

Sudan University of science and technology

Collage of graduate studies

**Determination of CT Number of Normal Liver in Sudanese Population using
Computed Tomography**

تحديد الرقم المقطعي للكبد الطيفي عند السودانيين باستخدام الاعة المقطعية

A thesis submitted for partial fulfillment for the Requirement of M.Sc. Degree in
Diagnostic Technology

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الآية

قُلِ اللَّهُمَّ مَالِكَ الْمُلْكِ تُؤْتِي الْمُلْكَ مَنْ تَشَاءُ وَتَنْزِعُ الْمُلْكَ مِمَّنْ تَشَاءُ

وَتُعِزُّ مَنْ تَشَاءُ وَتُذِلُّ مَنْ تَشَاءُ ۗ بِيَدِكَ الْخَيْرُ ۗ إِنَّكَ عَلَىٰ كُلِّ شَيْءٍ

قَدِيرٌ (26)

Dedication

To the souls of the martyrs of the glorious December revolution

**I also dedicate this work to spirit of my uncle “Abdelgader Mohamed Ahmed”
who bravely fought the disease until he died**

Acknowledgment

Praise is to Allah who blessed me with knowledge of which I knew not and enable me write this thesis. I would like to acknowledge and thanks Dr. Asma Ibrahim Elamin, my supervisor at Sudan University of Sciences and Technology, for her supporting, guidance, suggestions and encouragement to complete this thesis.

Also, a special thanks to technologist Ahmed Awad for his help in collection of data.

ABSTRACT

To determine the liver CT number among Sudanese people using spiral CT.

A designed data sheet was used to collect data from 50 patients refer to CT abdomen , which was done using images of slice thickness (5mm) and slice gap (7-10mm) , three readings were taken from three points in axial cuts.

The mean CT number of liver among the males was found to be 57.24 ± 7.98 HU , and that among females was 56.19 ± 10.77 the mean different was found to be 1.05 which was statically insignificant within p-value of 0.932 .

When the patients age was correlated to the CT number of liver , the relationship was found to be a weak positive relationship with correlation coefficient of $r=0.027$, this relationship was found to be statically significant within p-value of 0.932 .

The mean of CT number of normal liver among Sudanese patients was found to be 56.90 ± 8.87 HU , the CT number of normal liver is not affected by gender , age affects liver CT number with a weak direct relationship .

ملخص الدراسة

الهدف العام لهذه الدراسة تحديد الرقم المقطعي المحوسب للكبد بين أفراد الشعب السوداني الأصحاء باستخدام الأشعة المقطعية المحوسبة .

تم استخدام ورقة مصممة لجمع البيانات من 50 مريض محول لعمل أشعة مقطعية للبطن وقد تمت بسمك شريحة (7ملم) ومسافة (7-10ملم) وأخذت ثلاثة قراءات من مقاطع راسية .

تبين أن متوسط الرقم المقطعي المحوسب للكبد عند الذكور كان 7.87 ± 57.90 وحدة هاونسفيلد وكان عند الإناث 10.77 ± 56.19 وحدة هاونسفيلد , وقد كان متوسط الأختلاف بينهما 1.05 وحدة هاونسفيلد والتي تعتبر إحصائيا ضئيلة بقيمة 0.932

عند ربط الدراسة بعمر المرضى وجدت علاقة ضعيفة بقيمة 0.027 ولكنها ذات قيمة إحصائية ثابتة بمقدار 0.932 .

وكان متوسط الرقم المقطعي المحوسب للكبد بين المرضى السودانيين 7.87 ± 56.90 وحدة هاونسفيلد . وقد تبين ان الرقم المقطعي المحوسب للكبد لا يتأثر بنوع المريض ولكن عمر المريض يؤثر تأثير مباشر ضعيف .

List of abbreviations

CT	Computed Tomography
BMI	Body Mass Index
HU	Hounsfield Unit
SPSS	Statistical Package of Social Sciences

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Chapter one

1.1 Introduction

Determination of liver CT number has important clinical implication. A thorough knowledge of liver HU is prerequisite for clinical assessment of liver disorders and it can facilitate decision making in liver transplant surgery especially to avoid donor-recipient graft mismatch. (Sakamoto - 2001)

Of several indexes of liver size, liver span and liver volume are important. Liver span (longitudinal diameter) was traditionally used because it can be conveniently measured using palpation and ultrasonography (USG). However, considering the complexity of liver shape, liver span alone cannot appropriately represent liver mass. Additionally, liver span as measured by palpation and USG is prone to inter-observer variability and poor repeatability. Few studies have explained that palpation and perfusion provide vague evidence of liver enlargement. (Sakamoto 2001)

Organ volume must be related to an individual's age, gender and body habitus for a more precise interpretation of abnormality, for example liver volume is decreased in pathologies leading to fibrosis and consequent shrinkage like cirrhosis of liver on one hand and in all the space occupying lesions leading to the increase in the size of liver like tumors of the liver on the other hand. (Sakamoto - 2001)

Size of liver is also an important factor when considering surgical correction during liver transplantation and any other liver pathology. (Sakamoto - 2001)

Liver volume can be measured by USG, but it is bounded by some variations due to observer bias. With development of more elaborate imaging methods such as magnetic resonance imaging (MRI), spiral computed tomography, measurement of mass or organ volume has become feasible. The spiral CT images which can

generate 3-D reconstruction images are particularly accurate in measurement of organ volume.(Sakamoto - 2001)

Spiral CT higher accuracy and reproducibility than conventional CT the accuracy of volume assessment was mainly determined by window setting used for image display using an optimized window center resulted in over estimation of true object volume.(Emirogl -2006)

In present study, normal liver volume of healthy adult Sudanese population has been estimated by using spiral computed tomography scans and its relationship with various body indices has been statistically calculated.(Emirogl -2006)

1.2 Problems of the study:

There was lack of reference for Sudanese population in CT number of normal liver.

1.3 Objectives

1.3.1 General objectives:

To Estimate CT number of normal liver in Sudanese population

1.3.2 Specific objectives

- To measure CT number of liver.
- To find out the normal standard value as local reference for Sudanese.
- To compare the findings with other population and literature.
- To correlate between patient age, gender and body mass index (BMI) and CT number of liver.

Chapter Two

Literature Review

2.1 Anatomy

The liver is largest gland in the body, with both external and internal secretion, which is formed by the hepatic cells. The external secretion, the bile, is collected after passing through the bile capillaries by the bile duct which joint like the twigs and branches of the tree to form two large ducts that unite to form the hepatic duct. The bile is either carried to the gall-bladder by the cystic duct or poured directly into the duodenum by the common bile duct where it aids in digestion. The internal secretions are concerned with the metabolism of both nitrogenous and carbohydrates material absorbed from the intestine and carried to the liver by the portal vein. The carbohydrates are stored in the hepatic cells in the form of glycogen which is secreted in the form of sugar directly into blood stream. Some of the cells lining the blood capillaries of the liver are concerned in the destruction of red blood corpuscles. (Richard -2005)

It is situated in the upper and right part of the abdominal cavity, occupying almost the whole of the right hypochondrium, the greater part of the epigastrium, and not uncommonly extending into the left hypochondrium as far as the mammillary line. In the males it weighs 1.4 - 1.6 kg while, in the females 1.2 -1.4 kg. It is relatively much larger in the fetus than in the adult, constituting, in the former, about one-eighteenth, and in the latter about one thirty -sixth of the entire body weight. Its greatest transverse measurement is 20 - 22.5cm, vertically, near its lateral or right surface, it measures about 15-17.5cm, while its greatest antero-posterior diameter is on a level with the upper end of the right kidney, and is 10-12.5cm. Opposite the vertebral column its measurement from before backward is reduced to about 7.5cm. (Richard -2005)

2.1.1 Surfaces:

The liver possesses three surfaces, superior, inferior and posterior surface .A sharp, well -defined margin divides the inferior from the superior in front; the other margins are rounded. The superior surface is attached to the diaphragm and anterior abdominal wall by a triangular or falciform fold of peritoneum, the falciform ligament, in the free margin of which is rounded cord, the ligament teres (obliterated umbilical vein). (Richard -2005)

The line of attachment of the falciform ligament divides the liver into two parts, termed the right and left lobes, the right being much the larger. The inferior and posterior surfaces are divided into four lobes by five fossae, which are arranged in the form of letter H. (Richard -2005)

The left limb of the H marks on these surfaces the division of the liver into right and left lobes; it is known as the left sagittal fossa, and consists of two parts, the fossa for umbilical vein in front and the fossa for the ducts venous behind. The right limb of the H is formed in front by the fossa for the gall-bladder, and behind by the fossa for the inferior vena cava; these two fossa are separated from one another by a band of liver substance, termed the caudate process. The bar connecting the two limbs of H is the portal (transverse fissure); in front of it is the quadrate lobe, behind it the caudate lobe. The superior surface (facies superior) (Fig2.1) comprises a part of both lobes, and, as a whole, is convex, and fits under the vault of the diaphragm. (Richard -2005)

which in front separates it on the right from the sixth to the tenth ribs and their cartilages, and on the left from the seventh and eighth costal cartilages. (Richard -2005)

Its middle part lies behind the xiphoid process, and, in the angle between the diverging ribs cartilage of opposite sides, is in contact with the abdominal wall.

