DESIGN AND TECHNIQUES OF SURGICAL PROCEDURES RELATED TO MEDICAL RESEARCH AND INVOLVING THE LIVER

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INTRODUCTION

Surgery began as a handicraft. In ancient times it was performed by journeymen who combined surgery and the barber trade as a means of livelihood. Gradually, because of the vision and the continued efforts of a series of guilds and corporations, surgery was elevated from a craft to a science and art. Today's surgeon is an exquisitely trained and learned individual, a product of universities, medical schools and teaching hospitals.

Physicians and surgeons in the past were largely dependent upon factual knowledge derived from observations of clinical cases or from studies within the basic sciences of anatomy, physiology and pathology. Observations of clinical cases have spanned many centuries, and the general structures of the human and animal bodies have been known for a long time, but knowledge of neither produced rapid advances in the surgical treatment of disease. It was not until in the late eighteenth and early nineteenth centuries that the scientific era of Koch, Pasteur and Bernard developed the experimental methods for elucidating the factual basis of human physiology and pathology and provided the impetus for the development of modern medicine.

Hand in hand with the acquisition of fundamental knowledge came the development of clinical surgery. With the advent of the Listerian era of asepsis, one of the major obstacles to the rapid development of surgery was removed. Subsequent advances in anesthesia, medical care and pharmaceuticals have added to

the scope of surgery, until today surgery can be performed on practically all parts of the body.

With increased knowledge the need arose for the adoption of standardized operative procedures to enhance the effectiveness and success of the surgeon's efforts. Extensive research revealed some of the advantages and disadvantages of various types of incisions, suture materials and tissue repair. New instruments were developed to facilitate the surgical techniques as various operative procedures were being developed. Records were maintained and the results continually reviewed so that today many standard operative procedures are utilized throughout the world.

Simultaneous with technical development came increased investigations concerning basic physiology and pathology and the need for the creation of experimental pathologic conditions or access to various organs by surgical means. These procedures were most commonly utilized in experimental laboratories.

Because of its structure, shape and functions, the liver has been subjected to a variety of experimental surgical techniques. The liver plays the role as one of the most important organs in the body. Its functions include: (1) carbohydrate metabolism and glycogen storage, (2) secretion of bile, (3) destruction of uric acid, (4) destruction of fatty acids, (5) formation of urea, (6) synthesis of fibrinogen and prothrombin, (7) synthesis of blood proteins, (8) detoxication of poisonous substances, (9) the concentration of alkaline phosphatase in

the blood, and (10) the formation of vitamin A and the storage of vitamins A and D. These vital physiological functions made the liver of great importance in the medical research.

Many different surgical techniques have developed for investigating the liver's physiologic functions and to assess the results of treatment of disease conditions occurring when the liver functions are impaired.

This report is concerned with surgical procedures which were used and those which are still being used in medical research concerning liver physiology and pathology.

HISTORICAL REVIEW

One of the earliest methods employed in investigations of organ activity was to study the effect of removal of the organ. The liver, because of its anatomical peculiarities, lent itself to just such exploration. As we might anticipate, its removal in mammals was routinely unsuccessful because of its many vital functions. With the advent of experimental surgery, several techniques were developed which made it possible either to remove the liver or to study its function.

One of the first experiments concerning liver physiology was performed by Bock and Hoffman (1874) when they excluded the liver from the circulation by ligation of the hepatic veins. They were interested in changes which might occur in blood sugar levels.

The first surgical procedure used in research and treatment

of a diseased condition of the liver was the Eck fistula, an operation which was devised by Von Eck (1877). In this technique the portal blood was shunted to the vena cava by side-to-side anastomosis of these vessels and ligation of the portal vein close to the liver; cited by Mann (1927) and Markowitz (1964).

The first successful operations involving total removal of the liver were performed on birds by Minkowiski (1886); cited by Pavy (1903) and Markowitz (1964).

The first successful hepatectomy in mammals performed without permanently interrupting either portal or caval circulation was reported by Mann (1921). Animals in his experimental series lived from 5 to 11 hours after the operation.

Seegen (1890) conducted several experiments on dogs, in which the aorta and vena cava were ligated above the diaphragm through an incision in the chest. He was studying changes in the blood sugar and wanted to exclude the liver from a circulation restricted exclusively to the anterior part of the body. He observed that the liver became functionless as well as did other abdominal viscera; cited by Pavy (1903).

Schenck (1894) ligated all structures entering the "porta hepatis" in rabbits and studied the effect of the liver on carbohydrate metabolism; cited by Pavy (1903).

Pavy, et al. (1903) in investigations concerning blood sugar and its relation to liver function, removed the stomach, intestine and pancreas and left the liver in the abdominal

cavity without portal blood. The level of sugar normally present in blood was increased. In later experiments, the liver in addition to other abdominal viscera was removed. In this series the blood sugar fell from 1.3% to 0.5% within 4 1/2 hours. This was the first experiment in which the liver was actually removed from the body in mammals.

ANATOMY OF THE LIVER

A thorough knowledge of the anatomy of the liver is essential in research concerning this organ.

The liver of the dog has 4 lobes, the left, quadrate, right and the caudate lobes. The left lobe is divided into the left lateral and the left medial sublobes. The right lobe is also divided into medial and lateral sublobes while the caudate lobe is composed of the caudate and papillary processes and a connecting isthmus of the liver tissue.

The liver is attached to the diaphragm by means of a coronary ligament, two right and one left triangular ligaments, and the falciform ligament of the liver which is a remnant of the ventral mesentery extending between the liver, diaphragm and ventral wall caudally to the umbilicus. The portion which extends from the umbilicus to the diaphragm appears as a fat filled irregular fold. It may weigh several pounds in obese subjects. The hepatorenal ligament is a delicate peritoneal fold; extending from the medial portion of the renal fossa to the ventral surface of the right kidney.

The lesser omentum is a thin, lacy, fat streaked, loose peritoneal fold which is the remnant of the ventral mesentery. It extends from the hilus of the liver to the lesser curvature of the stomach and cranial part of the duodenum.

The small visible functional divisions of the liver are the hepatic lobules. The central vein is found in the center of the lobules and forms the beginning of the efferent venous system of the liver. Adjacent central veins fuse to form the interlobular veins which unite with each other to form the hepatic veins. The hepatic veins empty into the vena cava.

The portal vein supplies about 4/5 of the blood entering the liver. The hepatic artery furnishes the liver with the blood which nourishes its cells. It supplies primarily the liver framework, its capsule, the walls of the blood vessels, the intrahepatic biliary duct system and the nerves.

The liver is supplied by both afferent and efferent nerve fibers from the vagus and by sympathetic fibers from the celiac plexus. Two branches arise from the ventral vagal trunk and one from the dorsal trunk at the level of the cardia. They pass through the lesser omentum towards the "porta hepatis" and supply the liver parenchyma and biliary system. The sympathetic fibers that supply the liver arise from the splanchnic nerves, celiac ganglia, and celiac plexus, and continue on the common and proper hepatic arteries as the common hepatic plexus and the proper hepatic plexus. Alexander (1940) cited by Miller (1964) stated that in some specimens the

biliary system receives afferent fibers from the phrenic nerves.

The liver of the rat is a firm, dark red organ and according to Hunt, cited by Higgins and Anderson (1931), is composed of 4 lobes. The median lobe is cleft by a longitudinal fissure, dividing it into right central and left central sublobes. The right central sublobe is flanked by the right lateral lobe, which is cleft transversely by a fissure dividing it into two sublobes, the posterior of which caps the anterior pole of the right kidney. The left lateral lobe is a large lobe and lies immediately behind the left central lobe. The caudate lobe is also cleft by a transverse fissure and comprises two sublobes near the curvature of the stomach.

Anatomically, the median lobe and the left lateral lobe, form a unit which lends itself to surgical removal.

According to Drury (1927) the liver of the rabbit consists of two relatively separate masses connected by a thin isthmus of paranchyma. The larger mass comprising the three cephalad lobes, has been termed the "main liver", and the smaller portion the "posterior lobe mass". The main portal trunk divides on approaching the liver and sends its first branch to the "posterior lobe mass". At about this level it also receives a tributary, the superior pancreatico-duodenal vein. In this region the hepatic artery and the portal trunk are in close apposition. Another tributary, the left gastro-epiploic, enters the portal vein about 1 cm. cephalad to the juncture of the portal and superior pancreatico-duodenal vein. The

relationship of these structures is not constant. The superior pancreatico-duodenal vein may enter the portal vein either anterior or posterior to the portal branch of the "posterior lobe mass" of the liver.

SURGICAL TECHNIQUES

Bile Fistula

Hooper and Whipple (1916) investigated bile pigment output and the influence of diet on bile pigment production. Dogs were prepared for surgery utilizing ether anesthesia preceded by a preanesthetic dose of morphine. The abdominal cavity was opened by a midline incision and the gallbladder dissected free from the liver. Double ligatures, 1 cm. apart, were placed about the common bile duct, and the duct divided between the ligatures. The gall bladder was inserted through a small stab wound in the right rectus abdominis close to the costal margin, and fixed by silk sutures to the external sheath of rectus abdominis. The gall bladder was incised and a small piece of rubber tubing about 1 cm. in diameter was inserted into its lumen, extending to the exterior of the body, and fixed by two stay sutures. The median abdominal incision was closed.

The tube was removed on the sixth or eighth day. Hooper and Whipple stated that care should be taken to insure the tube did not become occluded otherwise icterus would develop and result in a prolonged convalescence and a useless subject for research. In the absence of complications, the dog should be

in good condition for bile collection by the third postoperative week.

This procedure was utilized to study bile pigment output and the influence of diet on bile pigment production. It can also be used to establish an outlet for bile in the relief of obstructive jaundice.

Portocaval Shunt in the Dog

Keefe, et al. (1961) utilized a portocaval shunt in the treatment of ascites in a dog. The dog was anesthetised with pentobarbital sodium and intubated. The incision was made from the xiphoid cartilage obliquely and caudad across the upper right quadrant, and extended several centimeters into the lower right quadrant. A babcock retractor was placed in the incision. The posterior vena cava was fully exposed cranial to the right renal vein. Since the portal vein was positioned too far forward and was too short to conveniently perform a side-to-side anastomosis with the vena cava, the common mesenteric vein was chosen for the anastomosis. A Pott's clamp was placed on the vena cava to exclude the area of anastomosis from the circulation while simultaneously allowing a bypass flow of venous blood back to the heart. Bulldog clamps were placed on the splenic vein close to its union with the common mesenteric vein, and on the portal vein just cranial to its juction with the splenic vein. This technique prevented a back-flow from the liver. A third clamp was placed on the common mesenteric

vein just caudad to the region to be incised (Fig. 1-A).

An elliptical section of the wall of the vena cava, approximately 1/2 inch long and 1/8 inch wide, was excised. The elliptical shape of the excision prevented excessive closure of the shunt aperture. A small incision was made in the wall of the common mesenteric vein within the clamped area. The incision was slightly longer than the elliptical resection of the vena cava. No. 4-0 silk was used as the suture material for the anastomosis. A stay suture was placed at the cranial end of the incision in the mesenteric vein and another at the caudal end. A traction suture was placed in the middle of the upper margin of the incision (Fig. 1-B). The lower margin of the incision in the mesenteric vein was sutured to the wall of the vena cava using a continuous suture (Fig. 1-C). The traction suture was removed, and the upper margin of the incision was sutured in the same method as the lower margin. All clamps were then removed starting with the Pott's clamp. The author reported some leakage which subsided in a few minutes after removal of the clamps. Thirteen days after the operation the abdomen appeared entirely normal. Two and a half months following surgery the animal was still fairly comfortable; however, ascites reoccurred whenever meat or meat by-products formed a large portion of the dog's diet.

The portocaval shunt technique has been used in the treatment of liver cirrhosis and the accompanying ascites, and in the procedures of hepatectomy and functional hepatectomy.

Partial Functional Hepatectomy in Rabbits

Rous and Larimore (1920) demonstrated that the occlusion of portal branches to a part of the liver would lead to progressive and ultimately complete atrophy of the parenchyma in the deprived tissue with subsequent hypertrophy of the hepatic tissue remaining normal to excess amounts of blood. Rabbits were used in the study. The anatomical peculiarity of a rabbit's liver was conducive to the type of experiment performed. The liver masses are unequal in size, with the larger or "main liver" formed of the left anterior and posterior lobes and the right anterior lobe which includes the gall bladder. The "main mass" is 3 times as large as the smaller, or "lobe mass" which consists of the right posterior and the caudate lobes.

In Rous and Larimore's experiments the portal trunk to the "main liver" was ligated just above the caudate lobe, so that the whole portal stream was diverted to the smaller "lobe mass". In addition the small vein arising from the portal trunk at the level of the ligature, was ligated and cut away from the caudate lobe. Care was taken not to interfere with the main bile duct and hepatic artery while ligating the portal trunk.

The operation was performed on rabbits weighing from 1400 gm. Ether was the anesthetic. Following surgery an occasional animal was lost from a fatal necrotic process, however the majority of animals recovered without complication and remained in excellent health.

Three-stage Hepatectomy

Mann (1921) devised a technique for the removal of the liver in which the operation was performed in three stages. The advantage was that it allowed one to study the events following the removal of the liver without complications other than those of the anesthetic.

The first stage consisted of performing an anastomosis between the portal vein and the vena cava in the manner of the Eck fistula, except that the vena cava was ligated instead of the portal vein. The ligature was applied immediately anterior to the right lumbo-adrenal vein. The procedure resulted in increased pressure in the vena cava below the ligature and in the portal system. Because the pressure of the liver capillaries was greater than the resistance offered by the collateral route formed by the azygous and internal mammary veins, most of the blood from the extremities soon passed through the latter route. Collateral circulation developed to such an extent that the second operation could be undertaken in 3 to 4 weeks.

