Introduction

The incidence of gallstones rises with age, so that between 50 and 65 years of age about 20% of women and 5% of men are affected **(*Beckingham*, 2001).**

Laparoscopic Cholecystectomy is the gold standard for the surgical treatment of symptomatic gallstones. The advantages of this surgical approach have included a positive impact on the postoperative quality of the patient's life as well as optimal short and long term results ***(Klin Khir, 2014).***

Postoperative cystic duct leakage is reported in 0.3% to 2.1% of patients undergoing laparoscopic Cholecystectomy ***(Kennedy et al., 1999).*** It is a potentially serious complication, causing formation of biliary peritonitis, fistula, or biloma. Due to this, different techniques have been proposed for closure of the cystic duct including resorbable clips and ultrasonic dissection ***(Li Li-Xia et al., 2014).***

Originally, the LigaSure TM device [LigaSure vessel sealing system (LVSS), Valleylab, Boulder, CO, USA] was designed for sealing vessels up to 7 mm in diameter as an alternative to the use of clips or ligature ***(Yao et al., 2009).***

Comparative studies have been proven that it is as safe, feasible, and even beneficial as other vessel closure techniques such as the plasma trisector, Ultracision, surgical clip application, harmonic scalpel, and conventional hemostasis ***(Cakabay et al., 2009).***

In recent years, there have been an increasing number of reports in the literature on the use of the LVSS not only for sealing vessels but also for the dissection/transection of various soft and parenchymatous tissues such as during liver resection, pancreatectomy, pulmonary resections, hysterectomy, LigaSure-assisted laparoscopic appendectomy, and even hemorrhoidectomy ***(Lambert et al., 2010).***

Also, the use of the LVSS for the transection of major Glisson bundles and major bile ducts, as well for the closure of the cystic duct during cholecystectomy, has been reported in animal model trials and in the ex vivo setting ***(Nii et al., 2008).***

An earlier animal study showed that bipolar electrocoagulation with the LigaSure system is safe for sealing of the cystic duct in pigs ***(Schulze et al., 2002).***

Aim of the Work

The aim of this work is to compare between closure of the cystic duct during laparoscopic cholecystectomy using LigaSure and clips versus LigaSure only as regard:

1. Safety (comparison between complications recorded as biliary leakage, Biliary stricture, transmitted heat)
2. Feasibility (comparison between operative time)
3. Cost (costs of every technique used)

With the aim of developing possible non-sophisticated harmless technique.

Embryology and Anatomy of the Biliary Tract

Understanding the anatomy of the gallbladder and the extrahepatic biliary system is essential to all clinicians caring for patients with hepatobiliary disorders. Biliary anomalies are not uncommon and over 50% of all patients undergoing a biliary tract procedure will have either a ductal or an arterial anomaly. The failure to recognize such a congenital problem can result in significant perioperative morbidity ***(Borley, 2005)***.

Embryology of the bile duct system:

NORMAL DEVELOPMENT :

By the third week of intrauterine life, two buds develop at the junction of the foregut with the midgut. A dorsal bud giving rise to the dorsal pancreas and a ventral bud which divides into two parts, giving rise to the ventral pancreas and a hepatic diverticulum.

The hepatic diverticulum divides again into two parts; a caudal portion which forms the gallbladder and cystic duct, and a cranial portion giving rise to the rest of the duct system and the cords of liver cells.

As the duodenal loop rotates 90 degrees to the right, the ventral and dorsal buds are brought close to each other and lie in the concavity of the duodenal loop, and by the seventh week of intrauterine life, the dorsal and ventral parts of the pancreas unit together and the main pancreatic duct opens with the common bile duct in a common opening in the second part of the duodenum. **Figure (1)**

Early in their development, the extra hepatic bile ducts are solid structures containing multiple spaces lined with epithelial cells. At the seventh week of intrauterine life, these spaces coalesce together to form the lumen of these ducts ***(Last, 1988).***

First the common bile duct and common hepatic duct acquire their lumens, followed by the cystic duct, which also expands at its distal end forming the gallbladder.