Behind this the diaphragm separates the liver from the lower part of the lungs and pleurae the heart and pericardium and the right costal arches from the seventh to the eleventh inclusive. It is completely covered by peritoneum except along the line of attachment of the falciform ligament. (Richard -2005)

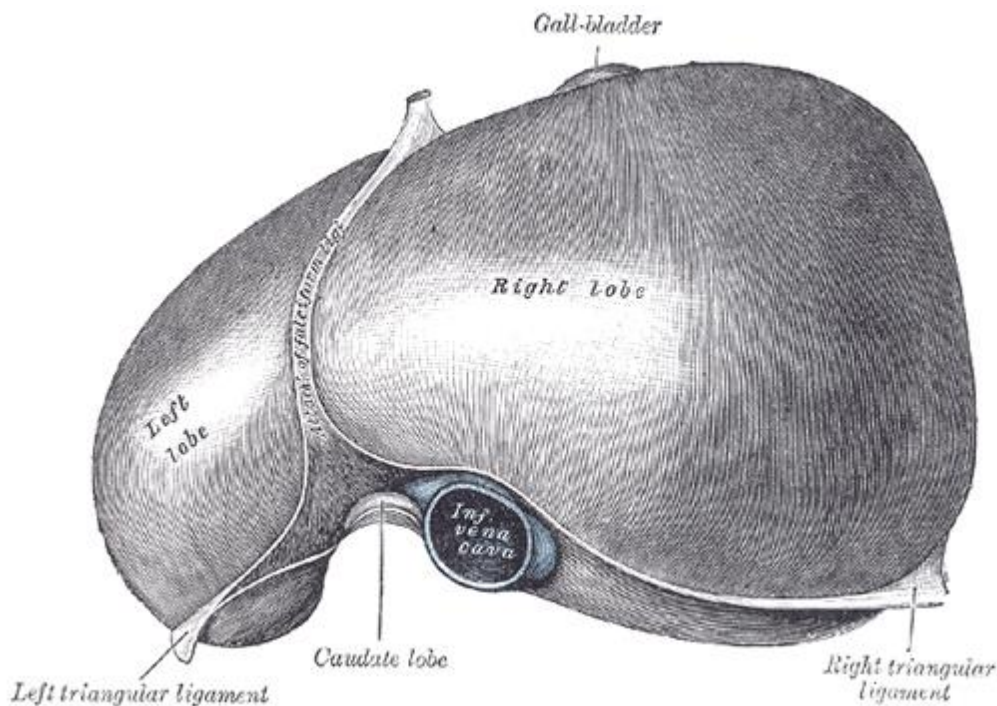


Figure2.1 shows the superior surface of the human liver (Benjamin 2012).

The inferior surface(facies inferior ;visceral surface) (Fig2.2) is uneven, concave, directed downward, backward, and on the left, and is in relation with the stomach and duodenum, the right colic flexure, and the right kidney and suprarenal gland .The surface is almost completely invested by peritoneum ; the only part devoid of this covering area were the gall- bladder is attached to the liver and at the porta hepatis were the two layers of the lesser momentum are separated from each other by the blood vessels and ducts of the liver . The inferior surface of the left lobe presents behind and to the left the gastric impression, moulded over the antero-

superior surface of the stomach, and to the right of this a rounded eminence, the tuber omentale, which fits into the concavity of the lesser curvature of the stomach and lies in front of the anterior layer of the lesser omentum. (Richard -2005)

The under surface of the right lobe is divided into two unequal portions by the fossa for the gall-bladder ;the portion to the left, the smaller of the two, is the quadrate lobe, and is in relation with the pyloric end of the stomach, the superior portion of the duodenum, and the transverse colon . (Richard -2005)

The portion of the under surface of the right lobe to the right of the fossa for the gall-bladder presents two impressions, one situated behind the other, and separated by a ridge .The anterior of these two impressions, the colic impression, is shallow and is produced by the right colic flexure; the posterior, the renal impression, is deeper and is occupied by the upper part of the right kidney and lower part of the right suprarenal gland. Just in front of the inferior vena cava is a narrow strip of the liver tissue. The caudate process, which connects the right inferior angle of the caudate lobe to the under surface of the right lobe, forms the upper boundary of the epiploic foramen of the peritoneum. (Richard -2005)

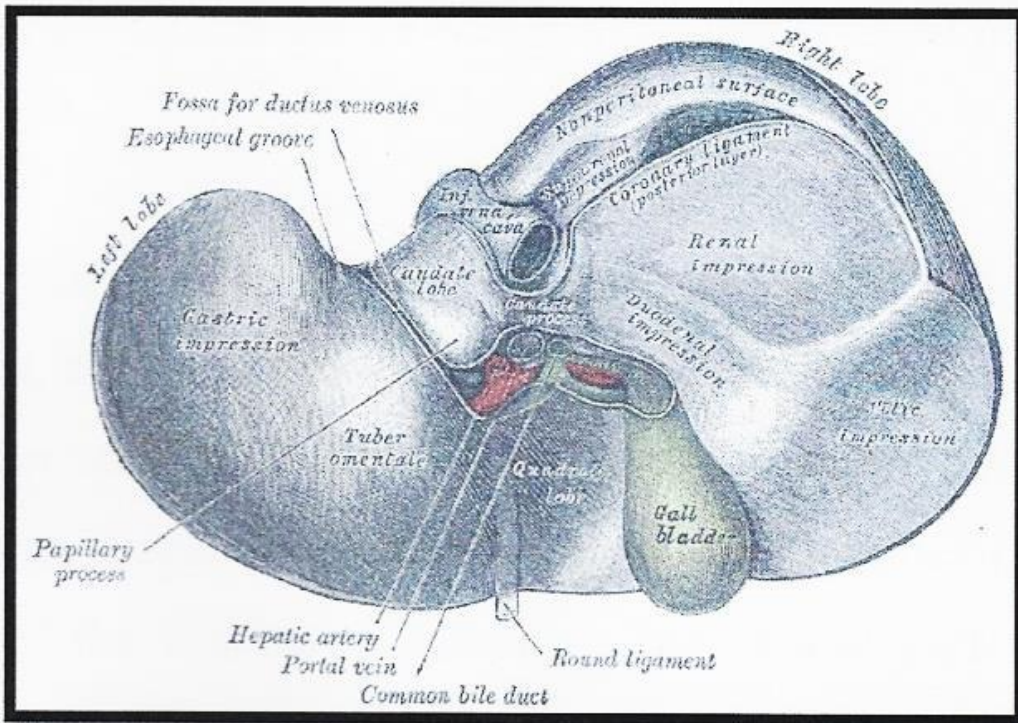


Figure 2.2 shows the inferior surfaces of the human liver. (Benjamin 2012).

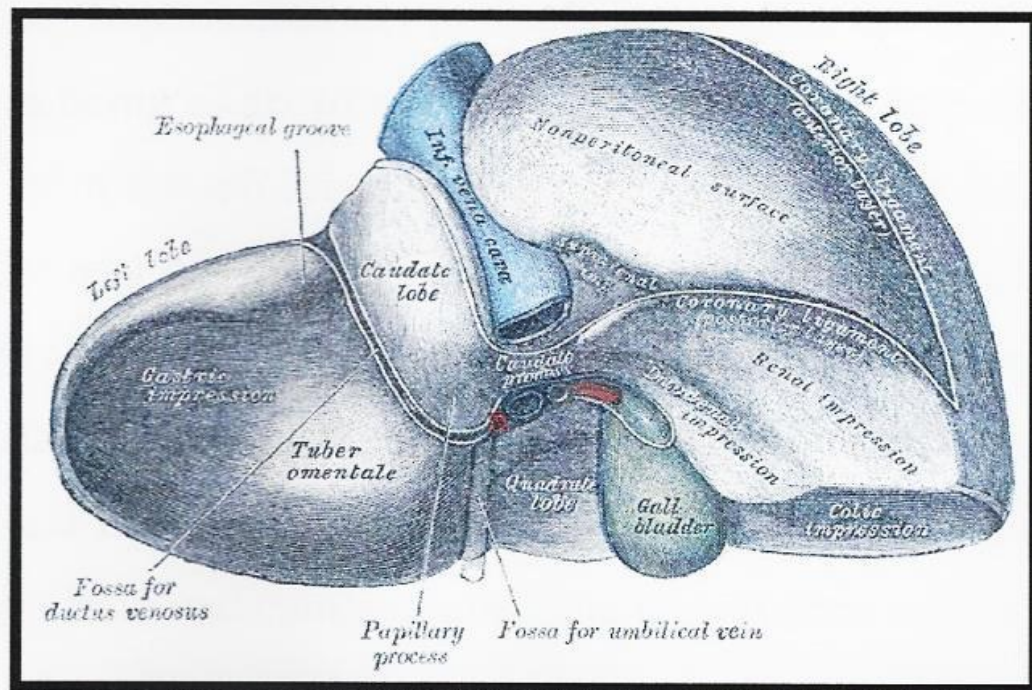


Figure 2.3 shows the posterior and inferior surfaces of the human liver. (Benjamin 2012).