At the second operation the portal vein was ligated just before its entrance to the liver and after its anastomosis with vena cava (Fig. 2). This procedure resulted in all the blood from the posterior extremities and the portal system passing to the heart through the peripheral collateral circulation.

The third operation consisted of ligating the hepatic artery and the vena cava just below the diaphragm, along with whatever small collateral veins had developed along the gastro-

hepatic omentum, and then removing the liver completely.

That difficulties were encountered was indicated by Mann's statement--"as in all experiments in which more than one operation is necessary, every experiment was not successful". Factors contributing to the unsuccessful experiments included an anatomical condition in which the portal vein was unusually narrow and following ligation of the vena cava the pressure in the portal system was excessive resulting in the viscera becoming congested and cyanotic and resulting in the death of some of the animals. Problems with thrombosis sometimes occurred. In some animals collateral circulation did not develop sufficiently to permit ligation of the portal vein. In others a collateral circulation through thin-walled veins developed around the field of operation and resulted in unavoidable hemorrhage at the final operation.

Mann recommended that the second operation be performed at least 1 month after the first operation and that 2 weeks lapse between the second and the third operation. He further recommended that the final operation should be performed as quickly as possible with the use of a minimum of anesthetic. Even in instances where the surgery was considered successful the animals died from 5 to 11 hours after surgery.

This procedure has been used in medical research to further illucidate the liver functions.

Simplified Hepatectomy

Markowitz and Soskin (1927) described a simplified method for hepatectomy of dogs. The procedure consisted of partially ligating the vena cava anterior to the lumbo-adrenal vein with heavy linen to the extent that about 4/5 of its lumen was occluded. The portal vein was ligated at the point of bifurcation in the portal fissure in the same fashion. The result of partial occlusion was a mild congestion of the intestine without cyanosis.

Six weeks following the first operation a second operation, in which the liver was removed, was performed. The procedure consisted of ligating the portal vein, the vena cava with ligatures below the liver and between the diaphragm and the liver, and a third around the lesser omentum.

Most animals recovered and walked normally following the operation. The method was less complicated than the three-stage Mann's method and hence saved time although it followed the same basic principles of Mann's method. Markowitz, Mann and Ballman (1928) used this technique while studying the glycogenic function of skeletal muscle in a dehepatized dog.

One-stage Hepatectomy

Firor and Stenson (1928) studied the ability of an animal to tolerate the simultaneous interruption of both the portal vein and the inferior vena cava. This was the main objective in their plan for a one-stage hepatectomy. Initial experiments

were performed on animals under very light ether anesthesia. The hepatic artery, portal vein and the abdominal vena cava were clamped off. Thirty-one minutes were allowed to elapse then the clamps removed and the blood circulation allowed to resume. Observations made 20 minutes later failed to reveal discernible local or systemic effect.

After this initial success they proceeded with the one-stage hepatectomy on dogs. Medium-sized, well conditioned dogs, with long bodies and shallow chests were used as experimental animals. Dogs caged for any length of time were not considered desirable for this experiment. Food was withheld for 18 hours before the operation. Light ether anesthesia was applied by the open method with no preanesthetic.

The abdominal cavity was opened by a longitudinal incision lying 1 cm. lateral to the midline, with its anterior end directed medially to the xiphoid. The peritoneal fold between the liver and the right kidney was divided. The vena cava was isolated and a ligature of braided silk placed around it at a point just anterior to the lumbo-adrenal vein (Fig. 3-A).

The hepatic artery and the common bile duct were ligated and divided. At this point the portal vein and the vena cava were the only remaining structures attached to the lower portion of the liver. The liver was retracted from the diaphragm and the thin avascular suspensory ligaments carefully divided to avoid damage to the diaphragmatic veins. With careful dissection through the peritoneal reflections between the liver

and the diaphragm a tunnel was made under the vena cava. A curved clamp was passed through the tunnel in order to pull a heavy braided silk ligature through. Again the end of the ligature was passed through the tunnel and brought into place between the diaphragm and the liver to form a complete loop around the vena cava. This ligature is referred to as the diaphragmatic ligature for sake of clarity in describing the operation. The liver parenchyma was stripped from the vena cava until the first hepatic vein was fully exposed. Anteriorly the stripping was accomplished with the handle of the scalpel, and posteriorly by drawing from side to side the ligature previously placed about the vena cava. When excessive bleeding occurred, further stripping was postponed until the circulation was cut off. To this point of the operation there was no need for haste; however, subsequent procedures were performed as rapidly as possible.

The portal vein was doubly clamped with two hemostats as close to the liver as possible, (Fig. 3-B). The portal vein was ligated between the liver and the hemostat, and was then divided between hemostats. The vena cava was clamped between the braided silk ligature and the right lumbo-adrenal vein (Fig. 3-C). Simultaneously firm traction was applied on the loop and the ends of the diaphragmatic ligature. The vena cava was incised longitudinally starting at a point approximately 1.5 cm. anterior to the right lumbo-adrenal vein and extending foreward 2 to 3 cm. (Fig. 3-D). A properly prepared side armed

cannula filled with saline was slipped into the incised vessel and passed upward until it met the obstruction caused by the diaphragmatic ligature. The ligature was momentarily relaxed and the cannula pushed beyond it. Then firm traction was applied to the end of the ligature to draw the encircling loop tightly around the end of the cannula lying within the hepatic vena cava so as to prevent bleeding around the cannula and to help hold it in place. The open ends of the cannula were fitted with cork or rubber stoppers to prevent hemorrhage. A hemostat was applied 1 to 2 cm. from the severed end of the portal vein and the original hemostat was removed. A ligature with one tie was placed near the open end of the vessel. The margin of the divided end was grasped with 3 small forceps to keep it patent while the portal arm of the cannula was inserted and the ligature tied (Fig. 3-E). Thus when the hemostat was removed, the portal blood flowed through the cannula into the vena cava. The cannula was forced upward toward the diaphragm, the cork was removed from the lower end of the cannula which was then slipped into place in the vena cava. The previously placed ligature was immediately and carefully pushed upward and tied over the cannula to prevent hemorrhage and to keep the cannula in place. The hemostat was removed and circulation was restored (Fig. 3-F).

Blood loss varied from 5 to 50 ml. as the lower end of the cannula was being slipped into place.

Once the circulation was shunted through the cannula, the

diaphragmatic ligature was inspected and securely tied. The liver was removed by blunt dissection around the hepatic veins. A posterior strip of the vena cava was left in place.

Before closing the abdomen all vessels were checked for bleeding. The abdominal incision was closed with 3 layers of silk suture. The ether mask was removed at the time the portal circulation was reestablished. The procedure required 40 minutes to complete.

An accessary portal vein running from the duodenum to the liver was noted in a few animals. It was found to be impossible to connect this vein with the cannula, since to do so, produced a threat of gangrene to the upper part of the intestine. The number of successful operations ranged from 80% to 90%. Animals could walk, bark, run, void, defecate and drink water after recovery from anesthesia. If glucose was given intravenously following the operation the animals would live from 10 to 16 hours. Those which were not given glucose died within 2 to 3 hours after removal of the liver.

Two-stage Hepatectomy in Rabbits

Drury (1929) modified the method of Markowitz and Soskin to hepatectomize rabbits instead of dogs. In his first trials the vena cava and the portal vein were exposed from the right side of the abdomen. The experiments were unsuccessful because of the consequent injury to the ventral surface of the liver and the peritoneum resulting in massive adhesions. Breakage

of the adhesions resulted in excessive blood loss when the liver was removed during the second stage operation. Subsequently a method was devised in which the veins were approached from the left side without exposing the liver thus leaving the right side free from adhesions for the second operation.

Ether was employed as the anesthetic. Following preoperative preparation of the site, an incision was made 1 cm. to the left of the midline extending from the level of the xiphoid to the umbilicus. The stomach was pressed forward, and the portal vein was freed from the surrounding tissue. A silk ligature, which had been soaked in petrolatum was passed around the portal vein just caudad to the branch of the "posterior lobe mass" and the junction of the superior pancreatico-duodenal and the portal vein. A specially designed glass rod with one end tapered and at a right angle to the main shaft was placed beside the portal vein, and the two were ligated together. The tapered end facilitated withdrawal of the rod which left the lumen of the vein constricted to the size of the rod by ligature. Drury recommended that the vein be constricted to a lumen size of 2 mm. for an animal weighing 2 kilograms (Fig. 4). The superior pancreatico-duodenal vein was ligated near its junction with the portal vein as was the small vein arising on the caudal surface of the pylorus and leading into the portal vein at a point 1 cm. above the entrance of the superior pancreatico-duodenal vein. The veins, unless they were occluded, had a tendency to enlarge with extreme rapidity in an

attempt to provide an adequate supply of blood to the liver. The small left gastro-epiploic vein was dissected along the posterior wall of the pylorus, and ligated below its last tributary.

Finally the vena cava was partially occluded by placing a ligature around the vessel immediately anterior to the right adrenal vein. The abdominal wound was closed with a triple layer of sutures. Recovery from the operation was usually rapid. Collateral circulation soon developed through the azygous and internal mammary veins. A three weeks interval was generally allowed to elapse between the preliminary and the second operation. It was, however, possible for the second operation to be performed after 5 days; thus indicating the speed with which the collateral circulation could develop.

The second operation consisted of removing the liver. A midline incision extending from the xiphoid to the umbilicus was used. The entire gastro-hepatic omentum was ligated, including in the tie the portal vein, bile duct, and hepatic artery. The vena cava was ligated just cephalad to the right adrenal gland, and again just cephalad to its union with the hepatic vein from the "main liver". The vena cava was then severed between the ligatures. The gastro-hepatic omentum was cut between the liver and the tie which was placed about it. The hepatic ligaments to the diaphragm and the peritoneum in the regions where it is intimately attached to the liver on either side of the vena cava, were divided. The small

diaphragmatic vein located at the right side of the vena cava slightly anterior to the entrance of the hepatic veins from the "main liver", was ligated and divided. At this point in the procedure the liver was removed in toto.

Drury reported that rabbits deprived of their livers in this manner would live for varying periods up to 40 hours, provided they were given glucose intravenously immediately after surgery.

Two-stage Hepatectomy in Rats

Meehan (1954) employed on rats the same method used by Markowitz and Soskin on the dog, and by Drury on the rabbit. This was the first surgical removal of the liver from a rat without circulatory complications. Rats given glucose immediately after surgery lived as long as 27 hours. Before death they became comatose as did the rabbit or dog. The comatose condition was ascribed to hypoglycemia.

Partial Hepatectomy in Rats

Higgins and Anderson (1931) described a method of partial hepatectomy in rats. Ether was used as the anesthetic. The abdominal cavity was opened via a midline incision extending 3 to 4 cm. posterior to the xiphoid cartilage.

The vessels and ducts of the median and left lateral lobes were ligated with linen sutures and the lobes excised. Thus 65% to 75% of the total liver was removed, leaving only the

right lateral lobe and the small caudate lobe. The abdomen was closed with two layers of suture. The peritoneum and the abdominal muscles were closed in the first layer and the skin in the second layer.

No special postoperative care was employed, except that the animals were given 20% dextrose in the drinking water during the first 24 hours.

Hypertrophy of the remaining lobes of the liver was observed after the partial hepatectomy. Higgins, et al. reported that within 14 to 21 days the liver was restored its normal weight.

Brues, Drury and Brues (1936) used a similar method to the one used by Higgins and Anderson but with some modification. The median and lateral lobes were delivered as in Higgins' method, and the pedicle containing the hepatic artery, bile duct, and portal vein to these lobes was ligated with silk suture about 2 mm. above the point where the vessels separated from those supplying the posterior lobes. A hemostat was applied anterior to this ligature, and the lobes allowed to fall back into the abdominal cavity until as much blood as possible had passed out of the ligated lobes through the hepatic vein. The pedicle was then divided between the ligature and the hemostat along with the attached hepatic ligaments. A heavy thread was passed around the hepatic veins of the lobes to be removed, and was tied; the lobes were dissected free just distal to this tie. The accumulated blood was

removed from the peritoneal cavity using gauze moistened with sterile saline. The abdominal incision was closed with two layers of silk sutures. This technique proved useful in studying the quantitative cell growth occurring during hypertrophy of the remaining liver lobes.

One-stage Functional Hepatectomy in Rats

Reinhardt and Bazell (1946) functionally hepatectomized rats in a one-stage operation. The nonsuture technique of anastomosing blood vessels was used. They were of the opinion that this was the only practical method for use in such small animals.

A midline incision was made which extended from the xiphoid process to the pubis. The gastro-enteric tract was exteriorized to allow adequate visualization of the portal vein and inferior vena cava. The exteriorized viscera were kept warm and moist with gauze packs soaked in saline. The left renal vein was exposed and the adjacent fat stripped off. The suprarenal and gonadal veins were ligated and divided. The renal artery was ligated close to the aorta and then stripped away from the renal vein (Fig. 5-A). The renal vein was then ligated at the point of exit from the kidney and the kidney excised. A temporary ligature was placed about the renal vein at the point of entrance into the inferior vena cava thus preventing reflux of blood into the renal vein. A small thin-walled pyrex glass sleeve of appropriate size was threaded over

the renal vein (Fig. 5-B). Under the binocular dissecting microscope the ligature was removed from the free end of the renal vein, the vein was cuffed over the glass sleeve and tied securely in place with a fine silk ligature. The portal vein and the hepatic artery were isolated from the neighboring structures in the hepatic pedicle and ligated at the point of their entrance into the liver. A rubber band was placed as far posteriorly as possible as a temporary ligature around the portal vein. The rubber ligature was stretched and fastened with a mosquito hemostat. A small incision was made in the wall of the portal vein between the two ligatures and the glass sleeve with the everted free end of the renal vein was introduced into this aperture (Fig. 5-C, D). Thus the intima of the portal vein was brought into contact with the intima of the renal vein while the glass sleeve remained entirely extravascular in position. A fine silk ligature was placed around the portal vein and the cuffed end of the glass sleeve. The temporary ligature around the portal vein was removed to allow free circulation of the portal blood through the renal vein to the vena cava. The viscera was replaced in the abdominal cavity, and the incision closed.

