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Assessment of Morphological Variations and its Specific Location on the Surface of Adult Human Liver in Ethiopian Cadavers University of Gondar, Bahir Dar University, Addis Ababa University, St. Paulos Medical School and Hawassa University, Ethiopia

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ABSTRACT

Background: *Liver is the second largest organ next to skin and located in right hypochondrium, epigastrium and may extend to left hypochondrium in upper abdominal cavity. It accounts 2% to 3% of total body weight of individual. Land marking for interpreting different diagnostic image and localizing lesions in the liver is commonly done by major fissures. Sound knowledge about different morphological variations which are found on the surface of liver is mandatory to have safe surgical outcome. Segments of liver were extensively researched but there are only few studies dealt with the surface variation of the liver. Therefore, this study aims to assess morphological variations and its specific location on the surface of adult human liver in Ethiopian cadaver.* ***Methodology:*** *Institutional based cross sectional descriptive study design was conducted in 33 formalin fixed Ethiopian cadaveric livers in the Anatomy department of University of Gondar, Bahir Dar University, Addis Ababa University, St. Paulos Medical School and Hawassa University.* ***Results:*** *45.45% of the liver was normal but 54.55% showed one or more variations. Additional fissures and very small left lobe with deep costal impressions were seen 27.27% and 21.21% cases respectively. Pons hepatis connecting left lobe with quadrate lobe and very deep renal impression with corset constriction were noted in 9.09% cases each. Additional lobes and absence of quadrate lobes were found in 6.06% cases each.* ***Conclusion and Recommendation:*** *Morphological variations on the liver surface were accessory fissure, very small left lobe with deep costal impressions, pons hepatis, shape variation and absence of quadrate lobe. The most common one among the variations was accessory fissure on the visceral and diaphragmatic surface.*

Keywords: Liver, Variation, Lobe, Fissure

INTRODUCTION

From abdominal cavity organs, liver is the largest of all which occupy most portion of upper abdominal space. It accounts approximately 2% to 3% of total body weight for each individual [1,2]. Using peritoneal and ligament attachments to the surface, liver has four lobes which are named as right, left, caudate and quadrate lobes [3]. But based on the physiological classification, liver has eight segments. functional left lobe includes segments I, II, III and IV whereas functional right lobe includes segments V, VI, VII and VIII [4,5].

Liver performs wide range of functions related to digestion, metabolism, immunity, blood detoxification and the storage of nutrients within the body. These functions make the liver a vital organ without which the tissues of the body would quickly die from lack of energy and nutrients [6,7]. Major and minor grooves of the liver play a crucial role in hepatectomy as they are significant in localization of the tumour, marking the resection margins in hepatectomy, the anatomic evaluation and for the better surgical understanding of the liver [2,8].

Grooves have various lengths, being linear or curved in shaped and single or multiple in numbers which have been investigated as congenital development or acquired due to diaphragmatic or costal pressure, may result in erroneous interpretation of ski grams [9,10]. Studying about the appropriate position and size of the variations could be fruitfully utilized by radiologists, surgeons, anatomists and embryologists, respectively to avoid possible mistakes during interpretation of different diagnostic imaging's [11,12]. Therefore, assessing surface variations and its specific location on the surface of adult human liver is important to describe the appropriate position and size for radiologists, surgeons, and embryologists.

METHODOLOGY

Study area, design and period

Institutional based cross sectional descriptive study was conducted in University of Gondar, Bahir Dar University, Addis Ababa University, St. Paulos and Hawassa University medical schools. Gondar, Bahir Dar, Addis Ababa, St. Paulos and Hawassa medical school are the major medical schools in Ethiopia that are found northern, central and southern part of Ethiopia. This research was conducted, in Department of Human Anatomy dissection room in all study area from February 2014 to September 2014.

Sample size determination and technique

All embalmed cadavers and preserved livers were included with exclusion of livers that had destructed surface by using purposive sampling technique. Therefore, the total samples were 33 cadavers and preserved livers.

Data collection and analysis procedures

Data collection technique: The study was conducted on 33 cadaveric livers in the Department of Anatomy, Gondar, Bahir Dar, Addis Ababa, St. Paulos and Hawassa medical schools. Collecting specimens during routine dissection for medical undergraduate students and then preserved in 10% of formalin. Then inspected both the diaphragmatic and visceral surface of liver with naked eye and hand lens for any morphological changes. After detail observation on the visceral and diaphragmatic surface of liver specimens, pictures were taken using 16.1-megapixel cannon camera.

Data quality control: The quality of the data was assured by properly designed cheek list and each liver was examined by two different occasions by two examiners, and the results obtained was compared and ratified. Each day after data collection, the cheek list was reviewed and checked for completeness, accuracy and relevance by principal investigator and the necessary feedback was offered to the data collectors.

Data processing and analysis: The entire check list was checked visually, and the data was analysed to identify presence and various types of liver variations.

Results presented in the form of figures, tables and text using frequencies and summary statistics such as, percentage to describe the study population in relation to relevant variable.

Ethical considerations

Study subjects were prepared cadaveric livers for teaching purposes in the department of anatomy. Ethical clearance was obtained from Research and publication office of University of Gondar. Official letters were submitted to University of Gondar, Bahir Dar University, Addis Ababa University, St. Paulos and Hawassa University Medical Schools. The purposes and the importance of the study were explained. Confidentiality was maintained at all levels of the study.