The posterior surface (facies posterior) (Fig2.4) is rounded and broad behind the right lobe, but narrow on the left. (Richard -2005)

Not covered by peritoneum; this uncovered portion is about 7.5 cm. Broad at its widest part, and is in direct contact with the diaphragm it is marked off from the upper surface by the line of reflection of the upper layer of the coronary ligament, and from the under surface by the line of reflection of the lower layer of the coronary ligament. The central part of the posterior surface presents a deep concavity which is moulded on the vertebral column and crura of the diaphragm. (Richard -2005)

2.1.2 Lobes:

The right lobe (hepatic Dexter) is much larger than the left; the proportion between them being as six to one .It occupies the right hypochondrium, and is separated from the left lobes on its upper surface by the falciform ligament ; on its under and posterior surface by the left sagittal fossa ; and in front by the umbilical notch. It is of somewhat quadrilateral form, it's under and posterior surface being marked by three fossa; the portal and fossa for the gallbladder and inferior vena cava, which separate its left part into smaller lobes; the quadrate and caudate lobe. The impressions on the right lobe have already been described. (Richard -2005)

The quadrate lobe (lobe quadrate) is situated on the under surface of the right lobe. Bounded in front by the anterior margin of the liver; behind by the portal; on the right. By the fossa for the gallbladder, and on the left; by the fossa for the umbilical vein. It is oblong in shape, its antero-posterior diameter being greater than its transverse. (Richard -2005)

The caudate lobe (lobe caudate, spieling lobes) is situated upon the posterior surface of the right lobe of the liver, opposite the tenth and eleventh thoracic vertebra. It is bounded, below by the portal; on the right, by the fossa for the

inferior vena cava, and on the left, by the fossa for the duct venous. It looks backward, being nearly vertical in position; it is longer from above downward than side to side, and is somewhat concave in the transverse direction. The caudate process is small elevation of hepatic substance extending obliquely lateral ward, from the lower extremity of the caudate lobe to the under surface of the right lobe. It is situated behind the portal, and separates the fossa for the gallbladder from the commencement of the fossa for the inferior vena cava. (Richard -2005)

The left lobe is smaller and more flattened than the right it is situated in the epigastria and left hypochondria region. Its upper surface is slightly convex and is moulded on to the diaphragm; its under surface presents the gastric impression and omental tubercle. The liver is connected to the under surface of the diaphragm and to the anterior wall of the abdomen by five ligaments; four of these are the falciform, the coronary, and the two lateral venous are peritoneal folds; the fifth, the round ligament, is fibrous cord, the obliterated umbilical vein. (Richard -2005)

The liver is also attached to the lesser curvature of the stomach by the hypogastric and to the duodenum by the hepatoduodenal ligament. (Richard -2005)

2.1.3 Vessel and nerves:

The vessels connected with the liver are: the hepatic artery, the portal vein, accompanied by numerous nerves, ascends to the portal between the layers of the lesser omentum. The bile duct and the lymphatic vessels descend from the portal between the layers of the same omentum. (Richard -2005)

The relative position of the three structures is as follows: the bile duct lies to the right, the hepatic artery to the left, and the portal vein behind and between the other two. They are enveloped in loose areolar tissue, the fibrous capsule of Glisson. Which accompanies the vessels in their course through the portal canals in the interior of the angle. The hepatic veins convey the blood from the liver. They have very little

cellular investment and what there is binds their parietes closely to the wall of the canal through which they run; so that, on section of the organ, they remain widely open and are solitary, and may be easily distinguished from the branches of the portal vein, which are more or less collapsed, and always accompanied by artery and duct. The nerves of the liver are derived from the left vagus and sympathetic, which enter at the portal and accompany the vessels and duct to inter lobber spaces. Here, according to Korolokow, the modulated fibers are distributed almost exclusively to the coats of the blood vessels ; while the non-modulated enter the lobe and ramify between the cells and even within them (as shown in Fig2.4) (Richard -2005).

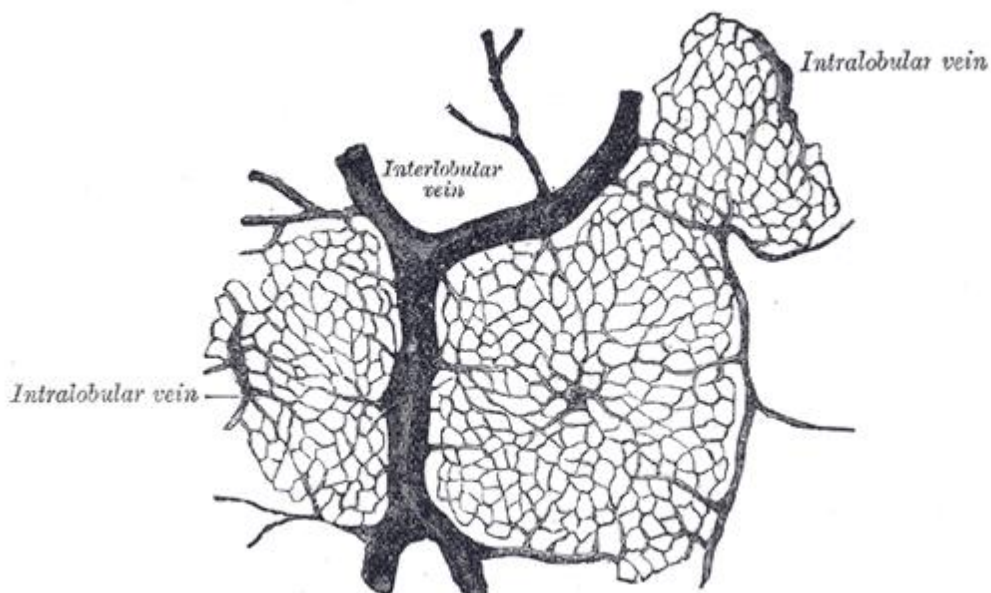


Figure2.4 Shows Section of the human liver vessels.

(Benjamin 2012).

2.1.4 Surgical lobe of liver:

The continued classification of liver anatomy divides the liver into eight functionally independent segments. Each segment has its own vascular inflow, outflow and biliary drainage. In the centre of each segment there is a branch of the

portal vein, hepatic artery and bile duct. In the periphery of each segment there is vascular outflow through the hepatic veins. (Richard -2005).

Right hepatic vein divides the right lobe into anterior and posterior segments. Middle hepatic vein divides the liver into right and left lobes (or right and left hemiliver). This plane runs from the inferior vena cava to the gallbladder fossa. Left hepatic vein divides the left lobe into a medial and lateral part. (Richard - 2005)

Portal vein divides the liver into upper and lower segments. The left and right portal veins branch superiorly and inferiorly to project into the center of each segment. (Richard -2005)

2.1.5 Liver Segments:

There are eight liver segments, primarily the division according to the portal and hepatic veins distribution. The numbering of the segments is in a clockwise manner. Segment 1 (caudate lobe) is located posteriorly. It is not visible on a frontal view. Segment 2-4 are donated to the left hepatic lobe, which lie left to the middle hepatic vein. Segment 4 is sometimes divided into segment 4a and 4b according to Bismuth. Segments 5-8 are donated to the right lobe, which lie right to the middle hepatic vein where segment 5 is the anterior inferior segment and segment 8 is the anterior superior segment (Richard -2005).

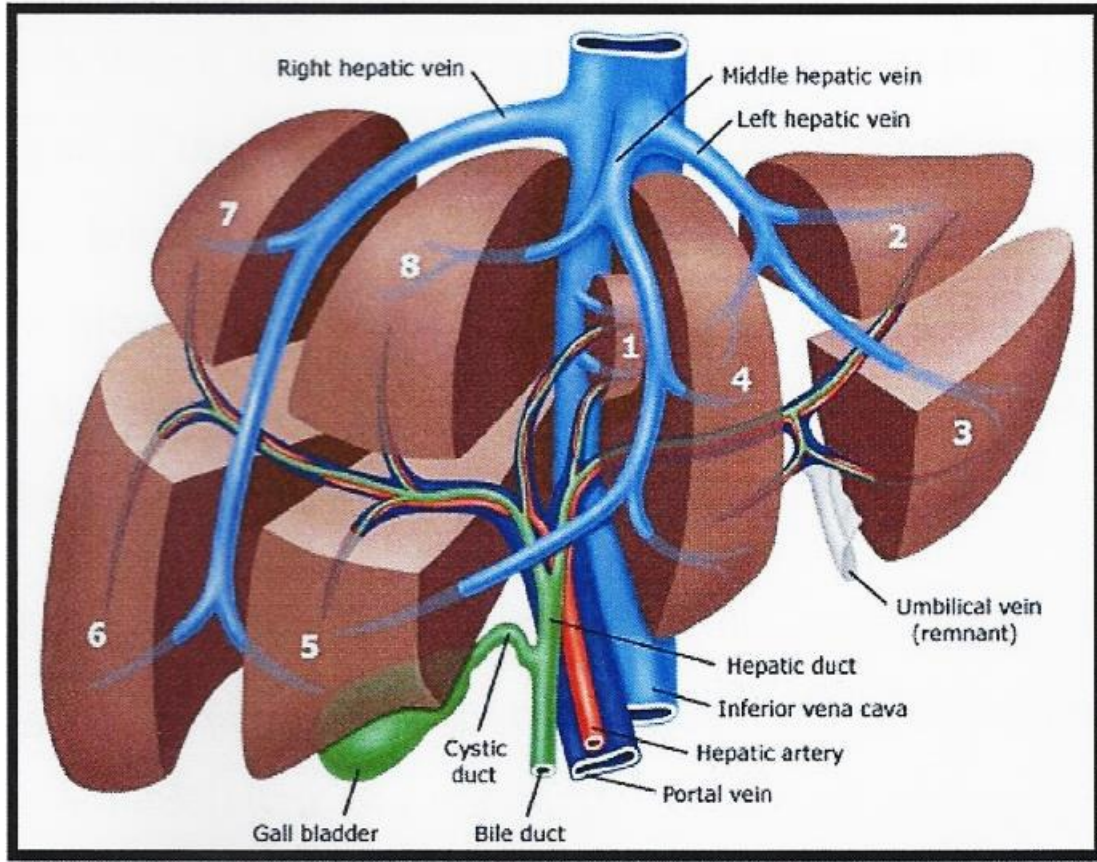


Figure 2.5 Shows Segmental anatomy of the liver.