Although the operation required 30 minutes, the actual period of obstruction of the portal vein did not exceed 5 minutes. The survival time averaged 11 1/2 hours with a range of 5 to 17 hours in a series of 12 unfasted adult rats. When the hepatic artery was left patent, the rat survived for an

indefinite period with a complete porto-caval shunt. Experimental animals used in this study were normal rats.

The operation was utilized for investigations concerning the function of the liver.

Modified One-stage Hepatectomy

Clay and Ratnoff (1951) modified Firor's method in their experiments.

Atropine was given as a preanesthetic at the rate of 0.1 mg. per kilogram body weight. Ether was utilized as the anesthetic. A mixture of 5% glucose and 0.85% sodium chloride was given intravenously by slow drip during the operation. The abdomen was opened by a paramedian incision which curved medially at its anterior end toward the xiphoid and which extended posteriorly to a point slightly beyond the umbilicus. The chest was opened on the right side through the 7th intercostal space. The opening in the chest was made in order to ligate the aorta and the vena cava. The aorta was ligated first to minimize engorgement of the abdominal viscera. A silicone coated cannula was substituted for the paraffin coated cannula used by Firor and Stinson. The silicone was relatively permanent, easily applied, sterilizable and uniformly prevented thrombosis within the cannula.

The technique used by Firor and Stinson was followed except for the modifications mentioned. During closure a small catheter was inserted into the chest cavity, the lungs were

inflated, and the ribs approximated with braided silk. The muscles and the skin were closed with continuous silk suture. The residual air in the chest was then aspirated through the catheter and the catheter withdrawn. The abdominal incision was closed with a continuous suture of braided silk through all layers except the skin. The skin was closed with a continuous suture of fine silk.

The suggested advantages of this modification to Firor's method were: (1) the temporary occlusion of the vena cava above the diaphragm eliminated the danger of air embolism, (2) cannulation was accomplished smoothly in a relatively dry field, without haste or blood loss, (3) there was no need for occlusion of the cannula with a stopper or to place a finger on the aperture of the side arm; furthermore bleeding did not occur during cannulation of the portal vein, (4) the thoracotomy permitted easy access to the aorta above the diaphragm and allowed temporary occlusion of this vessel before the portal vein became obstructed or the vena cava opened.

Hepatectomy without Injuring the Vena Cava

Frank and Jacob (1951) hepatectomized dogs without injuring the vena cava; a procedure which had previously been considered impossible. The patient was anesthetized with ether, and the abdomen opened by a midline incision. An intratracheal tube was passed to prevent lung collapse in case of inadvertent entry into the pleural cavity. The common bile duct, hepatic

artery and adjacent tissue were doubly ligated and divided between ligatures, thus exposing the portal vein. All ligaments and small vessels connecting the liver to the retroperitoneal tissue, esophagus, stomach, duodenum, kidney and adrenal were divided. The portal vein was clamped twice and divided obliquely between the clamps. The cut end of the portal vein was anastomosed to an oval opening in the ventrolateral wall of the vena cava just above the lumbo-adrenal veins. The anastomosis was facilitated by partial occlusion of the vena cava with Pott's clamp (Fig. 6-A). Congestion of the intestine due to partial occlusion of the vena cava and the portal vein occurring during anastomosis was relieved following removal of the clamps. A transfusion during the operation prevented a decline in arterial pressure during the 15 minutes period of partial occlusion. Ether administration was discontinued following completion of the anastomosis.

The termination of the hepatic veins was exposed and ligated or sutured flush with the caval wall following amputation of the individual lobes (Fig. 6-B). All hepatic tissue was removed.

This procedure was attempted on 4 dogs. In one the vena cava was accidentally opened and the animal died. The surgical procedure was successfully completed in the 3 remaining dogs.

Reversible Exclusion of the Liver

Lichtenstein, et al. (1956) described a technique for the reversible exclusion of the liver in dogs. A plastic T-tube was treated with Dessicote* several hours prior to use in an attempt to reduce the possibility of clot formation. According to Leveen Lewis, cited by Lichtenstein, "the difficulties in the one-stage method of Firor and Stinson arise from the use of a cannula which is rigid and which cannot be occluded by clamping during its insertion. Hemorrhage and air embolization are unavoidable operative catastrophies. A flexible cannula could be more easily manipulated . . . easier to introduce into the vena cava . . . (and) obviate the danger from hemorrhage and air embolization".

A right thoracoabdominal incision was utilized since adequate exposure could not be easily obtained with an abdominal incision. Morphine sulphate was used as preanesthetic and surital was the anesthetic. Oxygen with intermittent pressure was administered via an endotracheal tube. The abdominal and thoracic cavities were opened by a long midline incision which extended to the xiphoid, through the costal cartilage and into the 7th or 8th intercostal space. The diaphragm was divided between two clamps down to the vena cava, and all bleeders were ligated. A self-retaining retractor was employed to maintain an open thoracoabdominal incision. The duodenum was elevated into the wound, and the abdominal viscera were packed to the left of the duodenal mesentery, thus providing a barrier to

prevent the viscera from entering the surgical field. The vena cava was exposed and its adventitia stripped away from the segment extending from the right kidney to the liver hilus. The adrenal veins were ligated and divided carefully at their entrance to the vena cava. The right adrenal vein sometimes presented difficulty because it was quite adherent and required careful dissection. It was necessary to ligate and divide the left adrenal vein of small dogs, but for large dogs the surgery could be performed satisfactorily without disturbing either of the adrenal veins.

Two heavy silk ligatures were passed beneath the vena cava, one just anterior to the right kidney and the other just posterior to the liver. Two hemostats were placed on the plastic T-tube, one around the narrow arm and the other on the main cannula at the junction of the short segment to the small side arm. The next steps were performed with haste because the vena cava was completely occluded. The ligature posterior to the liver and around the vena cava was tightened, and a non-crushing arterial hemostat was placed around the vena cava just anterior to the site of the ligature of the vena cava lying anterior to the kidney. A 1 cm. transverse incision was made into the vena cava by means of scissors at a point not less than 2 cm. anterior to the renal vein. The incision was then bisected in a longitudinal fashion and extended anteriorly for a distance of 0.5 cm. The long segment of the cannula was inserted through this opening into the vena cava in a cephalad

direction to the point at which the side arm reached the limits of the incision in the vein. The ligature posterior to the liver was tightened about the vena cava and the main trunk of the cannula (Fig. 7-A). The short end of the cannula was then inserted into the vena cava through the same incision. The second ligature was tightened about the vena cava and the short segment of the cannula. The short segment of the cannula was kept sufficiently short so as not to occlude the renal vein. The arterial clamp and the hemostat were removed from the main trunk of the cannula and the vena cava to allow the blood to circulate through the cannula and the vena cava (Fig. 7-B). The entire procedure normally required no more than 3 to 4 minutes; the blood loss ranged from 5 to 10 ml.

The portal vein was then dissected free of its adventitia at a point from the hilus distally for at least 4 cm. The gastro-duodenal vein was doubly ligated close to its entrance into the portal vein and divided. The gastro-splenic vein was left intact. From this point in the operation the following procedures should be performed with haste because of the occlusion of the portal vein. A non-crushing arterial hemostat was placed around the portal vein some 4 cm. from the liver hilus. The portal vein was ligated at the liver hilus and divided, leaving the ligature on the liver side. The side arm of the cannula was inserted into the lumen of the portal vein and held in place with a ligature (Fig. 7-C). Then the non-crushing arterial clamp as well as the hemostat on the side arm

were removed, and the portal venous blood allowed to flow into the vena cava through the cannula. The time of the portal vein occlusion did not exceed 3 to 4 minutes, and the blood loss was under 5 ml.

At this point the common hepatic artery was isolated from surrounding structures and clamped. In the acute experiment, the entire hepatoduodenal ligament including the biliary structures and excepting the hepatic artery was divided between clamps and ligated. This procedure was performed with the intent of eliminating the blood supply via small vessels in the gastro-hepatic ligament to the liver and to insured complete denervation of the liver.

The liver was rotated clockwise and to the left side of the animal. The thin avascular mesentery connecting the right lobe of the liver to the diaphragm was incised. A cleavage plane was established between the diaphragm and the liver and the vena cava by means of blunt dissection. A heavy silk ligature was passed beneath the vena cava through this tunnel. The ends of the ligature material were placed within a Rumel tourniquet and the tourniquet tightened thus occluding the vena cava around the tube and preventing flow of blood from the hepatic veins (Fig. 7-D).

Collateral circulation was disrupted by division of the coronary ligament containing branches of the phrenic veins. Thus the liver was denervated and completely excluded from the dog's circulation. When the resultant anoxia persisted for at

least 1 hour, extensive hepatic necrosis occurred.

The procedure was used for investigations of the role of the damaged liver in the genesis of shock and to study the significance of bacteria and a vasodepressor substance in the development of shock.

The value of the procedure was that blood circulation through the liver could be reestablished in a matter of minutes by releasing the Rumel tourniquet.

Portocaval Shunt in Rats

Lee and Fisher (1960) described a technique for performing a portocaval shunt in the rat. End-to-side and side-to-side anastomosis were employed. Rats weighing more than 140 gm. were used. The procedure was performed under ether anesthesia. The abdomen was opened by a midline incision and the intestines retracted laterally to expose the portal vein and the vena cava. The portal vein was isolated and its gastroduodenal tributary ligated. The vena cava was dissected free at and above the entrance of the right renal vein and up to the liver hilus. A small hemostat, curved to resemble a Satinsky blood vessel clamp, was placed on the vena cava partially occluding it. A mosquito hemostat was placed across the portal vein at a point as far from the liver hilus as was practical in order to enhance the anastomosis technique. The blades of both hemostats had been ground and polished to reduce their thickness, before being covered by rubber tubing. An elliptical opening

was made in the clamped area of the vena cava. Following ligation close to the "porta hepatis", the portal vein was severed immediately posterior to the ligature. The end of the portal vein was then anastomosed to the vena cava over the elliptical opening. Number 7-0 braided silk attached to 2, 3/8 circle taper needles and a continuous suture pattern were used in the anastomosis of the portal vein and the vena cava. Bleeding from the anastomosis following removal of the clamps was controlled by a few moments of slight pressure with a gauze sponge. Throughout the surgical procedure the surgeon wore a binocular magnifier with a 2.25 inch diameter magnification and a 10 inch focal length. Following the surgery splenoportograms or mesenteric portograms were performed to determine patency of the shunt. Portograms were accomplished by insertion of a 21 gauge needle into either the splenic pulp or tributary of the mesenteric vein. Attached to the needle was a length of polyethylene tubing through which 1.25 ml. of radiopaque material (70% Urokon) was injected. The roentgenograms were taken with exposure factors of 50 Kv., 50 Ma., 1/20 second, and a target film distance of 29 inches.

Some subjects lived as long as 7 months after the portocaval shunt operation was performed.

Partial Hepatectomy

Sigel (1963) described a modified technique of partial hepatectomy on dogs.

Thiopental sodium was used to induce anesthesia which was then maintained by ether. The abdominal cavity was incised and a self-retaining retractor inserted. For descriptive and anatomical reasons, the lobes of the liver were grouped into 3 divisions. The left division consisted of the lateral lobe and the left central lobe. The central division sometimes called the "gall bladder lobes" was made up by the quadrate and right central lobes. The right division consisted of the right lateral and the caudate lobes. The left division, central division and the papillary process of the caudate lobe comprised about 70% of the liver and constituted the tissue removed in this experiment. Anatomically there is a tissue connection between the papillary process and the bases of the lobes of the left and central divisions. The tissue link provided by the papillary process serves as the main parenchymal union between the lobes of the right division and the remainder of the liver. It constitutes an ideal location for transecting the liver during excision. The afferent blood supply, hepatic veins, and bile ducts of the left and central division and papillary process are arranged in such a way as to permit ligation and division and yet allow the structures of the right division to be preserved.

The hepatic duct was dissected from its bed to a point immediately above the entry of the bile duct from the right division and was ligated and divided. The hepatic artery was isolated from the areolar and lymphatic tissues obscuring it.

It was then ligated and divided at a point closer to the liver than was the bile duct transection in order to preserve the arterial supply to the right division. Following division of the bile duct and hepatic artery, the portal vein located dorsal to the hepatic duct, became visible. Near the hilus of the liver the portal vein provides a large branch for the right division and then arches to the left to supply the remainder of the liver. The portal vein was carefully dissected above its first major branch, ligated and divided. At this point the lobes of the right division appeared red and were turgid in consistency, whereas the lobes of the left and central divisions and the papillary process were dark and flaccid.

Downward traction on the liver exposed the falciform and coronary ligaments. The falciform ligament was divided. The left triangular ligament was incised with care to avoid the left phrenic vein and small vessel usually located in the free edge of the ligament. At this point the entrance of the two constant hepatic veins into the vena cava became evident. The larger of the two veins was readily identifiable as the vein from the left division. The smaller vein lies lateral to the larger vein and drains the central division lobes. The hepatic vein from the left division is too short and too wide to be safely ligated. After dissection back of the larger hepatic vein, a vascular clamp was applied on this vein. The vein was divided and the stump was closed with a continuous 4-0 arterial silk suture. The hepatic vein from the central division was

ligated. The remaining portion of the gastro-hepatic ligament was then incised and the liver tissue to be resected was elevated through the surgical incision. A slim bridge of the liver tissue approximately 2 to 3 cm. in diameter remained as the only attachment. A heavy silk ligature was placed around this tissue bridge between the papillary process and the remainder of the caudate lobe. Care was taken to apply the ligature in an area of viable liver tissue below the discolored portion of the papillary process and above the location of the bile duct of the right division. The tissue bridge was then sectioned and the specimen removed. The abdomen was closed with 2 layers of suture.