During early fetal life the gallbladder is entirely intra hepatic. At about the third intrauterine month, the fetal liver begins to secret bile ***(Rain et al., 1984).***

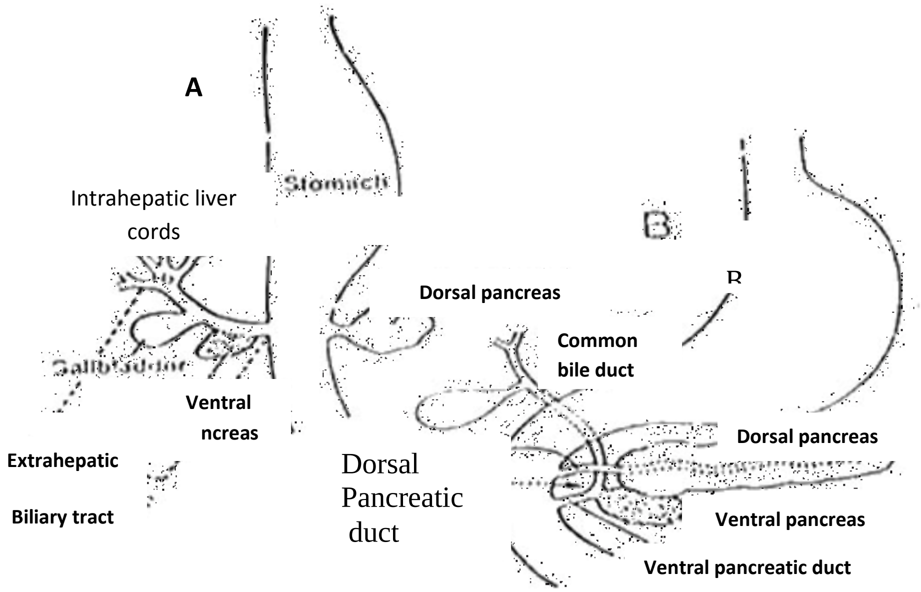

Figure (1): The development of the extra hepatic biliary tract.

A) The hepatic diverticulum, from which are formed the hepatic cords and intrahepatic ducts, the extra hepatic ducts, the gallbladder and the ventral pancreas

B) Rotation of the duodenum, bringing the common bile duct posterior to the duodenum and the two-pancreatic primordia together ***(Quoted from Skandalakis et al., 1992).***

Anatomy of the Gallbladder and the Biliary Tree

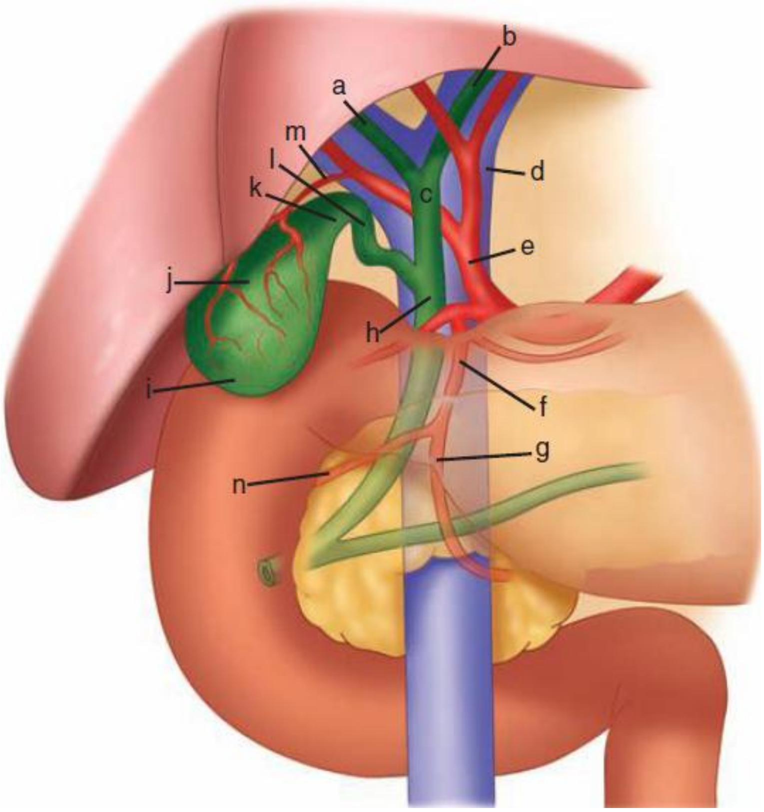

Figure (2): Anterior aspect of the biliary anatomy ***(Quoted from Thai et al., 2015)*.**

a:right hepatic duct; **b:**left hepatic duct; **c:**common hepatic duct; **d:**portal vein; **e:**hepatic artery; **f:**gastroduodenal artery; **g:**left gastric artery; **h:**common bile duct; **i:**fundus of the gallbladder; **j:**body of gallbladder; **k:**infundibulum; **l:**cystic duct; **m:**cystic artery; **n:**superior pancreaticoduodenal artery.