(Mentha-2002)

2.1.6 Structure of the liver:

The substance of the liver is composed of lobules, held together by an extremely fine areolar tissue, in which ramify the portal vein, hepatic artery, hepatic vein, lymphatic's and nerve ; the whole being invested by serious and fibrous coat . The serious coat (tunica serosa) is derived from the protenium and invested the greater part of the surface of the organ. It is intimately an adherent to the fibrous coat. (Richard -2005)

In the human subject their outlines are very irregular; but in some of the lower animals (for example, the pig) they are well-defined, and, when divided transversely, have polygonal outlines. (Richard -2005)

The bases of the lobules are clustered around the smallest radicles (sublobular) of the hepatic veins, to which each is connect by means of a small branch which issues from the center of the lobule (intralobular).the remaining part of the surface of each lobule is imperfectly isolated from the surrounding lobules by a thin stratum of areolar tissue, in which is contained a plexus of vessels, the interlobular plexus, and ducts. In some animals, as the pig, the lobules are completely isolated from one another by the interlobular areolar tissue. (Richard -2005).

If one of the sublobular veins be laid open, the bases of the lobules may be seen through the thin wall of the vein on which they rest, arranged in a form resembling a tessellated pavement, the centre of each polygonal space presenting a minute aperture, the mouth of an intralobular vein microscopic appearance. Each lobule consists of a mass of cells, hepatic cells, arranged. (Richard -2005)

In irregular radiating columns between which are the blood channels (sinusoid). These convey the blood from the circumference to the centre of the lobule, and end in the intralobular vein, which runs through its centre, to open at its base into one of the sublobular veins. (Richard -2005).

Between the cells are also the minute bile capillaries. therefore, in the lobule there are all the essentials of a secreting gland; that is to say; (1) cells, by which the secretion is formed; (2) blood vessels, in close relation with the cells, containing the blood from which the secretion is derived; (3) ducts, by which the secretion, when formed, is carried away the hepatic cells are polyhedral in form. They vary in size from 12 to 25 inch in diameter. (Richard -2005).

They contain one or sometimes two distinct nuclei. The nucleus exhibits an intranuclear network and one or two refractive nucleoli. The cells usually contain granules; some of which are protoplasmic, while others consist of glycogen, fat, or an iron compound. In the lower vertebrates, e.g., frog, the cells are arranged in tubes with the bile duct forming the lumen and blood vessels externally. According

to delepine, evidences of this arrangement can be found in the human liver. (Richard -2005).

The blood in the capillary plexus around the liver cells is brought to the liver principally by the portal vein, but also to a certain extent by the hepatic artery. The hepatic artery, entering the liver at the portal with the portal vein and hepatic duct, ramifies with these vessels through the portal canals. It gives off vaginal branches, which ramify in the fibrous capsule of glisson, and appear to be destined chiefly for the nutrition of the coats of the vessels and ducts. It also gives off capsular branches, which reach the surface of the organ, ending in its fibrous coat in stellate plexuses. Finally, it gives off interlobular branches, which form a plexus outside each lobule, to supply the walls of the interlobular veins and the accompanying bile ducts. From this plexus lobular branches enter the lobule and end in the network of sinusoids between the cells (Richard -2005).

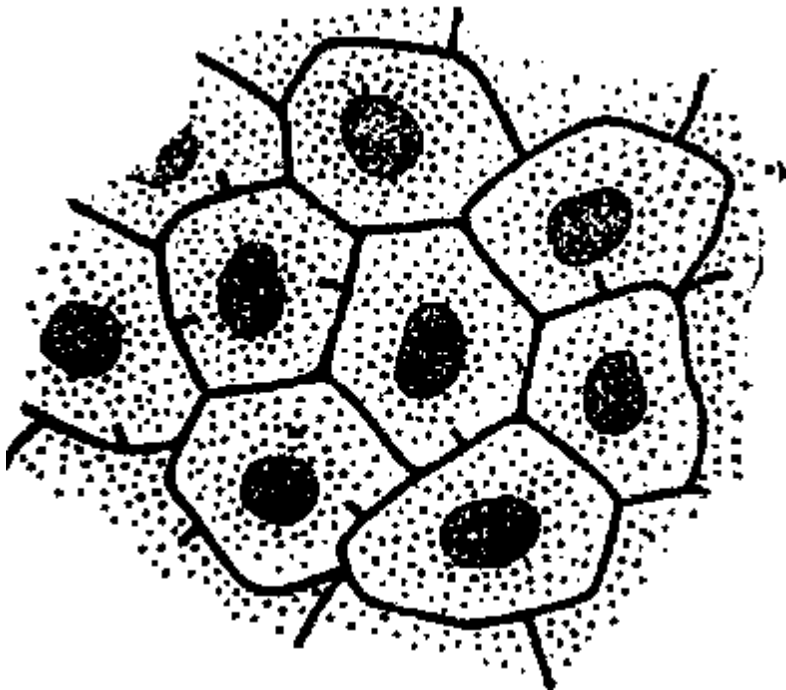


Figure2.6: Shows the bile capillaries in the Hepatocytes. (Benjamin -2012).

2.2 liver physiology

The various functions of the liver are carried out by the liver cells or hepatocytes. The liver is thought to be responsible for up to 500 separate functions, usually in combination with other systems and organs. Currently, there is no artificial organ or device capable of reproducing all the functions of the liver. Some functions can be carried out by liver dialysis, an experimental treatment for liver failure. (Benjamin -2008). The liver synthesizes and stores approximately 100g of glycogen via glycogenesis, the formation of glycogen from glucose. When needed, the liver releases glucose into the blood by performing glycogenolysis, the breakdown of glycogen into glucose. (Benjamin -2008). The liver is also responsible for gluconeogenesis, which is the synthesis of glucose from certain amino acids, lactate or glycerol. Adipose and liver cells produce glycerol by breakdown of fat, which the liver uses for gluconeogenesis. The liver plays a role in the production of clotting factors as well as red blood cell production. Some of the proteins synthesized by the liver include coagulation factors I (fibrinogen), II (prothrombin), protein S and antithrombin. In the first trimester fetus, the liver is the main site of red blood cell production. By the 32nd week of gestation, the bone marrow has almost completely taken over that task. The liver is a major site of production for thrombopoietin, a glycoprotein hormone that regulates the production of platelets by the bone marrow. (Benjamin- 2008). The liver plays several roles in lipid metabolism: it performs cholesterol synthesis; lipogenesis, the production of triglycerides, and a bulk of the body's lipoproteins are synthesized in the liver. (Jelkmann-2001)

The liver plays a key role in digestion, as it produces and excretes bile (a yellowish liquid) required for emulsifying fats and helps the absorption of vitamin K from the diet. Some of the bile drains directly into the duodenum, and some is stored in the gallbladder. (Jelkmann-2001)

The liver also produces insulin-like growth factor 1 (IGF-1), a polypeptide protein hormone that plays an important role in childhood growth and continues to have anabolic effects in adults. (Jelkmann- 2001) The liver is responsible for the breakdown of insulin and other hormones, and breaks down bilirubin via glucuronidation, facilitating its excretion into bile and excretion of many waste products. It plays a key role in breaking down or modifying toxic substances (e.g., methylation) and most medicinal products in a process called drug metabolism. The liver breaks down ammonia into urea as part of the urea cycle, and the urea is excreted in the urine. (Jelkmann-2001) **2.2.1 function of the liver are:** The liver stores a multitude of substances, including glucose (in the form of glycogen), vitamin A (1–2 years supply), vitamin D (1–4 months' supply), vitamin B12 (3–5 years supply), vitamin K, iron, and copper. (Benjamin- 2008). The liver is responsible for immunological effects-the mononuclear phagocyte system of the liver contains many immunologically active cells, acting as a (sieve) for antigens carried to it via the portal system. (Benjamin -2008). The liver produces albumin, the most abundant protein in blood serum. It is essential in the maintenance of oncotic pressure, and acts as a transport for fatty acids and steroid hormones. (Benjamin -2008).

The liver synthesizes angiotensinogen, a hormone that is responsible for raising the blood pressure when activated by rennin, an enzyme that is released when the kidney senses low blood pressure. (Benjamin -2008).

2.4 CT scan

Anatomy of a CT scan

CT scanners give doctors a 3-D view of the body. The images are exquisitely detailed but require a dose of radiation that can be 100 times that of a standard X-ray.