The mortality was reduced to 20% by using this technique alone as compared with 41% to 76% when another type of liver operation was performed at the same time or subsequent times.

Partial hepatectomy was used to study liver regeneration and liver function.

Homotransplantation of the Canine Liver

Goodrich, et al. (1956) reported a technique for homotransplantation of the liver in the dog. In their experiments attempts were made to ameliorate the effects of hepatic anoxia during the period of complete interruption of the liver blood flow while transplanting the organ. Two methods were investigated. In the first method the donor was given wide-spectrum antibiotics for 21 days before surgery in an attempt to

elimmate the activity of intrahepatic saprophytes. In the second method a polyethylene shunt was used between the recipient dog's aorta and the hepatic arterial tree of the donor's liver while the afferent anastomosis was being performed (Fig. 8-A). The latter technique proved to be more satisfactory. The arterial shunt was therefore used in Goodrich's method of the liver transplantation. Donor and the recipient dogs were prepared simultaneously by two surgical teams and the entire liver of the donor was transplanted with the accompanying vascular trunks into the lower part of the abdomen of the recipient. The recipient's liver was not disturbed. Donor animals were chosen which weighed from 5 to 10 kg. less than the recipient. Intravenous pentobarbital anesthesia was used for both the recipient and the donor animals. Artificial respiration via an endotracheal tube was used for the donor.

The donor's surgical team made a thoracoabdominal incision. The portal vein, vena cava anterior and posterior to the liver, and the hepatic artery and its proximal tree were isolated. Since the hepatic artery was usually too small to ensure reliable patency following an anastomosis, a segment of the aorta was utilized to shunt the recipient's arterial blood to the donor's liver.

Simultaneously the other surgical team prepared the recipient's vessels through a lower rectus abdominal incision. The inferior vena cava, the aorta posterior to the kidney and

the external iliac arteries were isolated. The vena cava was transected and fixed over a Blakemore-Lord cuff, in preparation for a nonsuture anastomosis to the subcardiac vena cava of the donor. The site of transection of the aorta was selected and a polyethylene tube inserted into this vessel in a position anterior to the level of transection (Fig. 8-B).

When the recipient had been prepared, the other team transected the donor's vessels between clamps as rapidly as possible and in the following order: the vena cava 1 cm. posterior to the liver which was also ligated, the portal vein, the aorta below and above the celiac artery, and the subcardiac vena cava. Then the liver was placed in the lower part of the abdomen of the recipient, and the hepatic outflow was established first by completing the vena cava anastomosis over the previously placed Blakemore-Lord cuff. The aortic segment preparation was usually used thus allowing the superior mesenteric artery to be used for a shunt. By use of the shunt in the operation it was possible to perform both proximal and distal aortic anastomoses accurately and less hurriedly, and to be assured of adequate oxygenation of the transplanted liver. When the arterial anastomosis was completed, the shunt was discontinued and the portal vein of the donor connected to the recipient's posterior vena cava over a second Blakemore-Lord cuff (Fig. 8-B). The diaphragmatic tags on the suprahepatic vena cava of the transplanted liver were tacked to the right psoas fascia with 1 to 2 sutures to prevent rotation of

the transplanted liver and kinking of the supra-hepatic vena cava. Finally, a plastic cholecystostomy cannula was inserted and positioned out through the abdominal wound. The abdominal incision was closed.

Another technique for liver transplantation was described in which an end-to-end anastomosis of the recipient's external iliac artery to the donor's hepatic artery or celiac artery was combined with anastomosis of the recipient's common iliac vein to the donor's portal vein. All animals in this experiment were given broad-spectrum antibiotics for periods ranging between 4 and 21 days in an attempt to prolong the hepatic tolerance to anoxia. No shunt was used in these experiments. This technique proved to be less satisfactory.

When the operations were successful, the animals lived at least 5 days; whereas in the unsuccessful experiments the recipients failed to survive more than 36 hours.

The purpose of the experiments was to determine whether the operation was technically possible with survival of the liver, and to determine the longevity of the transplants and their effects upon the recipient.

Homotransplantation of the Liver and Exclusion of the Recipient's Liver

Thomford, et al. (1965) described homotransplantation of the liver with subsequent removal of the recipient's liver 1 week later.

Adult mongrel dogs weighing from 15 to 20 kg. were used as recipients and a donor was chosen which weighed 5 kg. less than the recipient. Both donors and recipients were of the same sex.

Pentobarbital sodium was used as the anesthetic. The donor's abdominal cavity was first opened by a midline incision. The inferior vena cava posterior to the liver, and the portal vein were dissected free of the surrounding structures. The common bile duct, gastroduodenal artery and the gastrohepatic omentum were ligated and divided. The liver was packed with cracked ice and saline and the abdomen temporarily closed with towel clips. The left common carotid artery was then prepared for collection of blood which was to be used later for transfusion to the recipient.

The abdomen of the recipient was opened by a midline incision extending from the xiphoid process to the pubis and the spleen was removed. The vena cava was isolated, clamped and divided at a point 1 cm. caudal to the left renal vein. The left common iliac artery was isolated, ligated, and divided in preparation for placement of the liver graft in the pelvis.

The abdomen of the donor animal was reopened. The hepatic and celiac arteries were isolated. The splenic and the left gastric arteries were ligated and divided at their origins. The portal vein was cannulated and the liver perfused with 2000 ml. of cold (4 to 5 degree centigrade) lactated Ringer's solution to which had been added 1 gm. of procaine hydrochloride

and 500,000 units of crystalline penicillin per liter. As soon as perfusion had begun, 400 ml. of blood were withdrawn from the left common carotid artery of the donor animal and preserved by addition of citric acid, sodium citrate and dextrose. The celiac artery was divided at its origin and the vena cava ligated posterior to the liver and sectioned 1 cm. from the liver. A midline sternotomy was performed and the diaphragm incised. The suprahepatic portion of the inferior vena cava was dissected free by clamping, dividing and ligating the phrenic veins. The inferior vena cava was severed at its junction with the right atrium. The liver was removed from the donor animal and transferred to the recipient.

The cold perfusion was stopped. Blood circulation of the liver graft was established by an end-to-end anastomosis of the anterior end of the divided vena cava of the recipient to the suprahepatic vena cava of the donor, and of the left common iliac artery to the celiac artery of the graft, and of the [illegible]nd of the divided vena cava of the recipient to the portal vein of the graft (Fig. 9). Arterial blood flowed through the liver while the last anastomosis was being made. The liver grafts were without blood flow for 30 to 40 minutes. A cholecystoduodenostomy was made to provide internal biliary drainage for the graft. The abdominal cavity was closed after placing 500,000 units of crystalline penicillin in the peritoneal cavity. The procedure required 3 to 3 1/2 hours to complete. Four hundred ml. of the blood from the donor and

500 ml. of 0.9% saline were administered intravenously to the recipient during the operation.

In 10 of the recipient animals the original livers were removed by a second operation 1 week after implantation. Ether anesthesia was induced in an air-tight cage and maintained via an endotracheal tube using a semiclosed system.

A right thoracoabdominal incision was made at the level of the 10th intercostal space. The diaphragm was incised radially to allow exposure of the inferior vena cava. The phrenic veins were clamped, divided, and ligated to free the inferior vena cava from the diaphragm. The portal vein was anastomosed to the vena cava by end-to-side anastomosis to provide drainage for splanchnic venous blood. The remaining structures in the "porta hepatis" and the gastro-hepatic omentum were then ligated and divided. The inferior vena cava was isolated by blunt dissection in order to expose the hepatic veins which were ligated and divided. The liver was removed, the diaphragm reconstructed and the operative wound of the thoracic and abdominal cavities closed.

During the surgical procedure 400 ml. of blood and 500 ml. of saline were administered intravenously. Penicillin was given daily at least 1 week. Five hundred ml. physiological saline was given subcutaneously on the first and second post-operative days.

In the Thomford studies the first 20 operations were performed to establish a suitable technique. Dogs in which the

operations were technically successful were studied to determine the clinical course and the survival of these animals.

After a technically satisfactory method of transplanting the liver had been developed, hepatic grafts were implanted in a second series of 20 dogs to obtain liver tissue for study of the histologic changes in the liver graft.

The third series of 36 dogs received homografts after being treated with azathioprine. In this series 25 dogs lived for more than 24 hours and 19 of these lived for more than 7 days.

Ten of the 19 animals which survived 7 days or more had their own livers removed on the 7th day after grafting. Five of these died during the following week; 1 died during the 4th week after transplantation, and the remaining 3 lived 30, 52, and 64 days respectively. Of the 9 dogs surviving 7 or more days and that retained their own livers, 3 died during the second week, 2 died during the 3rd week, 2 died during the 4th week and 2 survived 40 and 60 days respectively.

SUMMARY

A review of the surgical techniques used in research concerning the liver reveals that the several difficulties encountered in manipulating this organ are attributable in part to its anatomical peculiarities and its many functions. The main problem during and following surgical intervention is the maintenance of circulation from the viscera and the lower

extremities to the heart, and the interruption of certain physiologic activities of the liver.

The maintenance of blood circulation from the viscera and the lower extremities can be solved by using a side-armed cannula. However there are no substitutions for the major liver functions.

The most important surgical procedures contributing to our knowledge of the liver include the portocaval shunt, hepatectomy and homotransplantation of the liver. The portocaval shunt has been extensively utilized in research of the function of the liver and for the treatment of ascites.

Several surgical techniques are used in performing hepatectomy which is a common procedure in medical research and practised on many species. The problem of interruption of the caval circulation has been solved by using side-armed cannula, or by suturing the hepatic veins flush with the vena cava following careful dissection of the hepatic tissue without affecting the caval circulation. Hepatectomy is of value in the study of the liver functions.

Partial hepatectomy techniques were used to study hypertrophy of the remaining part of the liver. One of the major problems in this procedure occurred when part of the isthmus of the caudal lobe connecting the bases of the other liver lobes were left intact. Autolysis of this tissue caused the death of the experimental animals.

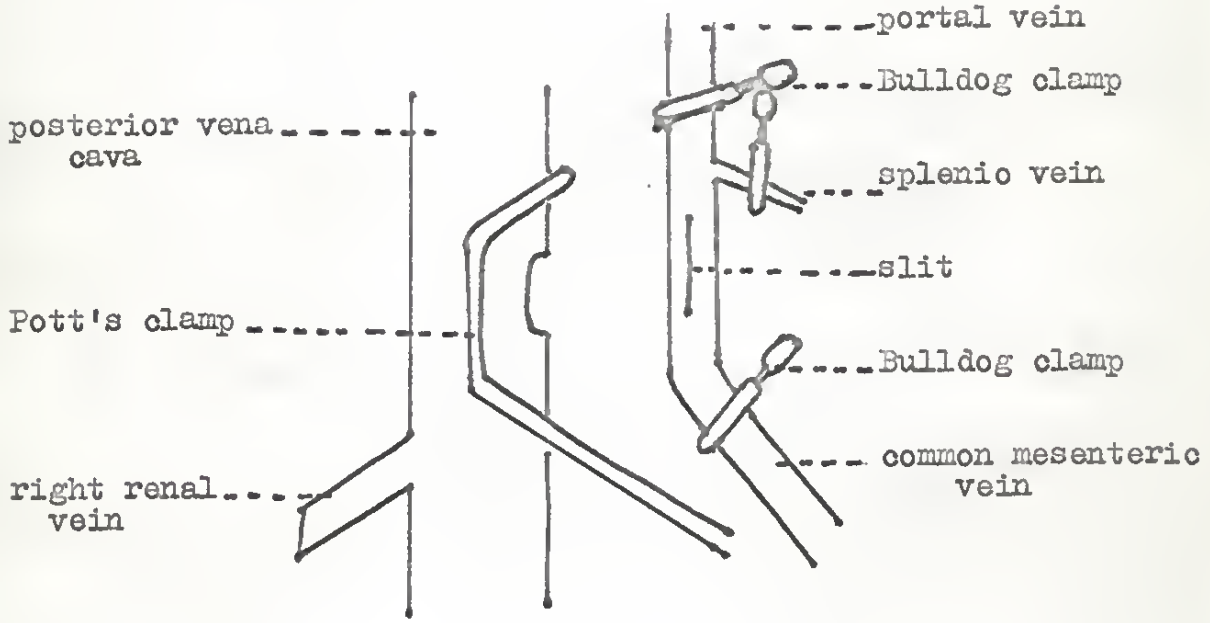
Homotransplantation of the liver has been successfully

performed on dogs. There are many techniques used to perform this procedure. The main problem encountered was anoxia of the graft. As a result of anoxia the intrahepatic saprophytes increased in activity and number and damaged the graft. This problem was solved by utilizing either the hypothermic technique or an arterial shunt.