Anatomy of the *gallbladder:*

The gall bladder is a pear shaped sac about 10 cm in length and is situated on the inferior surface of segment V of the right lobe of the liver. It has a capacity of 30 – 50 cc. The hepatic surface is attached to the inferior surface of the liver by connective tissue of the liver capsule. The anti-hepatic surface is covered with peritoneum. Normally there is no peritoneum between the gallbladder and the liver fossa. Small vessels and even biliary channels may connect the liver and gallbladder ***(Cuschieri et al., 2002).***

The gallbladder is divided into 4 anatomic portions: fundus, body, infundibulum and neck. The fundus project beyond the hepatic border and is completely covered with peritoneum and touches the anterior abdominal wall opposite the ninth costal cartilage at the lateral margin of the rectus abdominus muscle. It lies just to the left of the hepatic flexure of the colon. The body of the gallbladder is related to the transverse colon and to the first and proximal part of the second part of the duodenum ***(Last, 1988).***

In about 4% of cadavers, the body is completely covered by peritoneum and has its own mesentery. Such gallbladders (floating gallbladders) are prone to torsion and infarction ***(Skandalakis et al., 1992).***

The neck of the gallbladder is S-shaped and lies in the free border of the hepato-duodenal ligament. The mucosa at the neck is elevated into folds forming the spiral valve of Heister. However, there is no evidence of actual valvular mechanism in the gall bladder neck (***Scott et al., 1979).*** There are no glands in the mucosa of the gallbladder, but the mucus glands of the cystic and common hepatic ducts secret at a higher pressure than the liver cells. Thus the ducts may produce mucus (white bile) even through the diseased gallbladder produces no true bile secretion ***(Skandalakis et al., 1992).***

The most common deformity of the gallbladder (2-6%) is the Phrygian cap where the fundus is constricted and turned back on itself ***(Cuschieri et al., 2002)*. (Figure 3)** Hartmann's pouch, at the neck of gallbladder is probably a normal variation rather than a true deformity ***(Skandalakis et al., 1992).***

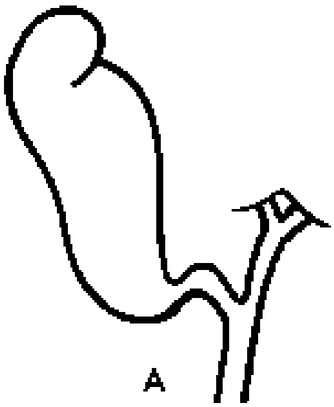

Figure (3): Deformities of the gall bladder. A, Phrygian cap deformity. B, Hartmann's pouch of the infundibulum is probably a normal variation rather than a true deformity ***(Quoted from John et al., 2000).***