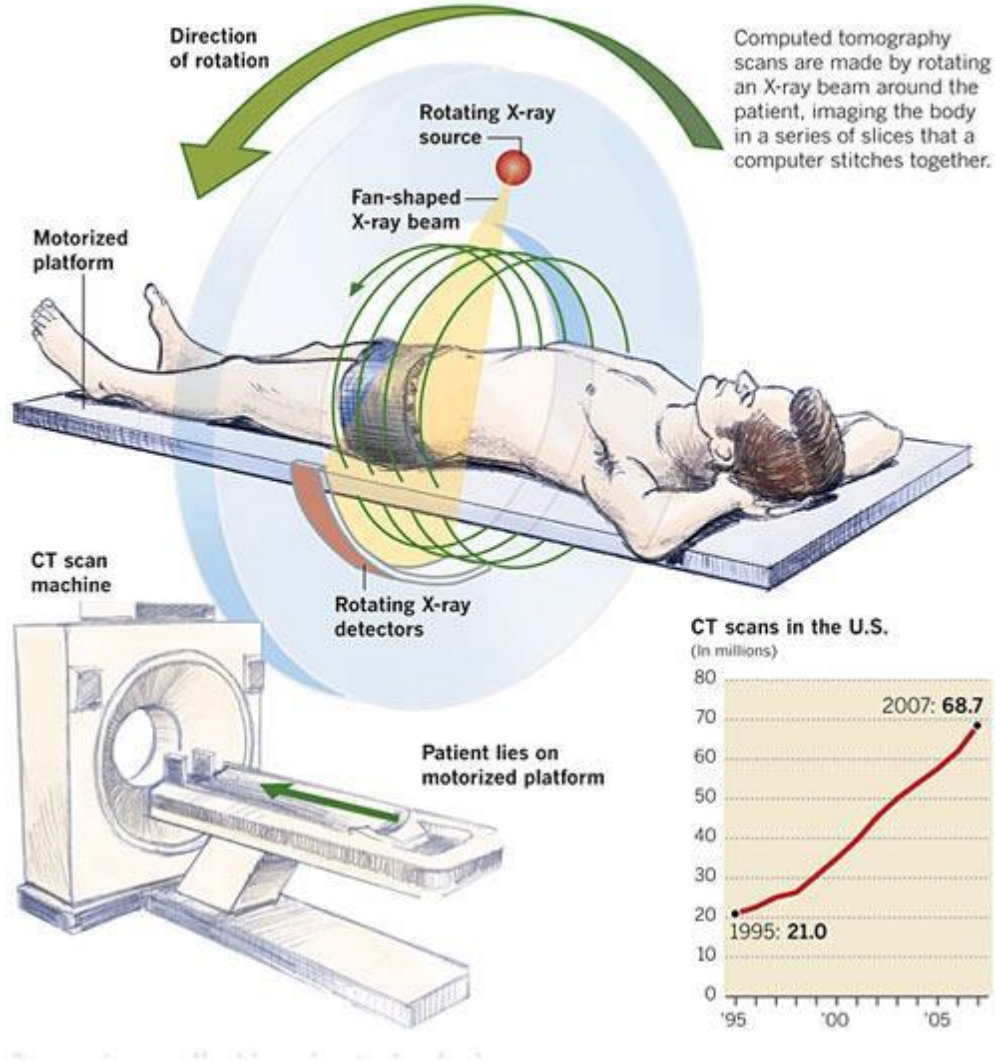


Figure 2.7 Shows anatomy of the computed tomography scan.

Computed Tomographic examination is currently one of the basic techniques of medical diagnosis. The significance of computed tomographic techniques in medicine is clearly demonstrated by the fact that when this type of apparatus in hospital breaks down, doctors will avoid making a definitive diagnosis until an examination can be carried out in center.(Reiser, 2009).

2.4.1 CT-scan component

The CT scanner is composed of two layers:

The computer layer and the physical layer. (Reiser-2009)

The computer layer consist of the operating system responsible for running tomography application, file management, communication with the external devise Whatever the differences in design of the different generation of the scanners, the main elements remain the same: (Reiser- 2009).

The gantry into which patient moved during the examination, the x.ray tube (the source of the x.ray), the detector array (convert the projection values. In the form of the radiation intensities, in to electrical quantities), the table (allow the patient to be guided easily into position).The table can be controlled manually before the actual scan begins, but it moves automatically during the scan (Reiser -2009).

A CT scanner also contains the following components:-

A data acquisition system that carries out the x-ray projection, a computer to reconstruct the images from the projection and to assist in the analysis of the reconstructed image, a variable power supply.

A monitor to display the routine operation of the computer system and to act as an interactive interface in the diagnosis of the reconstructed images, a documentation camera to produce an image on film similar to traditional x.ray images, Storage device (data archiving system) such as tape or disk. 7, other elements. (Reiser-2009)

2.4.2 The scanner:

Contains a number of sub-systems that drive and control the device enable precise positioning of the patient during the scan as well as facilitate communication with the patient (Buzug- 2008).

The design if each of the CT scanner generation contains one of the three basic tubes - detector projection system:-

Projection system uses a parallel beam of radiation (parallel - beam system), a system using a beam of radiation in shape of fans (a fan - beam system), system using a beam of radiation in shape of cones (a cone - beam system). (Buzug -2008)

2.4.3 CT - scan generation

2.4.3.1 First generation scanner:

Pencil beam or translation/rotation single detector scanner use a parallel —beam projection system in this type of scanner, there are two movement of the rigidly coupled tube detector system:

A lateral movement to take a single projection 2. A circular movement about the central opening in the gantry to gather all the projections necessary to reconstruct image. (Buzug- 2008)

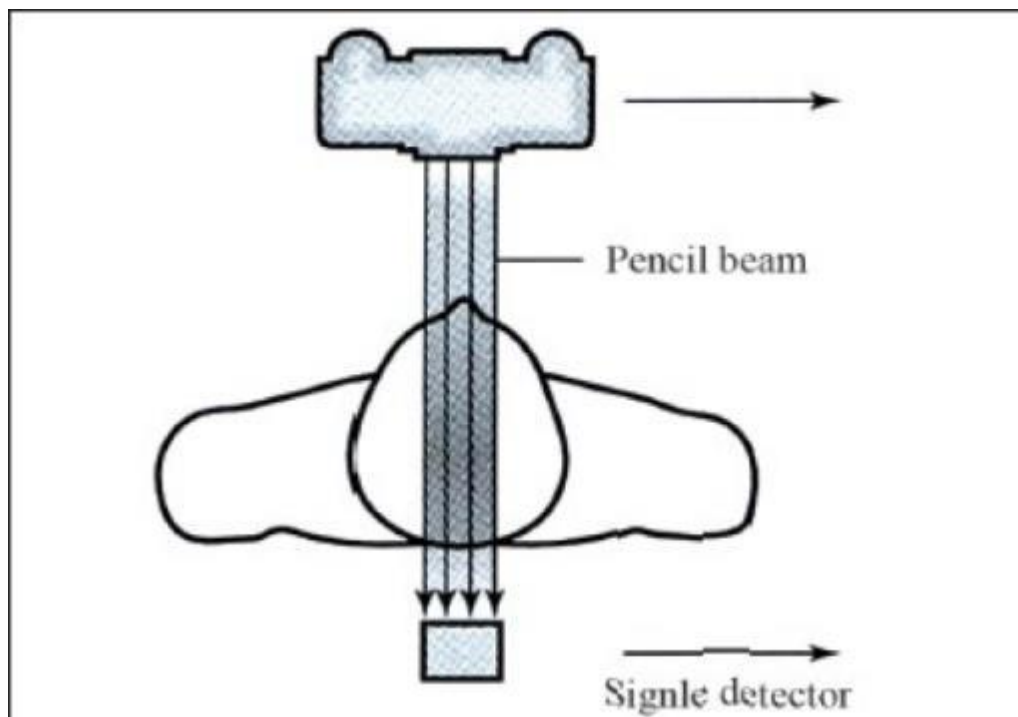


Figure 2.8 shows the first generation CT scan.

(Buzug- 2008)

The acquisition of the individual projections can be discrete, but each of these projections is obtained only at a discrete angle of rotation of the projection system.

This method of scanning is not fast enough. Both the single detector and the x-ray tube most travel a distance equal twice the diameter of the gantry opening during each projection. (Buzug - 2008)

2.4.3.2 Second generation scanners:

These second generation scanners, sometimes called partial fan beam, The use of the fan shaped radiation beam enabled the projections to cover a larger area of the patient's body at any one time and resulted in the reduction of the number of projections needed to reconstruct and image of satisfactory quality. (Buzug-2008)

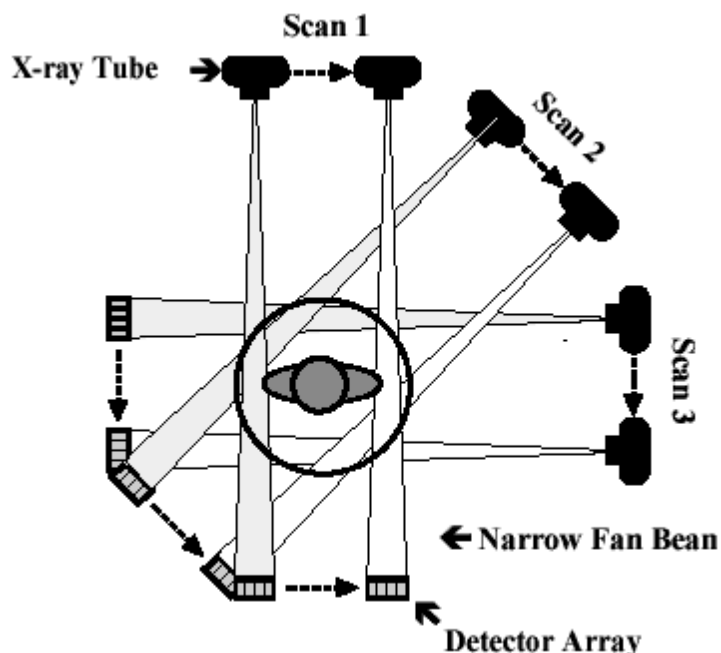


Figure 2.9 shows the second generation CT-scan.