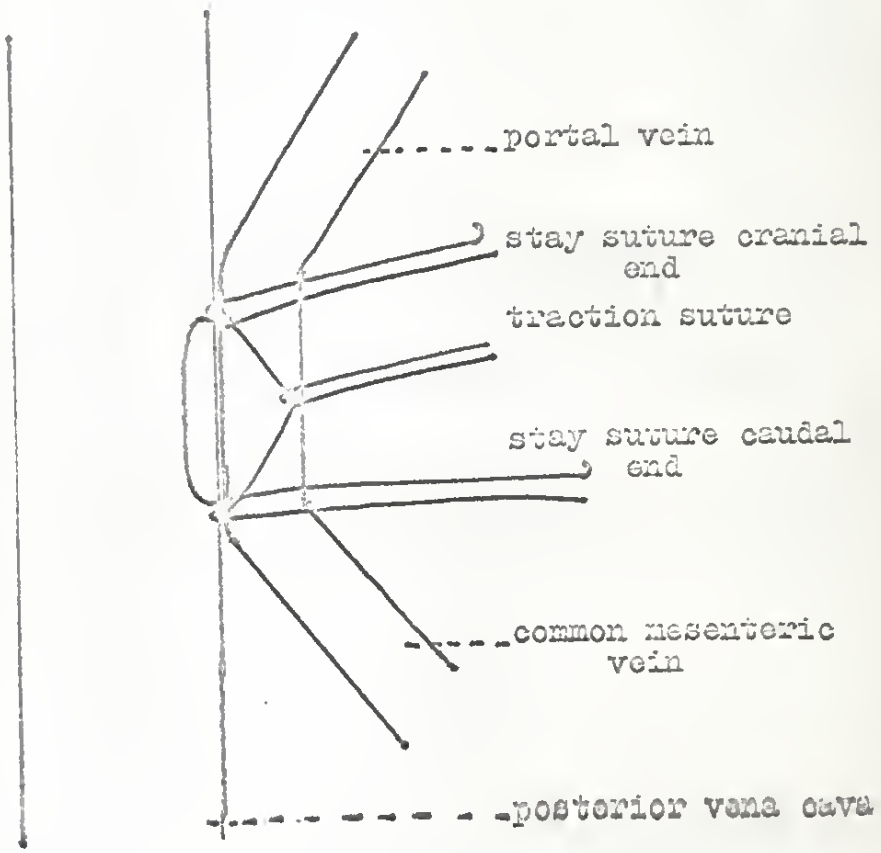
Future investigations involving the liver and requiring surgical procedures will require increasingly refined techniques and surgical skill. Information concerning organ transplants, prosthetic devices and artificial units will continue to challenge the most skillful surgeon in his attempt to apply newer knowledge and research involving the liver.

APPENDIX

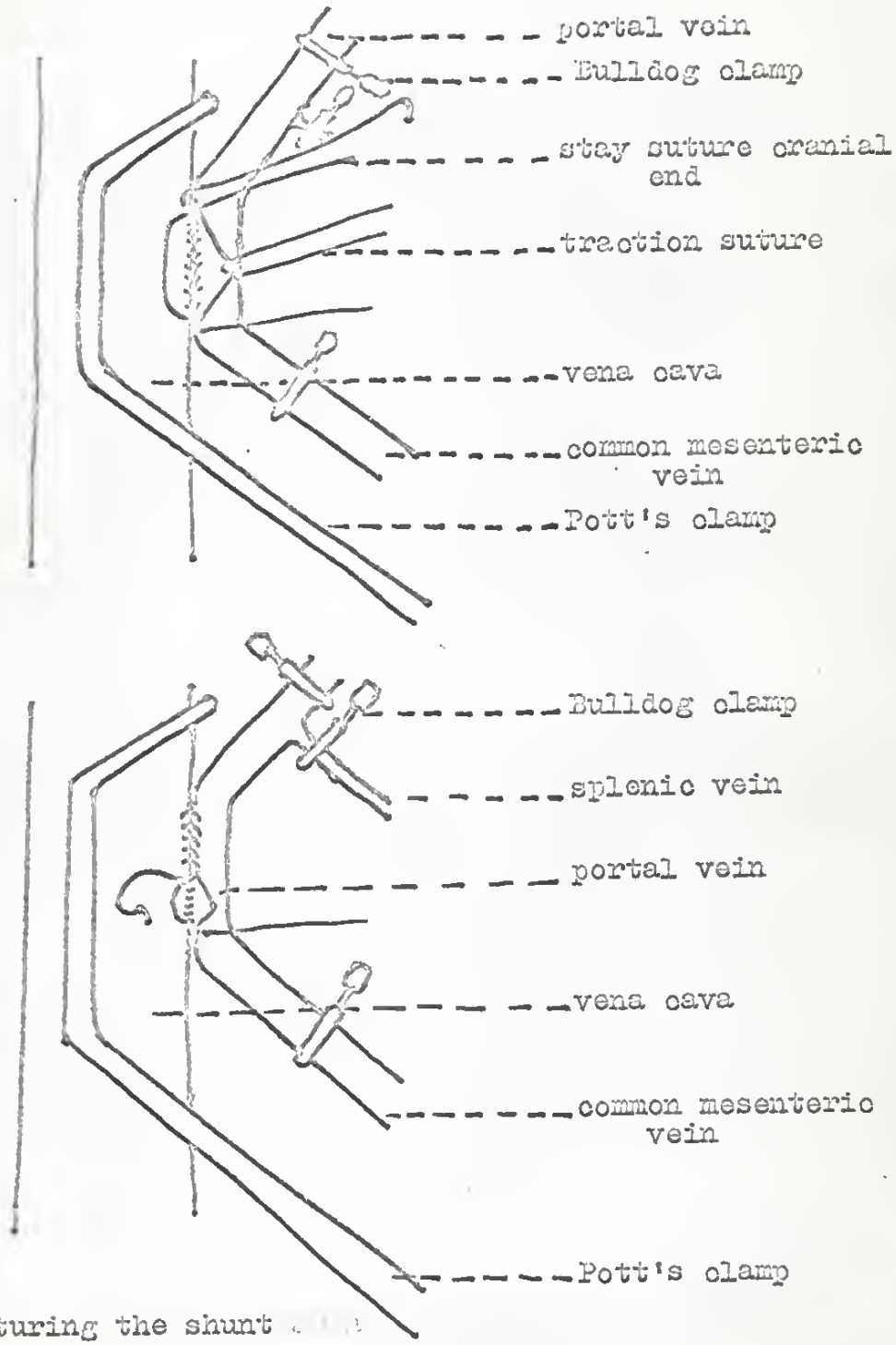
Fig.1. Schematic drawings of the surgical steps of the portocaval shunt



Step-A. Application of Pott's and Bulldog clamps and making an elliptical incision in the vena cava and a slit in the portal vein.



Step-B. Alignment of the vessels and inserting stay and traction sutures.



Step-C. suturing the shunt

Fig.2. Schematic drawing showing the location of ligatures employed in a three-stage hepatectomy

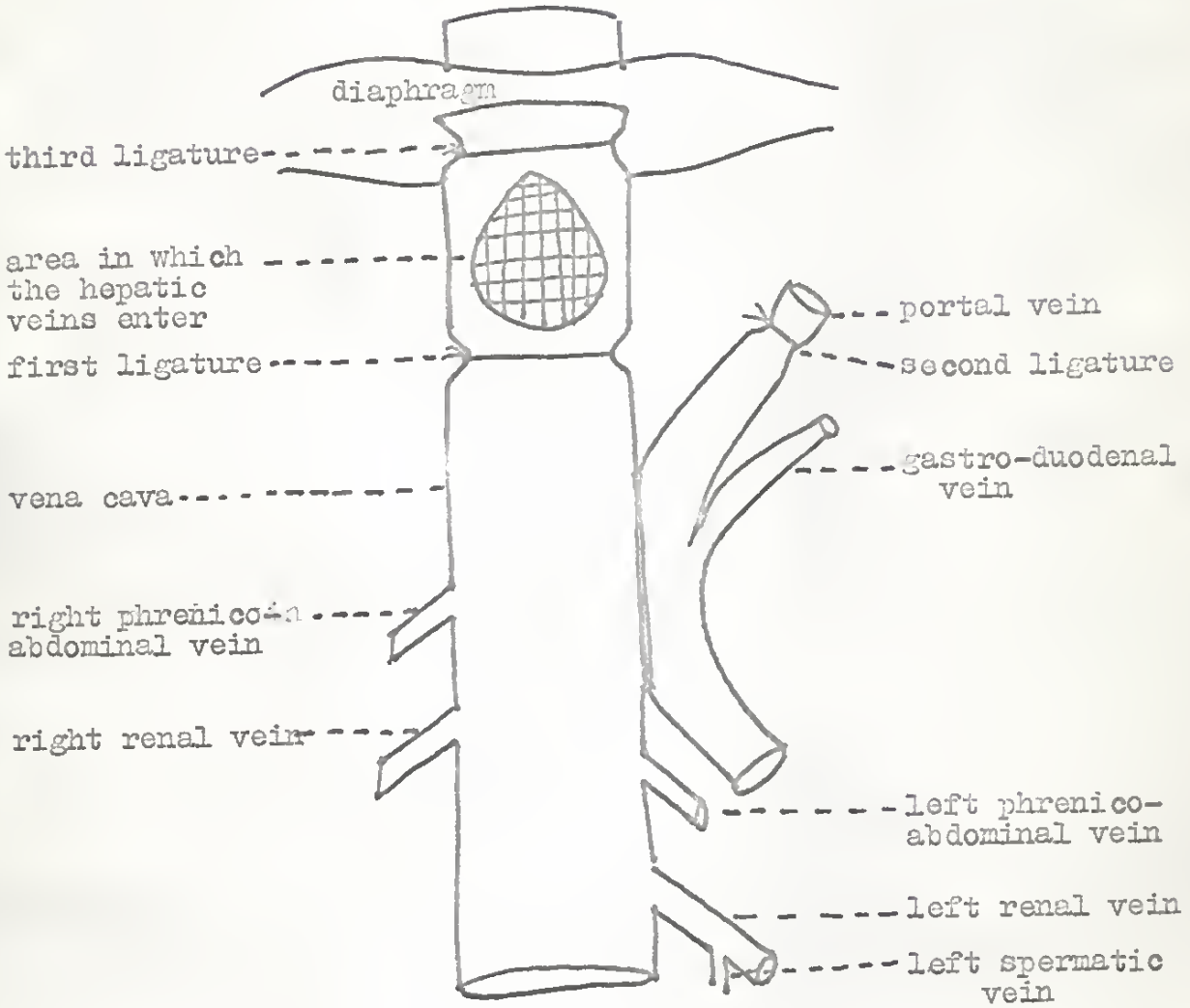
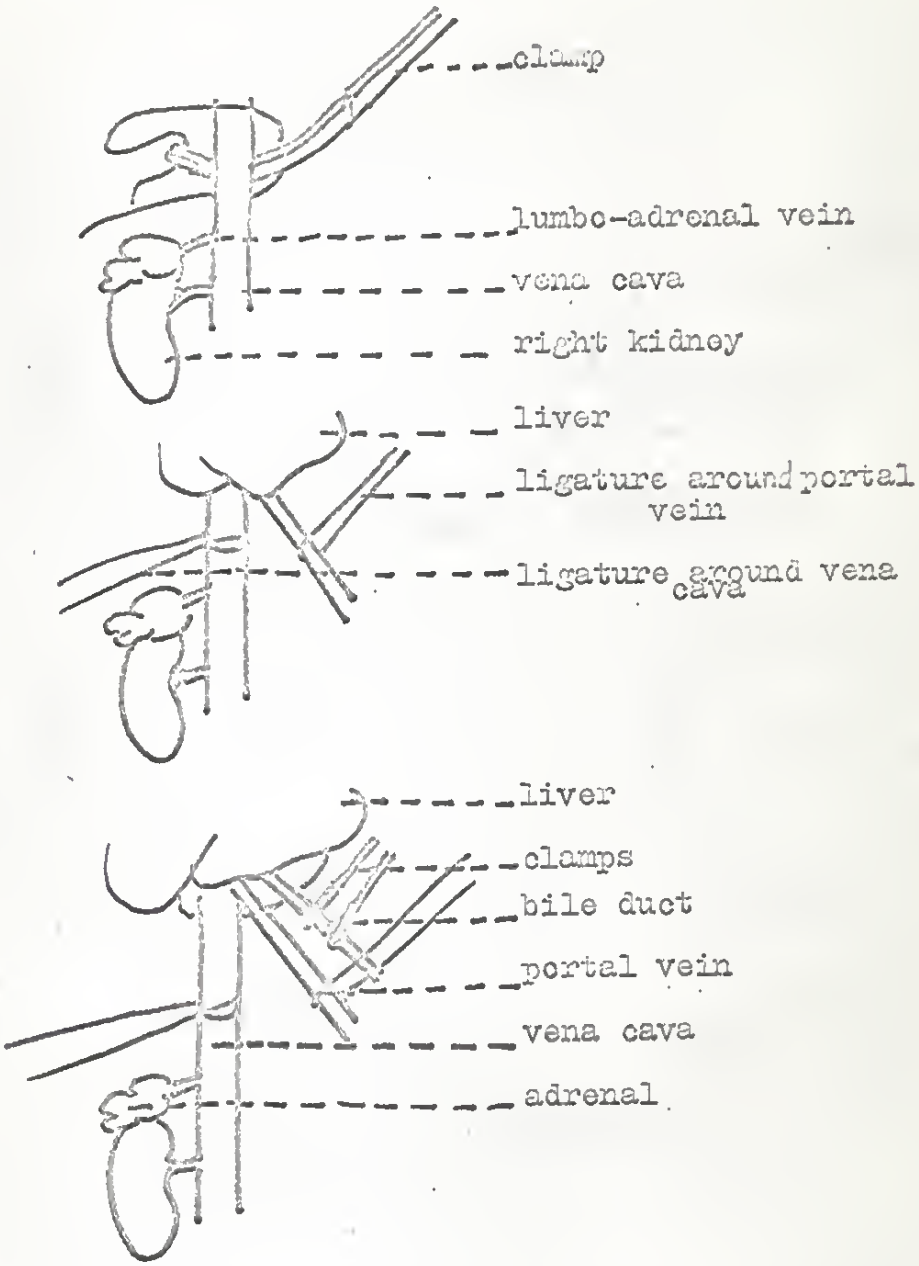
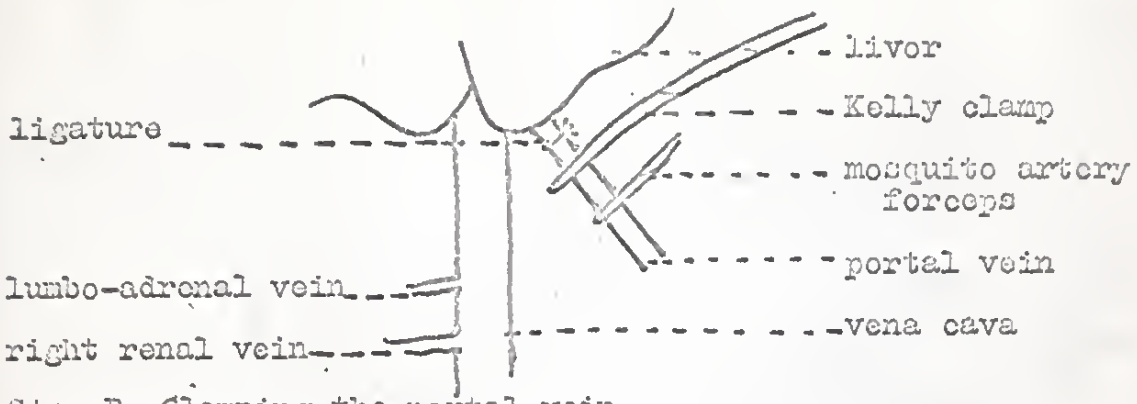