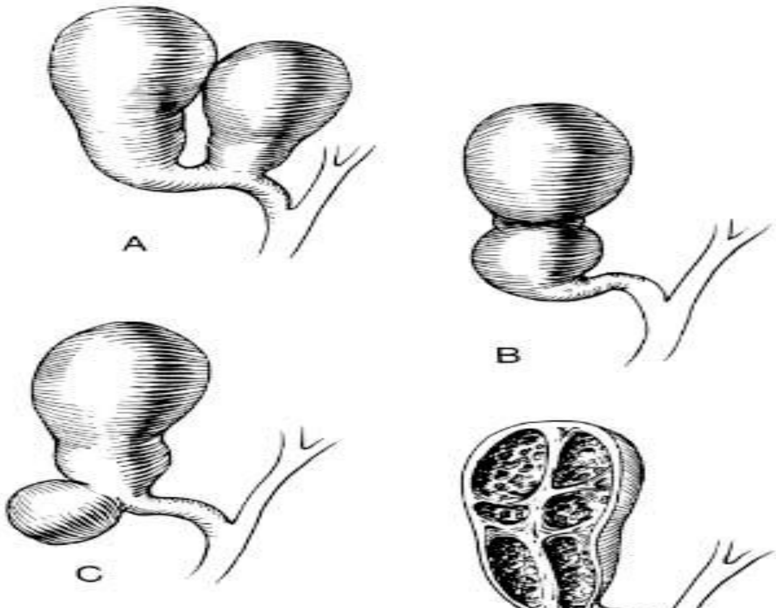

Figure (4): Anomalies of the gall bladder. A, Bilobed gall bladder. B, Hourglass gall bladder. C, Congenital diverticulum of the infundibulum. D, Septate gall bladder. ***(Shackalford's surgery of the alimentary tract, 6th ed 2007).***

A. THE CYSTIC DUCT :

It is about 3 mm in diameter and from 2 – 4 cm in length. The mucosa of the cystic duct is arranged in spiral folds known as the valves of Heister. Its wall is surrounded by a sphincteric structure called the sphincter of lutkins. While the cystic duct joins the common hepatic duct in its supraduodenal segment in 80% of cases, it may extend down into the retroduodenal or even retropancreatic part of the bile duct before joining. Occasionally the cystic duct may join the right hepatic duct or even the right hepatic sectorial duct ***(Rohatgi et al., 2006).***

It passes back, down and to the left from the neck of the gallbladder, joining the common hepatic duct to form the common bile duct. It is adherent to the common hepatic duct for a short distance before joining it, usually near the porta hepatis but sometimes lower, in which case the cystic duct lies along the lesser omentum's right edge. Its mucosa bears 5 to 12 cresentric folds like those in the gallbladder's neck. They project obliquely in regular succession, appearing like a "spiral valve" of Heister. The function of the spiral valve is believed to be strengthening of the wall and assisting in keeping the lumen open. When the duct is distended, the spaces between the folds dilate and externally it appears twisted like the neck of the gallbladder. ***(Tebala, 2006; Verbesey et al., 2008; Williams et al., 2008)***

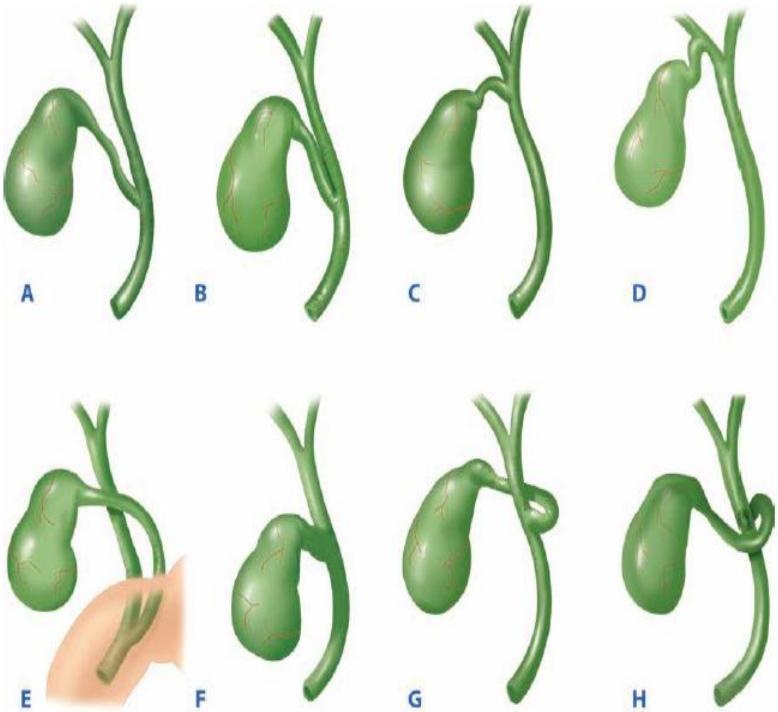

Figure (5): Variations of the cystic duct anatomy.
A. Low junction between the cystic duct and common hepatic duct. ***B.*** Cystic duct adherent to the common hepatic duct. ***C.*** High junction between the cystic and the common hepatic duct. ***D.*** Cystic duct drains into right hepatic duct. ***E.*** Long cystic duct that joins common hepatic duct behind the duodenum. ***F.*** Absence of cystic duct. ***G.*** Cystic duct crosses posterior to common hepatic duct and joins it anteriorly. ***H.*** Cystic duct courses anterior to common hepatic duct and joins it posteriorly ***(Quoted from Thai et al., 2015)*.**