(Buzug- 2008)

2.4.3.3 Third-generation scanners:

A projection system with a beam of radiation in the shape of a fan with an angular spread of between 40 and 55degrees, enough to encompass the whole of the test object -number of detector increased hence the time to acquire a reconstructed image was reduced to about 5s. (Buzug - 2008)

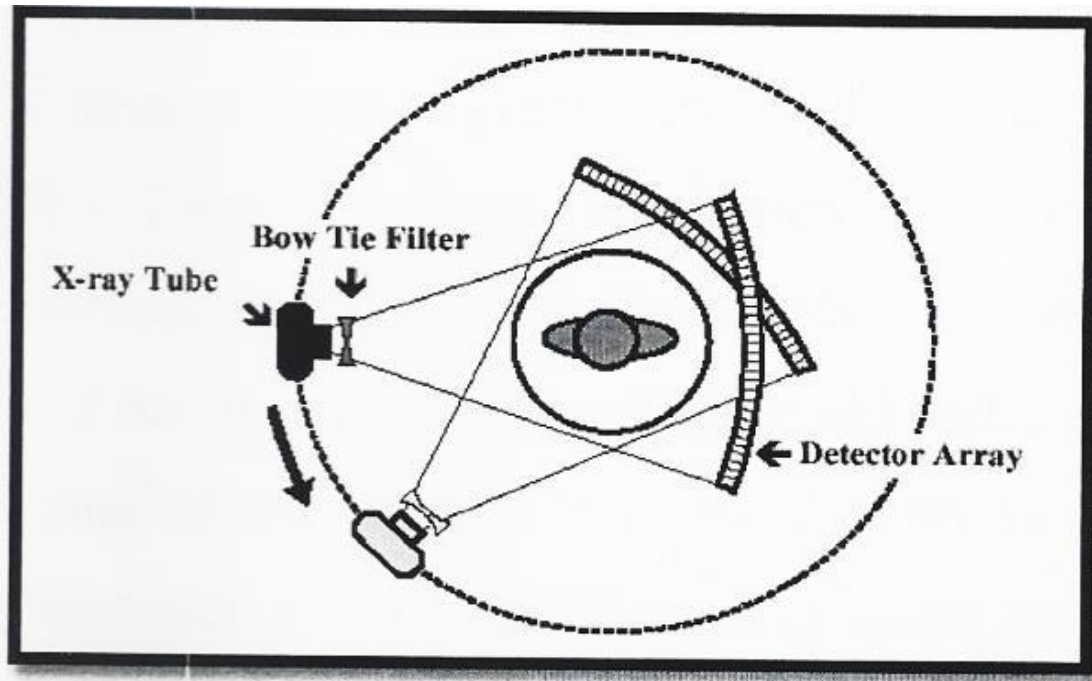


Figure 2.10 shows the third generation CT scan.

(Buzug-2008)

2.4.3.4 Fourth-generation scanners:

Rotate-fixed scanner. (Buzug-2008)

2.4.3.5 Spiral scanners:

The projection system moved in a spiral around the patient, In the initial phases of the development of spiral tomography, the scanners used a detector array in shape of an arc of a circle (single - slice spiral computed tomography scanner or (SSCT), In 1998 the multi-slice spiral computed tomography scanner (MSCT) in this type the detector array was made up of between 8 and 34 rows of detectors, making it possible for this design of scanner to obtain four adjacent slices .now ideit MDCT machines contains up to 640 detectors in a row, The beam now took the shape of a cone the first cone- beam spiral CT scanners (CBCT) were put into operation in the years (2001-2002). (Buzug- 2008)

2.5 Hounsfield unit (HU) scale:

Hounsfield unit (HU) scale is a linear transformation of the original linear attenuation coefficient measurement in one in which the radiodensity of distilled water at standard pressure and temperature (STP) is defined as zero Hounsfield units (HU), while the radiodensity of air at STP is defined as -1000HU.(Cierniak-2011).

For a material X with linear attenuation coefficient μ_X , the corresponding HU value is therefore given by $HU = \frac{\mu_X - \mu_{air}}{\mu_{water} - \mu_{air}} \times 1000$ where μ_{water} is the linear attenuation coefficient of water. Tissues can be characterized on CT by their Hounsfield Units or H.U. Each tissue has its own range of densities measured in Hounsfield units, and the scan can be manipulated by altering the window level and / or width of densities viewed to give more information (the CT machine can capture more dynamic range than can be displayed in gray scale and perceived by the human eye). (Cierniak-2011)

The liver parenchyma is normally homogeneous. Typically, the liver's attenuation is 54-60 Hounsfield units (HU), usually 8-10 HU greater than the spleen. Thus, the liver will appear hyperdense to (brighter than) the spleen. If the density of the liver on CT is less (darker) than that of the spleen, fatty change is most likely cause. (Cierniak-2011)

2.5 Normal CT images

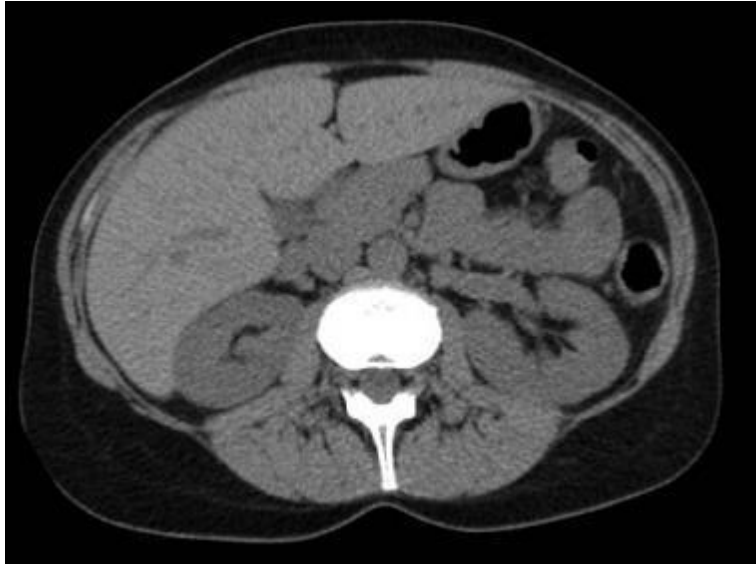


Figure 2.11 Shows Axial of normal CT Abdomen pre contrast (Benjamin-2012)

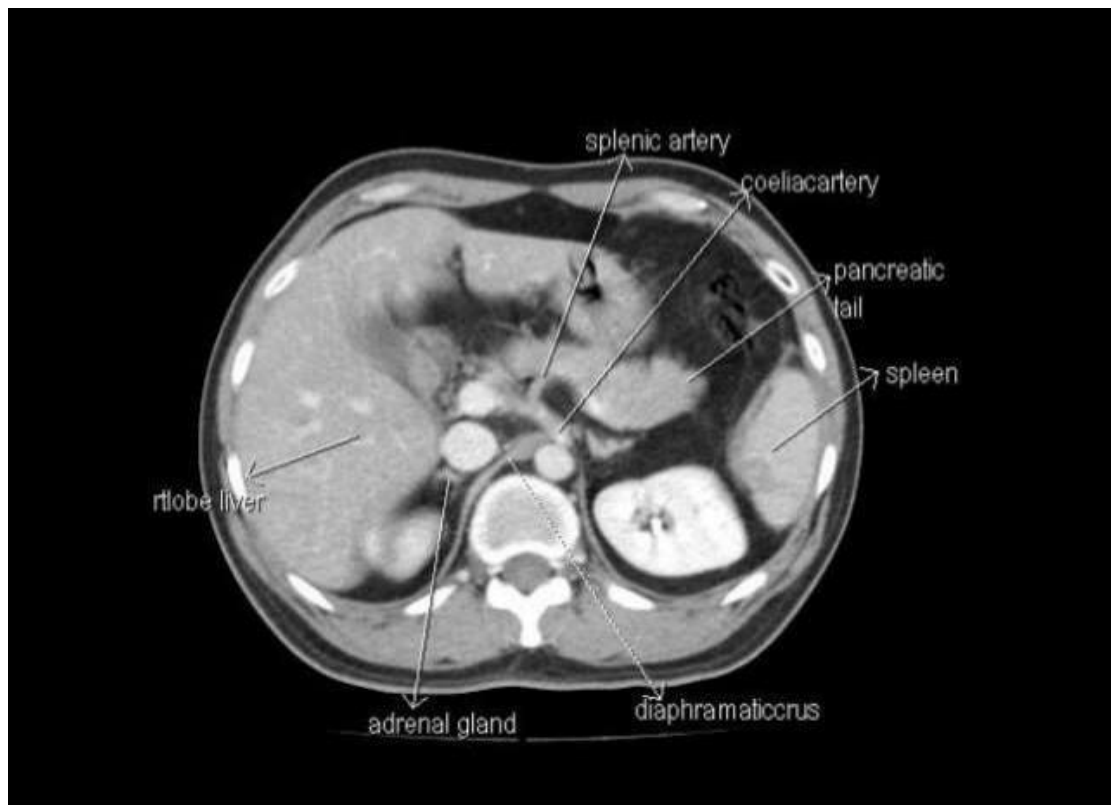


Figure 2.12 Shows Axial of normal CT Abdomen in portal phase. (Benjamin-2012)

2.6 previous study

Twenty patients in California, United States were examined with CT of the liver before, during, and 4 to 6 hours after i.v. administration of iodine (200 ml iohexol). The attenuation of normal liver parenchyma was measured. The mean attenuation of normal liver parenchyma on nonenhanced scanning was 62.6 HU and on delayed scanning 78.7 HU. It seems that iohexol is a suitable contrast medium for delayed scanning of the liver. (Ostra-2005)

Normal liver attenuation in Sweden, precontrast, is similar to spleen, but often slightly greater (+10 HU) - reported to be about 55 to 63 HU. (Ostra-2005)

Homogeneous increased attenuation (density) of the liver may result from a variety of causes to include drug toxicity. Hemochromatosis, hemosiderosis and cirrhosis may all result in increased density of the liver. Pharmaceuticals which have been implicated include thiorast, thallium, gold, and amiodarone. (Kojima2009)

Chapter Three

Materials and Method

3.1 Material

This is descriptive analytical cross sectional hospital-based study, the study was done in Khartoum state, at ASIA Specialized Hospital (Kh) and ALSAHA Specialized Hospital, the study was conducted in period from AUG to NOV 2018.