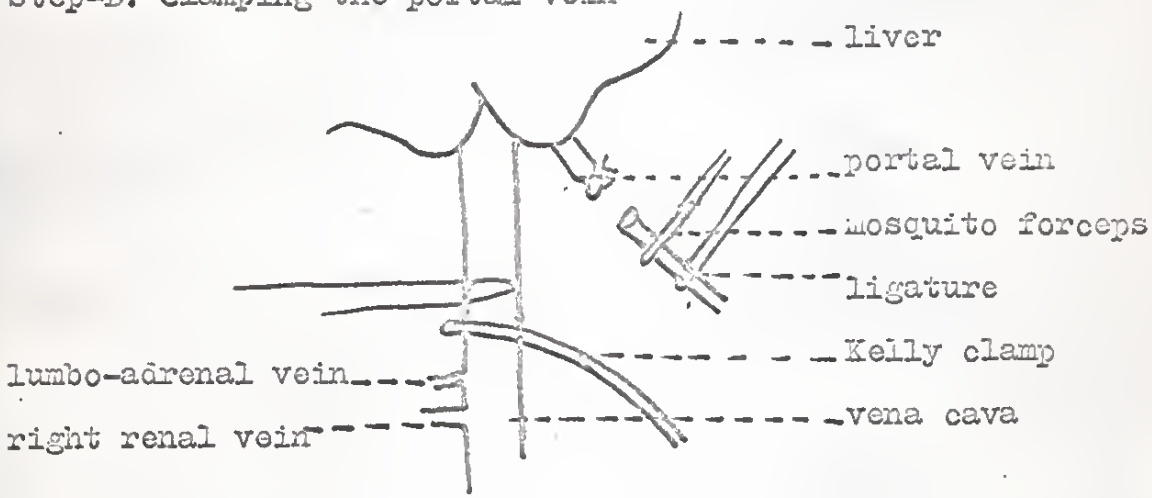
Fig.3. Schematic drawings of Firor's method of hepatectomy



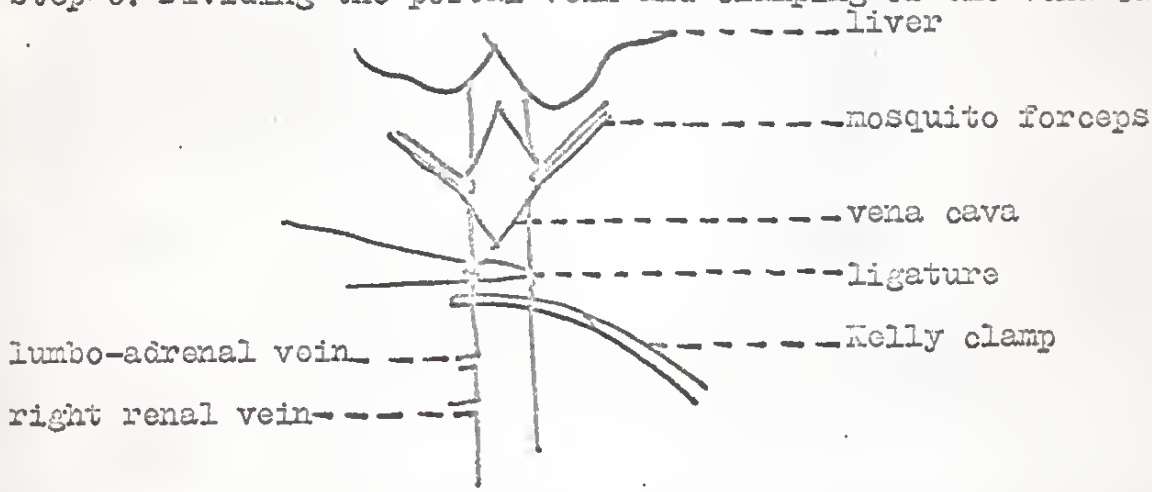
Step-A. Placing of ligatures and clamping the bile duct



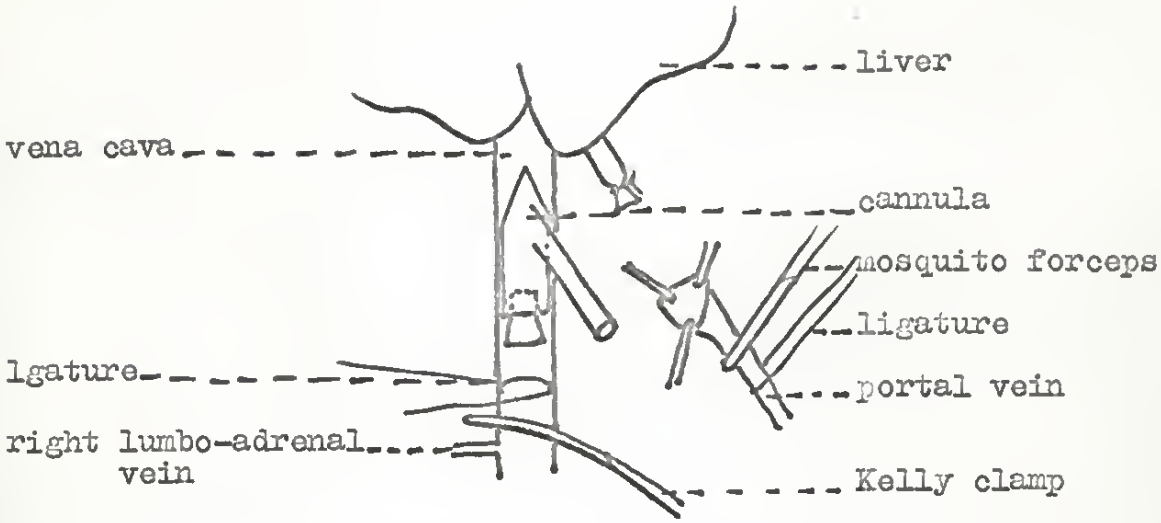
Step-B. Clamping the portal vein



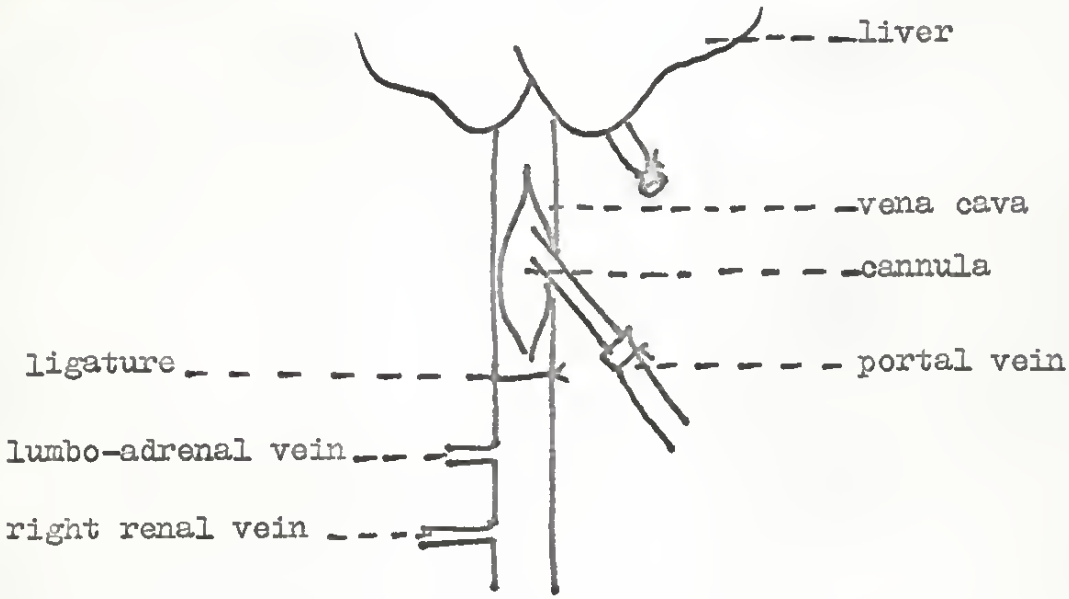
Step-C. Dividing the portal vein and clamping of the vena cava



Step-D. Incision into the vena cava for the insertion of the cannula



Step-E. Insertion of the long segment of the cannula into the vena cava



Step-F.Insertion of the short segment of the cannula into the vena cava and the side arm into the portal vein

Fig.4. Schematic drawing of Drury's method of hepatectomy showing the use of special glass rods to gauge the degree of the occluded vena cava and the portal vein.

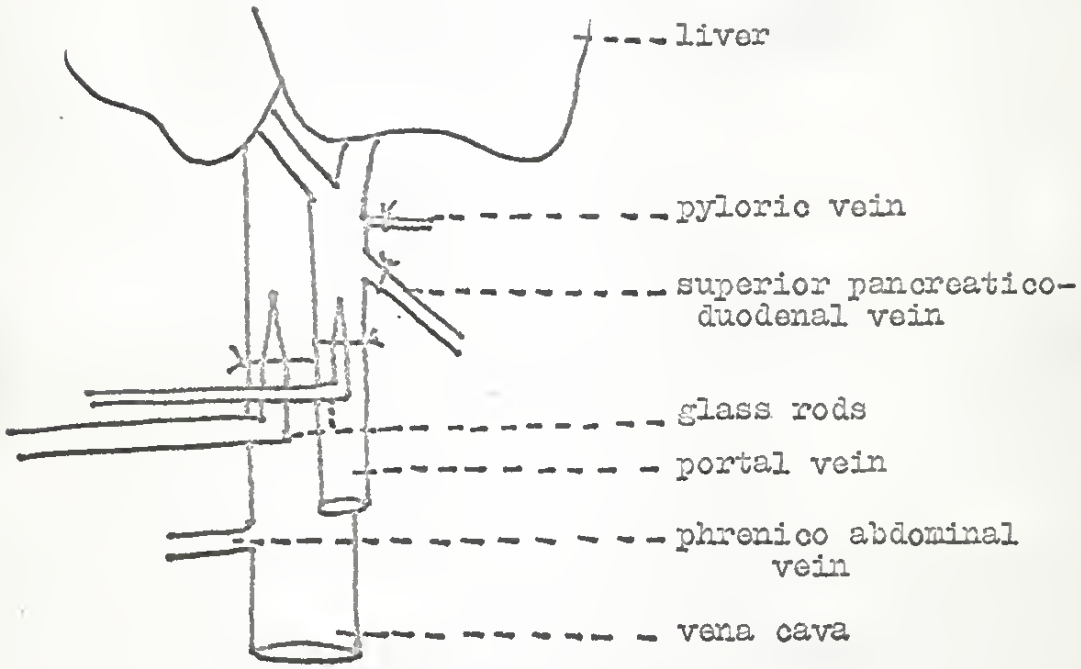
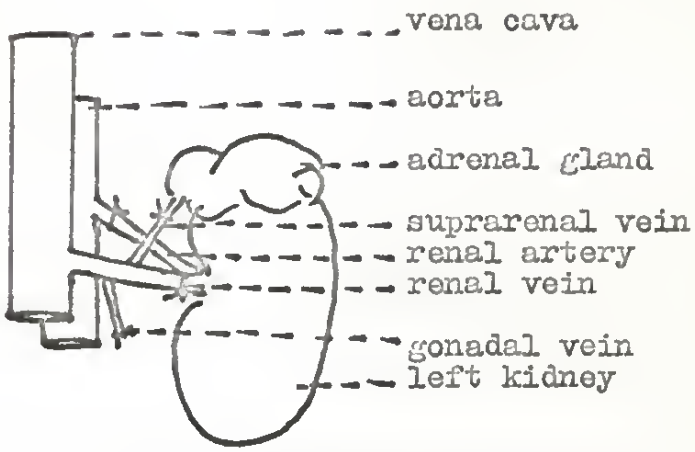
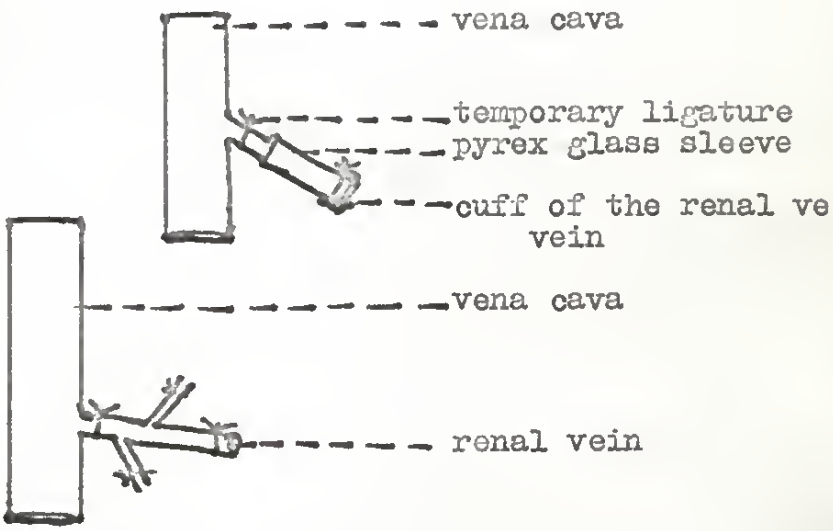