A. <u>The Right and Left Hepatic Ducts:</u>

The right and the left hepatic ducts emerge at the porta hepatis from right and left lobes of the liver in the shape of 'V'. Left hepatic duct has a greater propensity for dilatation as a consequence of distal obstruction. The right hepatic duct has a very short extra hepatic course and it is about 1 cm long. ***(Kitagawa et al., 1997)***

<u>Arrangements:</u>

The arrangement of structures at the porta hepatis, from behind forwards, is the branches of the portal vein, hepatic artery and hepatic ducts.

B. <u>The Common Hepatic Duct:</u>

<u>Arrangements</u>:

The common hepatic duct lies to the right of the hepatic artery and anterior to the portal vein. The main right and left hepatic ducts near the right end of the porta hepatis as the common hepatic duct unite near the right end of the porta hepatis as the common hepatic duct which descends about 3 cm before being joined on its right at an acute angle by the cystic duct to form the main bile duct. It makes up the left border of the triangle of Calot. The common hepatic duct is usually less than 2.5 cm long and is formed by the union of the right and left hepatic duct ***(Kitagawa et al., 1997)***.

C. <u>The Common Bile Duct:</u>

The common bile duct is about 7 to 11 cm in length and 5 to 10 mm in diameter. The upper third (supraduodenal portion) passes downward in the free edge of the hepatoduodenal ligament, to the right of the hepatic artery and anterior to the portal vein. The middle third (retroduodenal portion) of the common bile duct curves behind the first portion of the duodenum and diverges laterally from the portal vein and the hepatic arteries. The lower third (pancreatic portion) curves behind the head of the pancreas in a groove, or traverses through it and enters the second part of the duodenum. There, the pancreatic duct frequently joins it. The common bile duct runs obliquely downward within the wall of the duodenum for 1 to 2 cm before opening on a papilla of mucous membrane (ampulla of Vater), about 10 cm distal to the pylorus. The union of the common bile duct and the main pancreatic duct follows one of three configurations. In about 70% of people, these ducts unite outside the duodenal wall and traverse the duodenal wall as a single duct. In about 20%, they join within the duodenal wall and have a short or no common duct, but open through the same opening into the duodenum. In about 10%, they exit via separate openings into the duodenum. The sphincter of Oddi, a thick coat of circular smooth muscle, surrounds the common bile duct at the ampulla of Vater ***(Figure 6).*** It controls the flow of bile, and in some cases pancreatic juice, into the duodenum ***(Thai et al., 2015).***

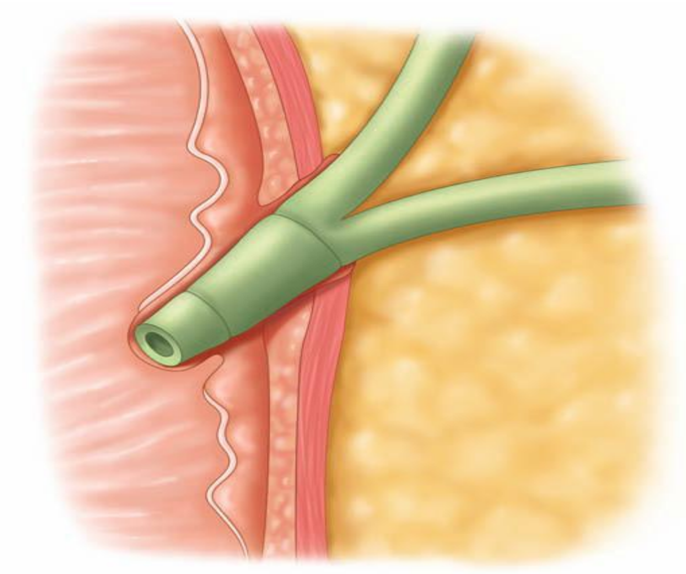

Figure (6): The sphincter of Oddi ***(Quoted from Thai et al., 2015)*****.**

The extrahepatic bile ducts are lined by a columnar mucosa with numerous mucous glands in the common bile duct. A fibroareolar tissue containing scant smooth muscle cells surrounds the mucosa. A distinct muscle layer is not present in the human common bile duct. The arterial supply to