3.1.1 Patients:

A total of 50 patients were included chosen by convince sampling Inclusion criteria patient with normal liver scan, Exclusion criteria patient with normal liver but have abnormal biliary tree. Patients referred to ASIA specialized hospital, ALSAHA specialized hospital for CT abdomen.

3.1.2 Machine used:

Multi detectors computed tomography with automatic injector for contrast media

3.1.3 Variable under study:

Gender, age, liver CT number.

3.2 Method:

3.2.1 Technique used:

The entire liver will be scanned successively.

A 5mm collimation and 5mm/sec table speed will be used. All scans will be taken in the craniocudal direction and during single breath hold. After obtaining a digital scout view, unenhanced scan of the liver obtained. 100-200 ml of 65% iodinated contrast material will be given by using power injector at a rate of 1.5 to 2ml/sec. after 22 or 27 seconds, the entire liver will be scanned in arterial phase 22 seconds after the end of arterial phase, the liver will be scanned in portal venous phase. The 20 seconds interscan delay is for the patient to rebreath and reposition the scan plane cephaled to the liver. After these two phases the third scan will be taken in

the equilibrium phase, 8-10minutes after injection of contrast the images acquired in different phases.

3.2.2 Data collection tools and technique

A designed data sheet was used to collect data from patients refer to CT abdomen according to the image contain slice thickness (7mm) and slice gap (7- 10mm) .Three reading will be taken from three point in axial cuts .

3.2.3 Data Analysis:

Data was collected cleaned and sorted. This was analyzed using Statistical Package of Social Sciences (SPSS), computer statistical analysis software .Charts were done by Microsoft office excel 2007. Data was presented in form of The mean and standard deviation were presented student T-test and correlation with an oc-level of 0,5 were considered to test for significance.

3.2.4 Ethical Consideration:

Ethical clearance and approval for conducting this research was obtained from the Sudan University of sciences and Technology. Permission and verbal consent are obtain from the affiliated medical hospital in which the research was conducted

Chapter four

Results

Table (4.1) frequency distribution of gender

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	34	68.0	68.0	68.0
Female	16	32.0	32.0	100.0
Total	50	100.0	100.0	

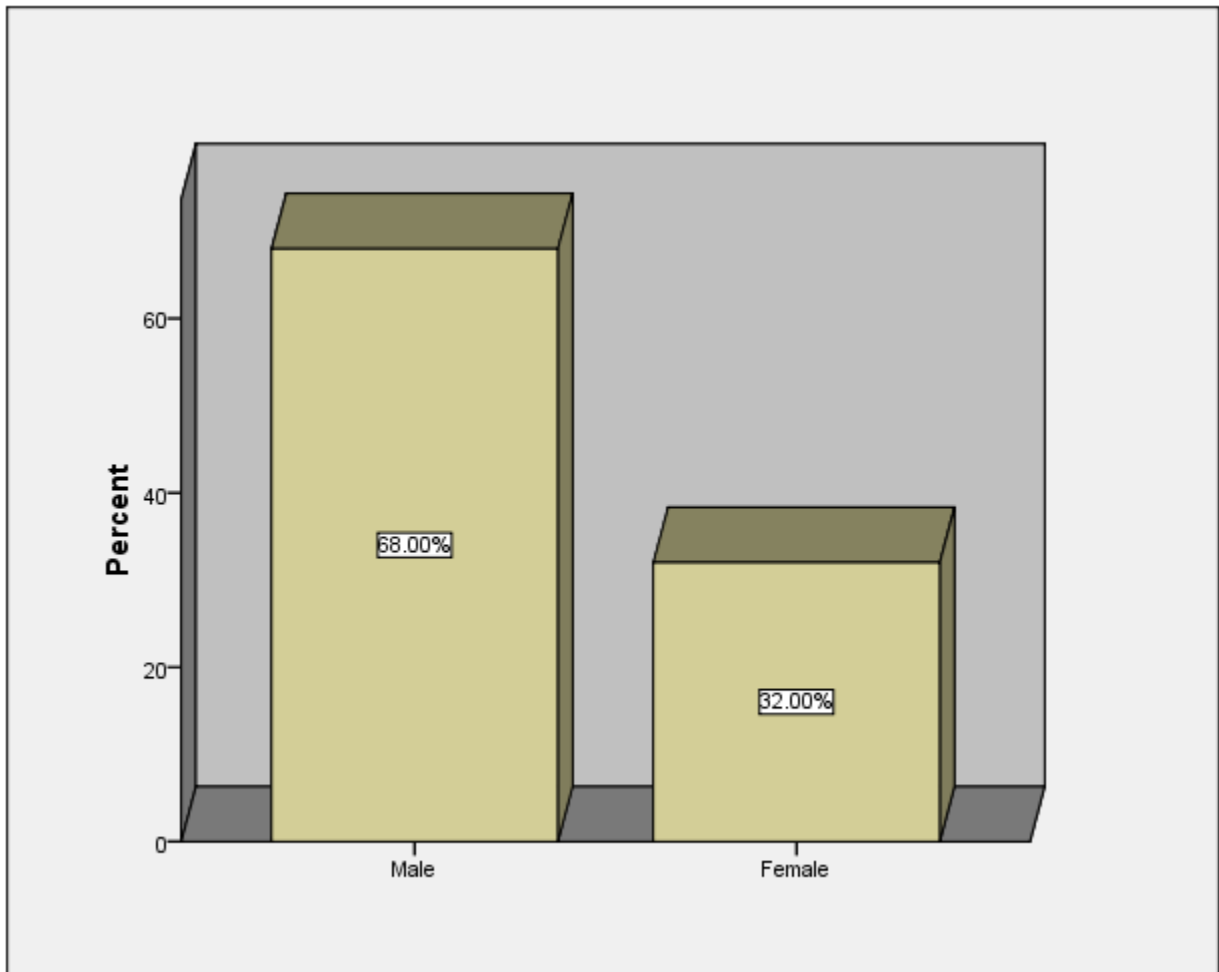


Figure (4.13) frequency distribution of gender

Table (4.2) frequency distribution of age\years

Age \years	Frequency	Percent	Valid Percent	Cumulative Percent
22-32	16	32.0	32.0	32.0
33-43	19	38.0	38.0	70.0
44-54	11	22.0	22.0	92.0
55-66	4	8.0	8.0	100.0
Total	50	100.0	100.0	

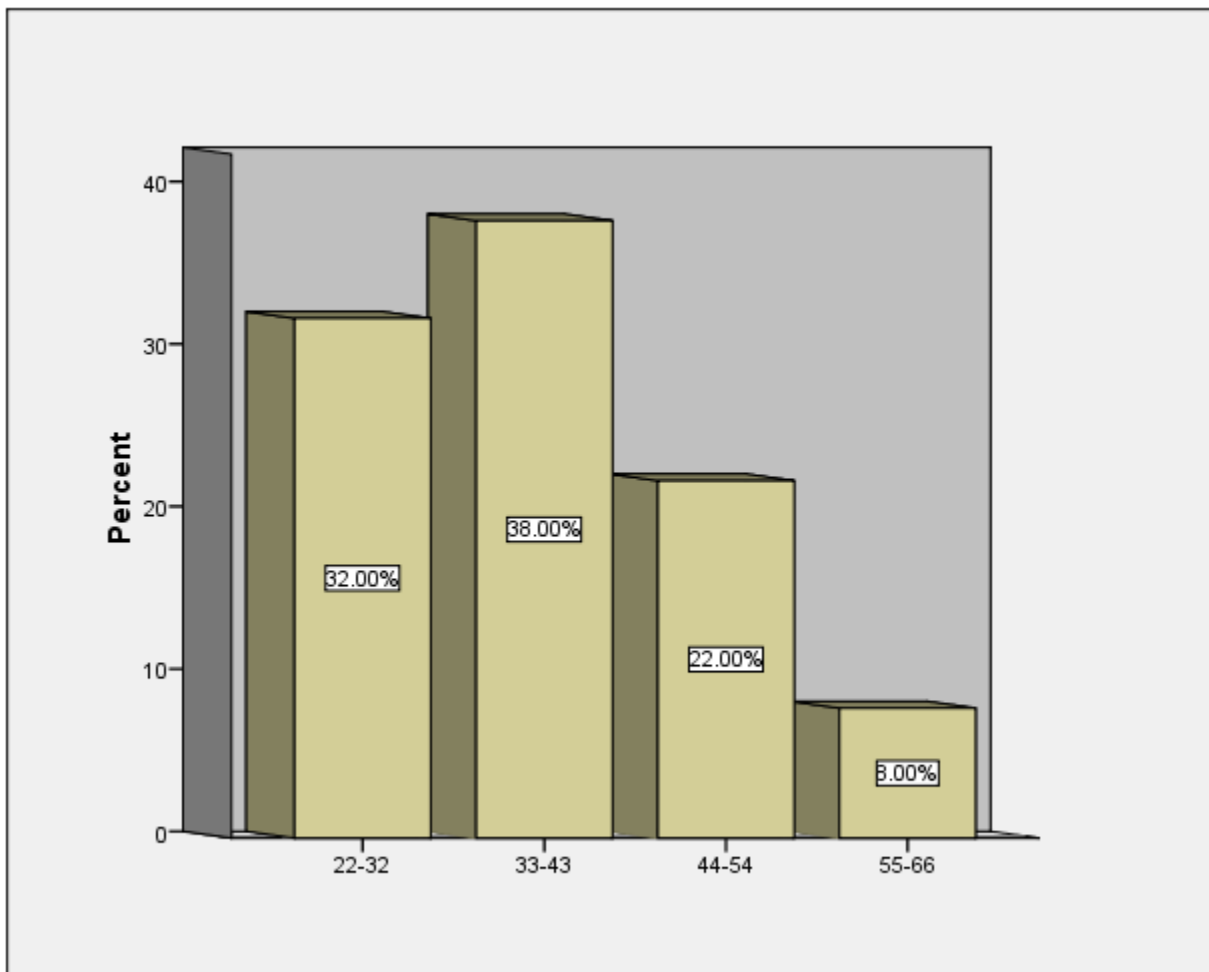


Figure (4.14) frequency distribution of age\years

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Age	50	22	66	39.76	10.905
Liver HU	50	39	84	56.90	8.876
Vertebrae HU	50	203	429	290.26	57.066
Valid N (listwise)	50				