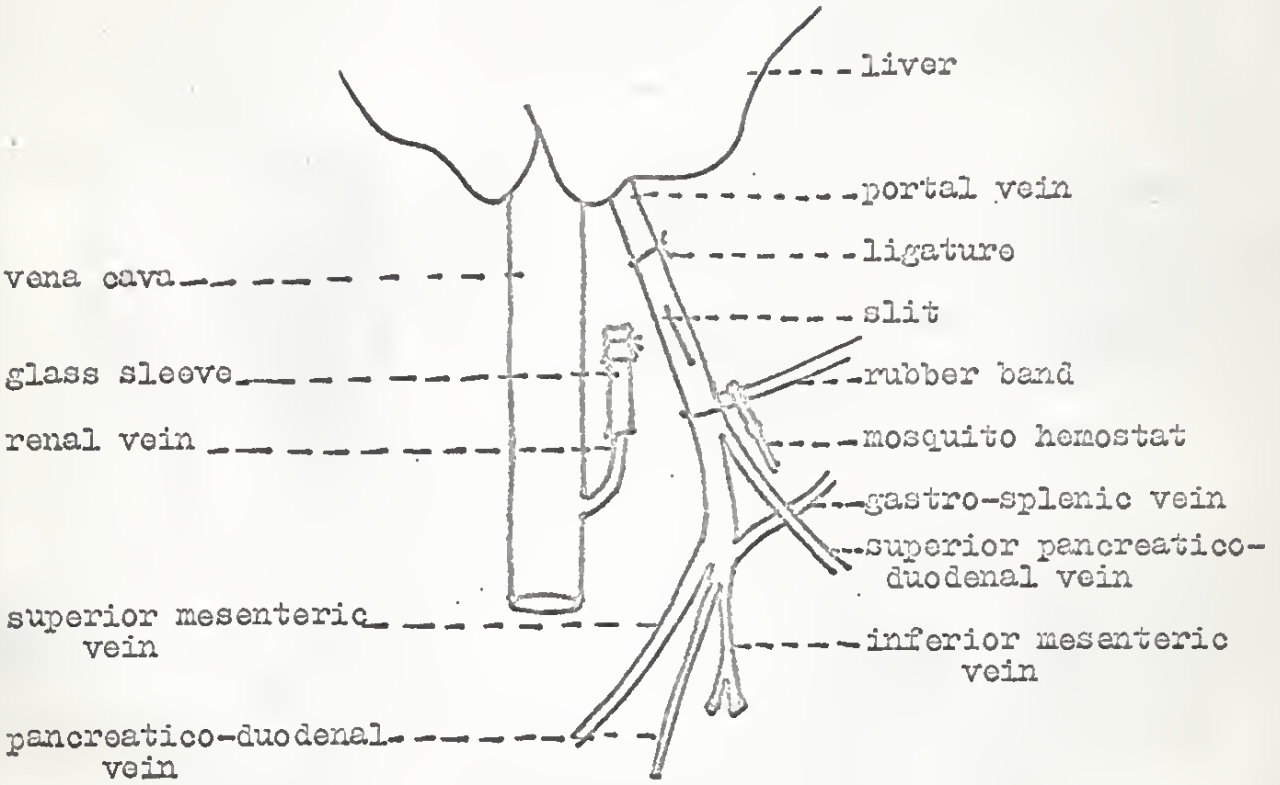
Fig.5.Schematic drawings of Reinhardt's method of functional hepateotomy



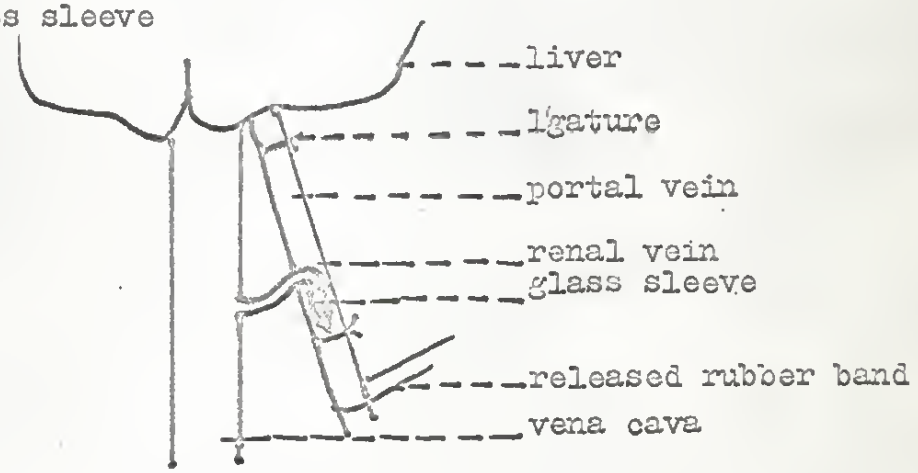
Step-A. Ligation of the renal artery, renal vein, suprarenal vein and gonadal vein



Step-B. Threading the renal vein into a glass sleeve

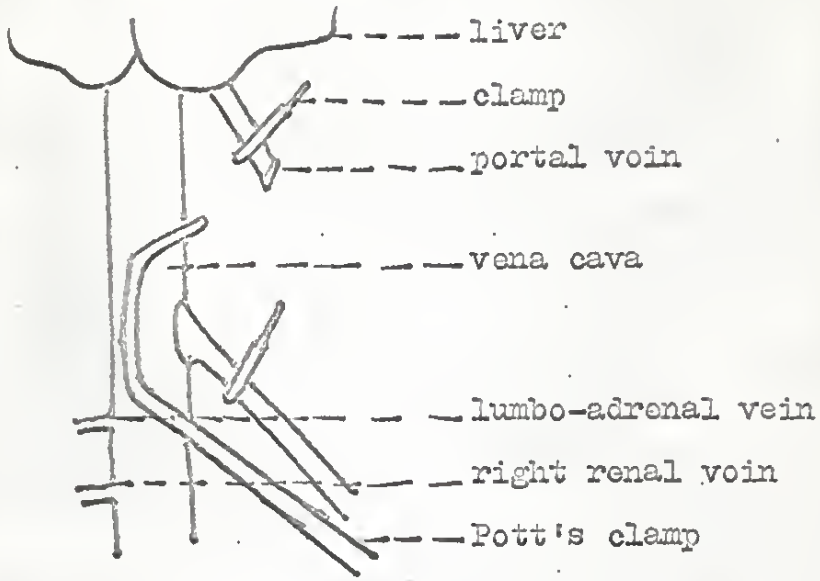


Step-C. Creation of an opening in the portal vein for the insertion of the glass sleeve

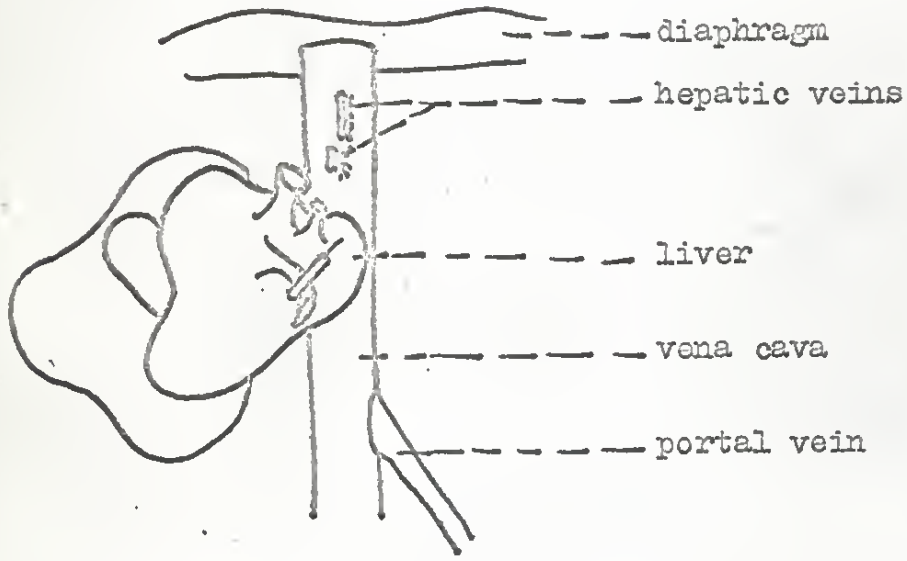


Step-D. Insertion of the glass sleeve into the portal vein and relaxation of the band

Fig.6.schematic drawings of Frank's method of hopatectomy

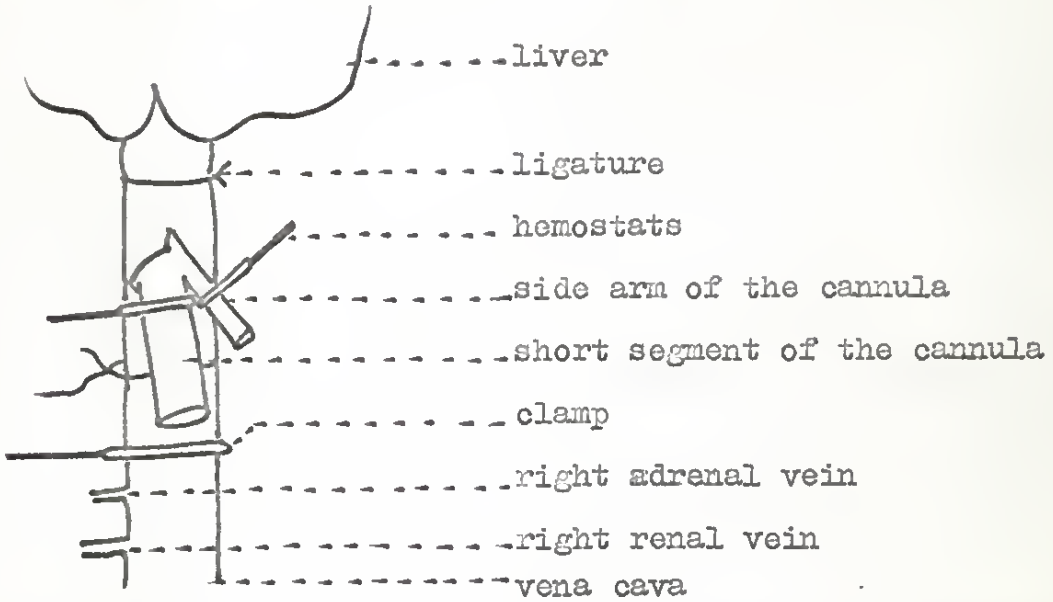


Step-A. End-to-side anastomosis between the portal vein and the vena cava

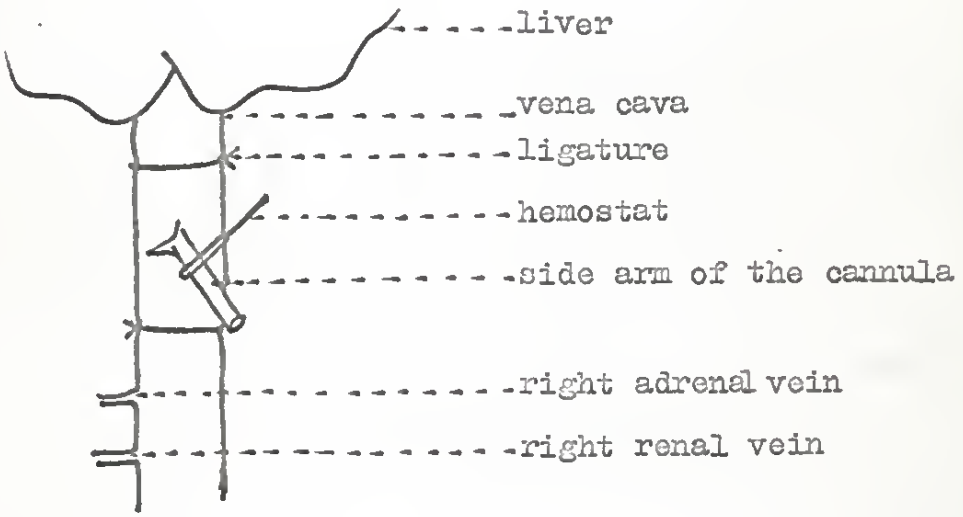


Step-B. dissection of the hepatic tissue from tho vena cava exposing the hepatic veins which are sutured flush with the vena cava

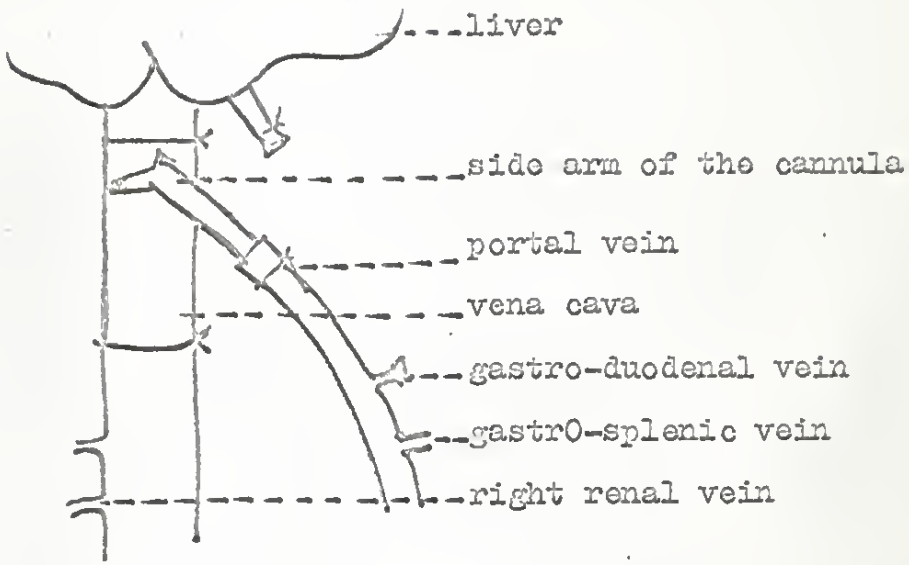
Fig.7.schematic drawings of the reversible exclusion of liver



