1.6%.

Non-Elective

Urgent resections may be required for a variety of catastrophic events, such as bleeding/rupture of a liver tumour, ruptured mycotic aneurysm of an intrahepatic artery. The most frequent indication is trauma. While a more conservative approach to liver injuries has been adopted over recent years, there are times when only resective surgery will salvage a patient who has sustained a devastating, bursting type liver injury.¹⁵ There were 98 patients who required urgent resection and there were 10 deaths (10.2%). These unheralded urgent situations occur at inconvenient times, with the patient in a parlous condition. In order to achieve a satisfactory outcome in these emergency procedures, a surgeon with considerable experience in elective liver surgery should be involved.

Resection for Liver Transplantation

The experience gained from involvement in liver transplantation enhanced the progress of liver surgery, which in turn has made a significant contribution to liver transplant programmes, through the development of innovative graft reduction techniques. The scarcity of small paediatric donors was addressed by volume reduction to a hemiliver that was engrafted orthotopically in the same way as a whole liver transplant.¹⁶ This required the donor liver to be obtained from larger children (Fig. 4). The challenge was to find a technique which would allow a portion of an adult liver to be accommodated in an infants abdomen together with performing a safe anastomosis between the size mismatch of the vasculo-biliary structures. In Brisbane the segmental graft technique was pioneered and fulfilled the challenges of marked size discrepancy, (Fig. 5)¹⁷ and

TABLE II: NON-MALIGNANT CONDITIONS WHERE LIVER RESECTION MAY BE INDICATED

Hydatid	Asian hepatolithiasis
Multiple abscesses	Primary sclerosing cholangitis
Cavernous haemangioma	Mycotic hepatic artery aneurysm
Hepatic adenoma	Cystadenoma
Focal nodular hyperplasia	Living-related liver donor
Intrahepatic duct stricture	Benign cystic disease
Caroli's disease	Iatrogenic hepatic duct injury

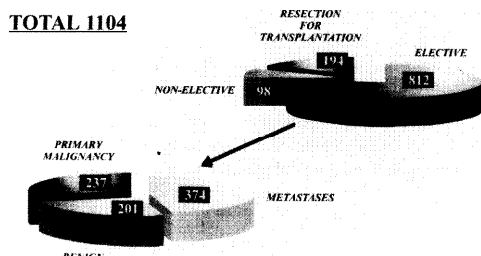


Fig. 3. The distribution of resections based on the indications.

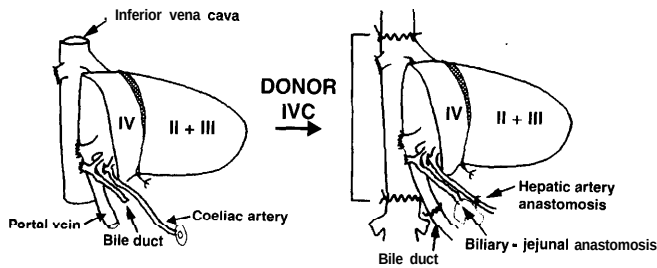


Fig. 4. Orthotopic reduced-size transplant using the left hemiliver.

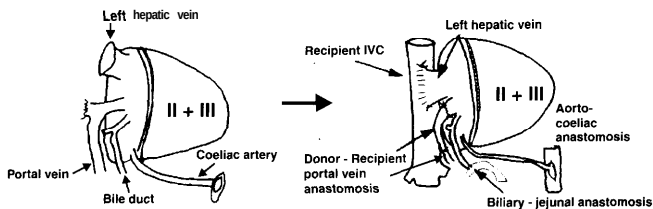


Fig. 5. Reduced-size segmental graft technique.

has been extended further to a monosegmental graft.¹⁸

The segment II/III graft technique was the forerunner of the split-liver, auxiliary partial orthotopic and living related liver transplantation. Split-liver transplantation utilises the otherwise discarded right hemi-liver which is transplanted into an adult recipient (Fig. 6). The early results were sub-optimal due to technical problems from poor donor organ selection and its use in urgent recipients, whose preoperative condition was parlous. Enthusiasm for the technique waned but a decrease in donor organ availability caused a resurgence of the procedure. Appropriate donor selection with careful delineation of individual donor anatomy has shown results equivalent to whole liver grafts in adults and reduced size grafts in children.¹⁹

Auxiliary orthotopic transplantation, using a hemiliver or segmental graft, is another extension of resective surgery in transplantation. It may be performed for metabolic disease or fulminant hepatic failure but it has a relatively limited place.²⁰

The natural extension of the segmental and split-liver techniques was living-related liver transplantation. The first successful transplant was performed from a mother to her son in Brisbane in 1989.²¹ Since that time around 1000 living-related transplants have been performed worldwide. The greatest impact has been in Asian countries where legal and cultural issues have delayed the evolution of cadaveric organ donation. The vast majority of living-related transplants have been children but adult to adult transplants-using the right hemiliver have been performed with increasing frequency. The number of donor deaths is not known but the author is aware of

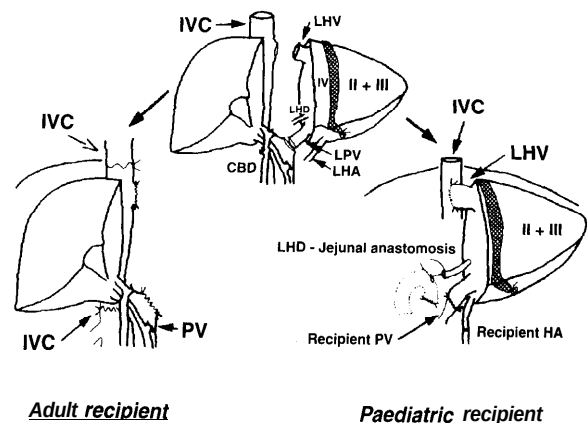


Fig. 6. Split liver transplantation into an adult and paediatric recipient.

six and this needs to be recognised in the decision making process of transplant programmes.

Conclusions

Resective surgery of the liver today is the culmination of a lengthy process from dream to reality. It is incumbent on us to recognise the burdens embraced by the pioneers who, through their efforts, laid the foundation for succeeding surgeons to elevate liver resection from a rarely to a commonly performed, safe procedure. Who doubts that the future will be any less dramatic as genetic engineering and molecular biology change the face of medical practice.

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