Table (4.3) descriptive statistic for age, liver HU and vertebrae HU (minimum ,maximum , mean±Std. Deviation)

Table

(4.4)

Age \ years		Vertebrae HU	Liver HU
22-32	Mean	297.44	56.06
	N	16	16
	Std. Deviation	53.511	10.382
33-43	Mean	291.53	57.42
	N	19	19
	Std. Deviation	60.985	9.305
44-54	Mean	286.82	56.45
	N	11	11
	Std. Deviation	58.254	6.283
55-66	Mean	265.00	59.00
	N	4	4
	Std. Deviation	63.770	9.201
Total	Mean	290.26	56.90
	N	50	50
	Std. Deviation	57.066	8.876
P value		0.791	0.932

compare mean liver HU and vertebrae HU in different age group

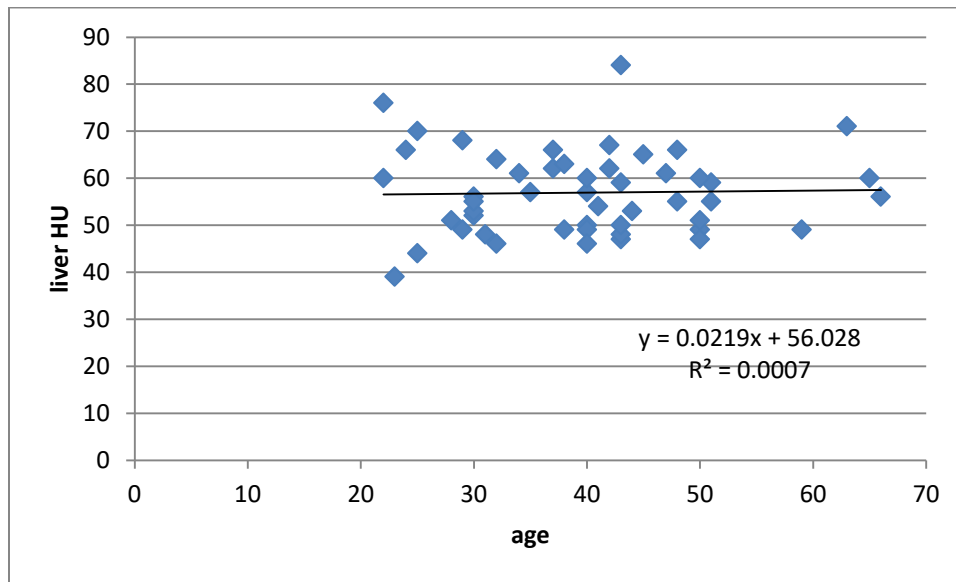


Figure (4.15) scatterplot shows relationship between age and liver HU

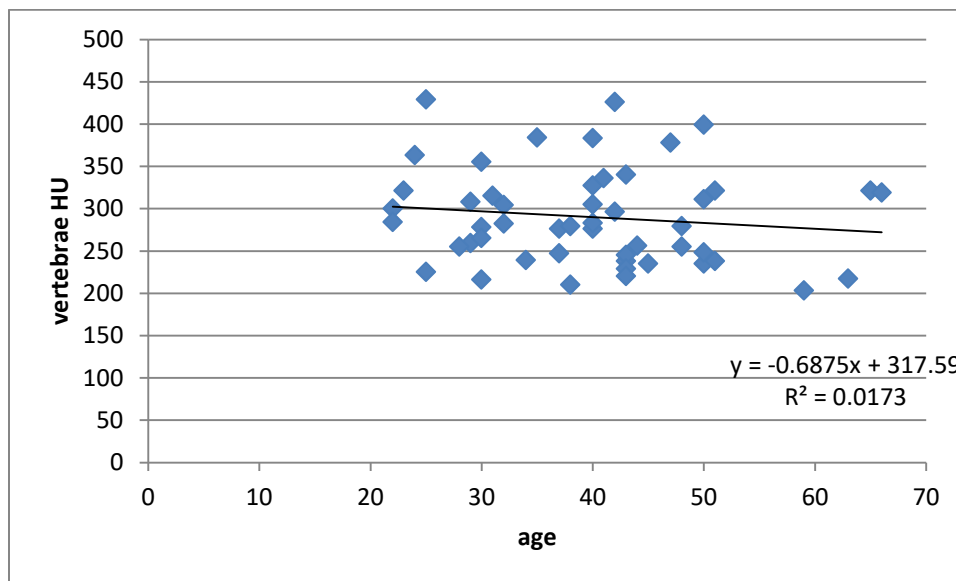


Figure (4.16) scatterplot shows relationship between age and vertebrae HU

Table (4.5) a. Compare means liver HU and vertebrae HU in different gender

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Vertebrae HU	Male	34	281.82	49.402	8.472
	Female	16	308.19	69.027	17.257
Liver HU	Male	34	57.24	7.989	1.370
	Female	16	56.19	10.778	2.694

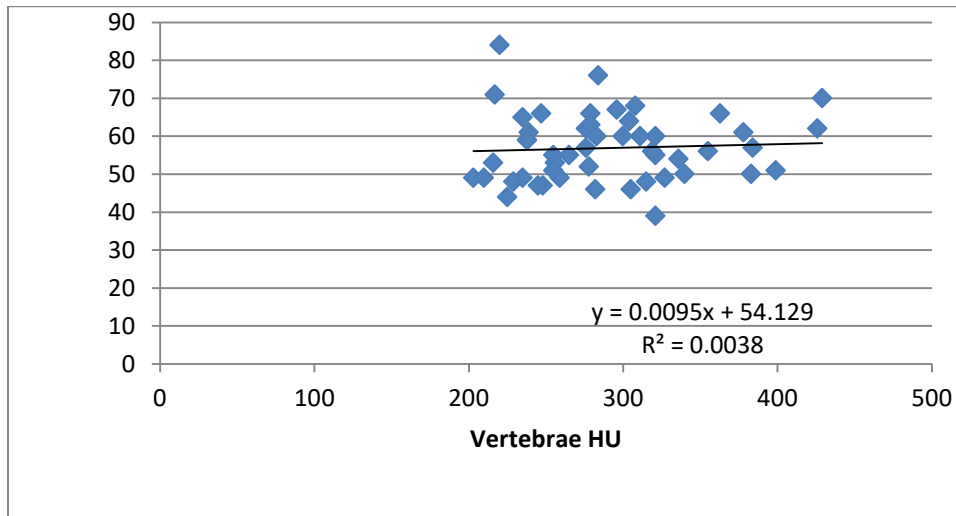


Figure (4.17) scatterplot shows relationship between vertebrae HU and liver HU

Table (4.6) b.Independent sample t-test for compare means liver HU and vertebrae HU in different gender

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Vertebrae HU	-1.545-	48	.129	-26.364-	17.061	-60.667-	7.939
	-1.371-	22.508	.184	-26.364-	19.224	-66.181-	13.453
Liver HU	.386	48	.701	1.048	2.715	-4.410-	6.506

Chapter five

Discussion conclusion and recommendations

Discussion:

A total of 50 patients were included, of which 34 were male (68%) and 16 were female (32%).

The mean age was found to be 39.76 ± 10.9 , with minimum 32 year and maximum 66 year. The mean liver HU was found to be $56.90 \text{ HU} \pm 8.87$

The P value of the total liver HU in the age groups was found to be 0.932 .

The mean liver CT number among the male was found to be $57.24 \pm 7.98 \text{ HU}$ and that among female was 56.19 ± 10.77 the mean difference was found to be 1.05 which was statically insignificant with a P value 0.932 this showing that gender does not affect the liver CT number, due to the organ not being related to gender .

When the patient age was correlated to the liver CT number value, the relationship was found to be weak positive relationship with correlation coefficient of $r=0.027$. this relationship was found to be statically significant with a P value of 0.932 .

Liver CT number $56.90 \pm 8.87 \text{ HU}$ their findings were found to be lower than the mean CT number of previous study done by Mohamed Ahmed et al 2016(Sudan) which was $58.66-60.29 \pm 15.39$.

Liver CT number $56.90 \pm 8.87 \text{ HU}$ findings were found to be lower than non-enhanced attenuation for patients in California, United States where attenuation was 62.6 HU.

Comparing with Sweden study of liver attenuation was reported to be 55 to 63 HU our readings were found to be at the same ranges with liver CT number $56.90 \pm 8.87 \text{ HU}$.

Conclusion

The study was descriptive analytical study conducted during the period extended from January 2019 up to march 2019 . CT measurements were performed at ALBUGGA hospital for 50 normal Sudanese subjects. The data were collected prospectively by measuring the liver and lumber vertebrae CT number using CT machine and the data were analyzed using SPSS. The majority of participants were males (68%) and their ages ranged between 22-66.The CT number of liver was found to be 56.90 ± 8.87 HU.

Recommendations

We recommended to increase the data value

Insert the BMI for other studies

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