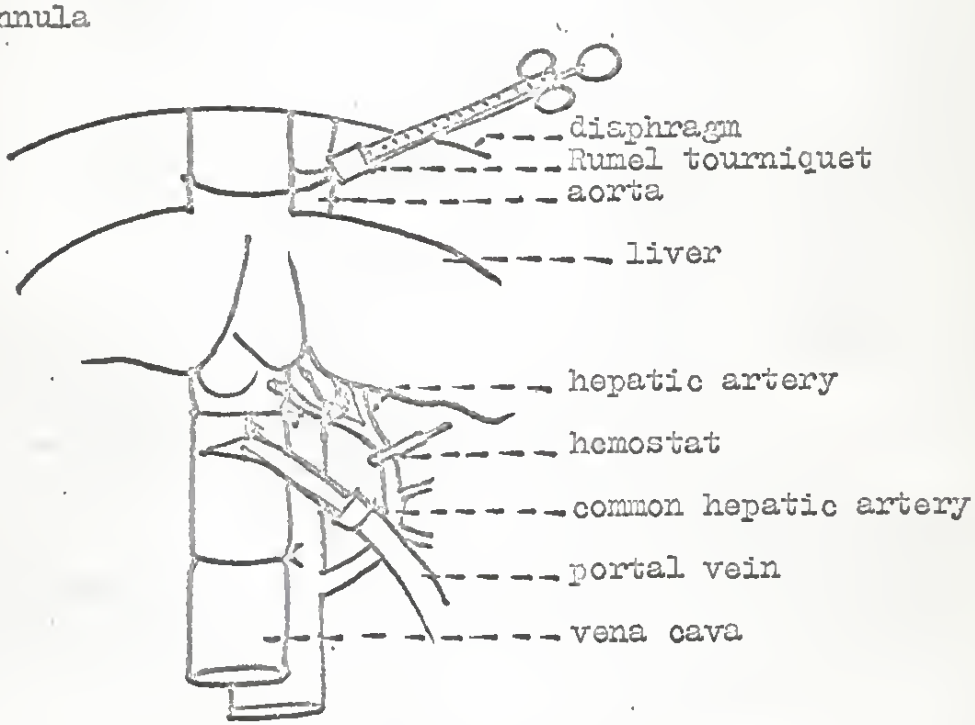
Step-A.Insertion of the long segment of the cannula into the vena cava



Step-B.Insertion of the short segment of the cannula

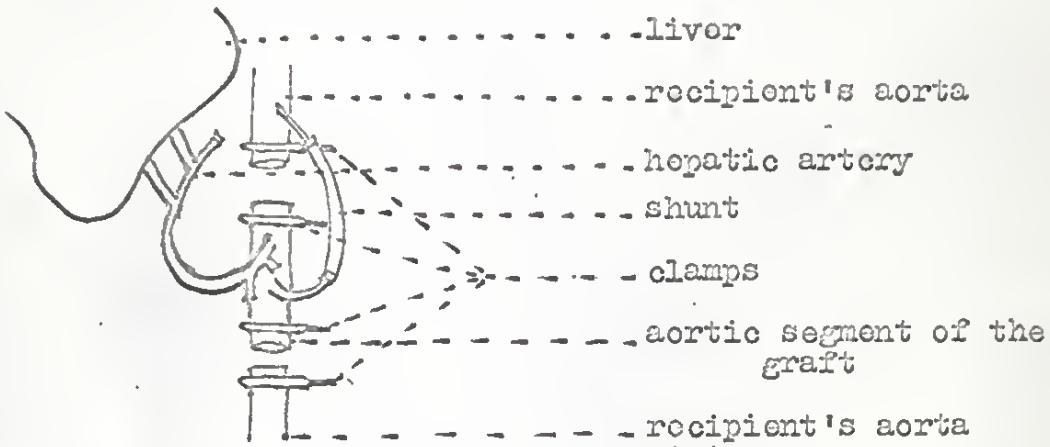


Step-C. Connecting the portal vein to the side arm of the cannula

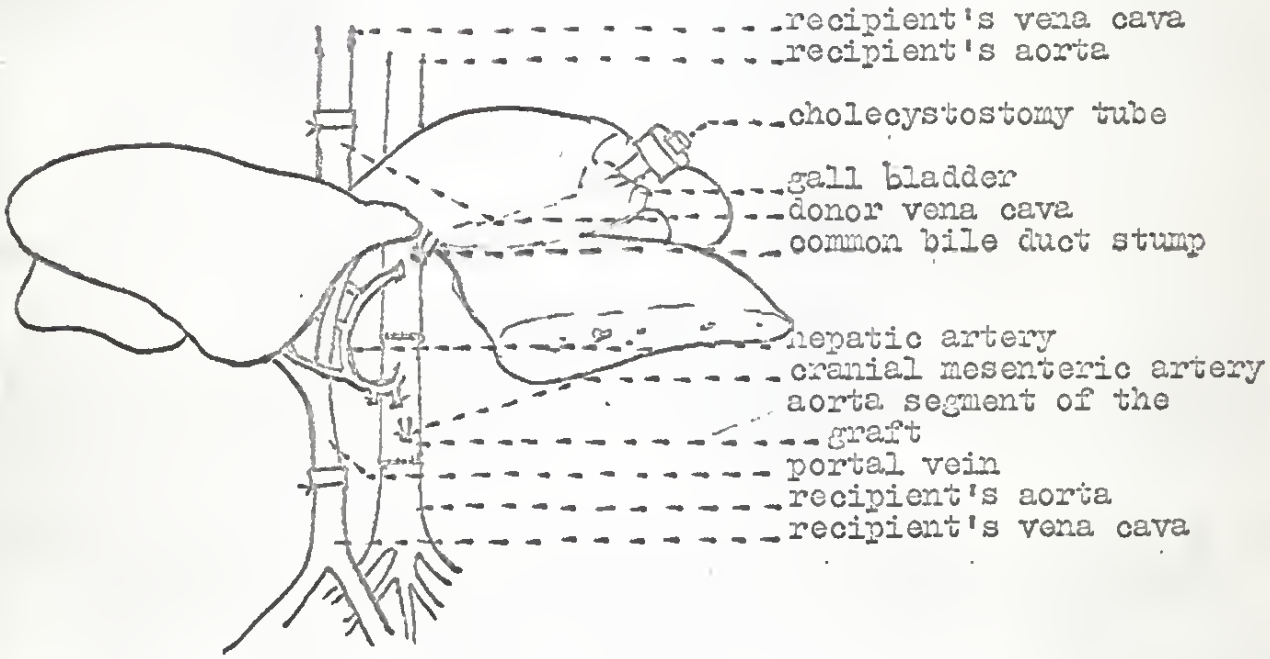


Step-D. The use of the Rumel tourniquet for temporary occlusion of the hepatic veins

Fig.8. Schematic drawings of the arterial shunt and the blood vessel anastomoses for the homotransplantation technique of the liver

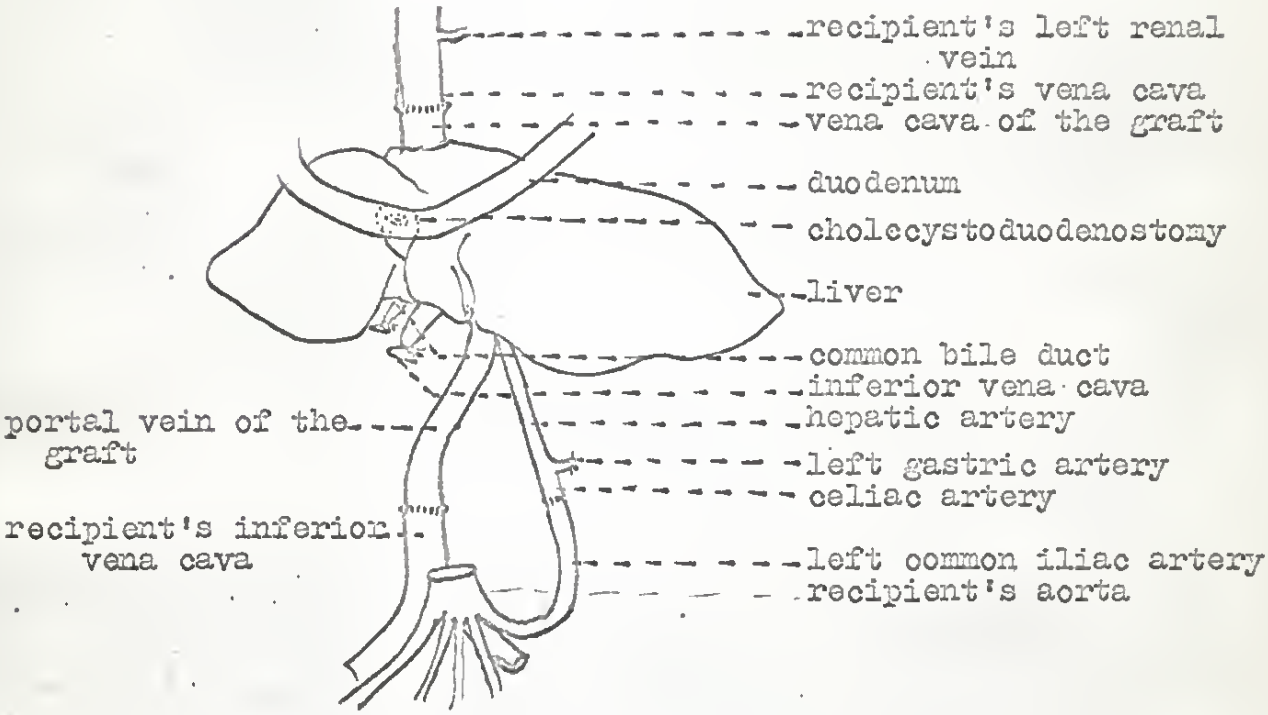


Step-A. Creation of the temporary shunt between the recipient's aorta and the donor's arterial tree



Step-B. Afferent and efferent blood vessel anastomoses

Fig.9. Schematic drawing of Thomford method of homotransplantation of the liver showing the blood vessel anastomoses



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DESIGN AND TECHNIQUES OF SURGICAL PROCEDURES RELATED TO MEDICAL RESEARCH AND INVOLVING THE LIVER

by

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B. V. M. S., Baghdad University, 1961

AN ABSTRACT OF A MASTER'S REPORT

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requirements for the degree

MASTER OF SCIENCE

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1967

Research involving the liver has resulted in the development of numerous surgical procedures, some of which have many techniques. Von Eck (1877) devised the portocaval shunt, and described 2 techniques. The straight Eck fistula consisted of shunting the portal blood into the inferior vena cava while the reverse Eck fistula consisted of shunting the vena cava blood into the portal vein. The usual Eck fistula consisted of the first technique.

Hooper and Whipple (1916) performed bile fistula by inserting rubber tubing into the gall bladder then ligating the common bile duct.

Rous, et al. (1920) performed partial functional hepatectomy in rabbits by ligating the portal trunk to the "main liver".

Mann (1921) described the first operation to remove the liver in mammals without immediate complications other than the effect of anesthesia. His procedure was performed in 3 stages. Success of the operation was dependent on the development of collateral circulation.

Markowitz and Soskin (1927) hepatectomized dogs in 2 stages. They first partially occluded the vena cava and portal veins then in the second stage ligated these vessels and removed the liver.

Firor and Stinson (1928) performed hepatectomy in one stage installing a special side-armed cannula designed to carry the blood from the portal vein and the infrahepatic vena cava

through the hepatic vena cava; and then removing the liver.

Drury (1927) used the method of Markowitz and Soskin in rabbits and Meehan (1954) used the same method in rats.

Higgins and Anderson (1931), and Brues, et al. (1936) described a partial hepatectomy in rats in which the pedicles of the left median and left lateral lobes were ligated.

Ranhardt and Bazell (1946) functionally hepatectomized rats in an one-stage operation. They anastomosed the portal vein to the left renal vein by using a nonsuturing anastomosis technique.

Clay and Ratnoff (1951) performed hepatectomy in one-stage by using a modification of the method of Firor and Stinson.

Frank and Jacob (1951) hepatectomized dogs without injuring the vena cava. In their procedure the hepatic veins were exposed by dissecting away the hepatic tissue. The veins were then sutured close and divided distal to the suturing.

Lichtenstein (1956) devised a method of reversible exclusion of the liver utilizing the Rumel tourniquet to control the blood flow from the liver into the vena cava.

Goodrich, et al. (1956) transplanted the liver from one dog to another. Two methods were utilized in attempts to reduce the activity of the intrahepatic saprophytes during that time the donor's liver was removed from circulation. Either wide-spectrum antibiotics or a temporary polyethylene shunt between the recipient's aorta and the hepatic arterial tree of the donor's liver were used during anastomosis of the graft

vessels to the vessels of the recipient.

Thomford et al. (1965) transplanted liver in dogs. The hypothermic method to eliminate the activity of the intrahepatic saprophytes during interruption of the circulation in the donor's liver was used. Thomford packed the liver in cracked ice to produce tissue hypothermia. The spleen of the recipient was removed. Azathioprine was used in an attempt to alter and delay rejection of the graft. He further removed the recipient's own liver 1 week after grafting of the donor's liver.

Many problems in liver surgery were solved as a result of the development of the surgical techniques. Solutions to these problems made it possible for hepatectomy of the mammals and liver transplantation to be successfully performed.