RESULTS

Among the total 33 studied livers, 15 (45.45%) were normal in their external appearance, number of lobes and fissures. However, 18 (54.54%) livers showed anomalies in lobes, fissures, and shape. Accessory sulcus or fissure (AS or AF) was found in 9 livers (27.27%) which includes unusually notched liver with diaphragmatic fissures that extended as prominent vertical grooves over the antero-superior surface (Table 1).

Table 1 Different morphological variations of liver

Morphological features	Number of specimens
Normal liver	15 (45.45%)
Accessory Fissures	9 (27.27%)
Pons Hepatis Connecting Left Lobe with Quadrate Lobe	3 (9.09%)
Superior and Inferior quadrate lobe	1 (3.03%)
No Quadrate Lobe	2 (6.06%)
Accessory Lobes	2 (6.06%)

Accessory sulcus was present only on visceral surface of 5 livers, diaphragmatic surface only in 2 livers and on both surfaces, are 2 livers. In the current study 4 (12.12%) livers had no fissure for ligamentum teres however, in one case (3.03%) it was found on the anterior surface. Pons hepatis (PoH) which bridge left lobe with quadrate lobe was seen in 3 (9.09%) specimens with different size and shape. Papillary process of the caudate lobe and complete transverse fissure dividing quadrate lobe into a superior and inferior lobe was seen in single specimen. There were additional lobes seen in two livers (6.06%) which were situated in lower lateral part of right lobe and around porta hepatis. The Absence of quadrate lobe and elongation of the left lobe were observed in 2 cases where the left lobe was seen to be extending into the left hypochondrium and reached up to the spleen. In one specimen (3.03%) liver was very flat and Quadrate lobe was ill-defined not reaching the inferior border (Table 2).

Table 2 Classification of liver according to Netter's anatomy

Types of liver	Characteristic features	Number of specimen
Type 1	Very small left lobe, deep costal impressions	7 (21.21%)
Type 2	Complete atrophy of left lobe	0 (0.0%)
Type 3	Transverse saddle like liver, relatively large left lobe	2 (6.06%)
Type 4	Tongue like process of right lobe	1 (3.03%)
Type 5	Very deep renal impression and corset constriction	3 (9.09%)
Type 6	Diaphragmatic grooves	4 (12.12%)

DISCUSSION

In the normal morphological appearances of the liver; the right lobe covers approximately 65% of total volume, external surface should smooth and sharp edge, anatomically should have four lobes and four major fissures. But it may congenital or acquired malformed that includes, absence of segments, absence of lobes, deformed lobes, smaller lobes, accessory fissures, and atrophy of lobes [13,14]. Anomalies of liver resulted from disturbed development of liver parenchyma due to excessive or under expression of growth factors. Sometimes liver anomalies may associate with congenital developments of other organs around it, like diaphragm and suspensory materials of the liver. The magnitudes of the alteration differ according to level of disturbance. The origins of congenital development of liver morphology occur during critical period of prenatal development but sometimes it may arise after birth from trauma and surgery. Nowadays, it has been reported that, there are subtle morphological changes detected in diagnostic imaging examinations which may be actual or pseudo lesions [15].

In the current study, accessory fissures were found in 9 (27.27%) livers on the right lobe, left lobe and quadrate lobe having different length, depth, number, and shape. Among 9 (27.27%) livers, AS present on the visceral surface only 5 (15.15%) livers, diaphragmatic surface only in 2 (6.06%) livers and both surface 2 (6.06%) livers (Figure 1). Similar study done in India with 50 specimens reported the presence of AS in 5 (10%) cases [16]. Another study done by 36 specimens in northern India revealed that the presence of AS on 8 (22.22%) livers. From 8 (22.22%) livers, AS present on inferior surface of 4 livers (11.1%), diaphragmatic surface in 2 (5.5 %) livers, posterior surface on 1 (2.7%) liver and right lateral surface in 1 (2.7%) liver [1].

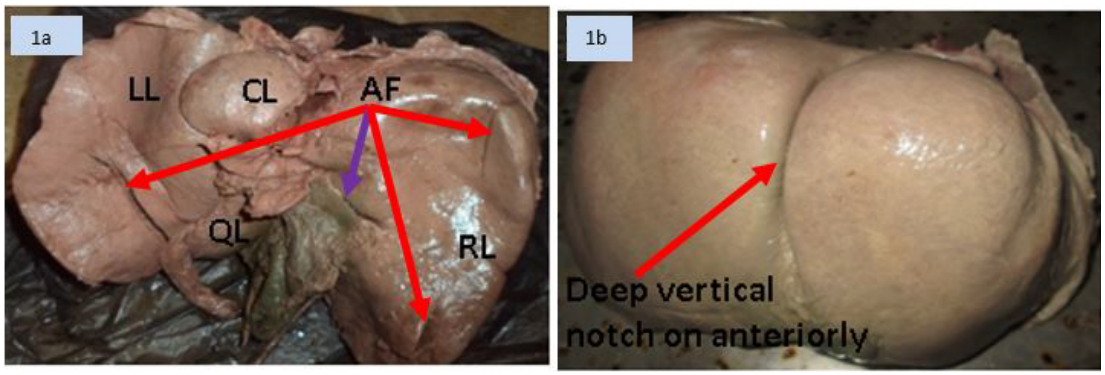

Figure 1 Pictures taken from Ethiopian cadavers I and II in 2014 illustrating accessory fissures (AF) and vertical deep notch on visceral and anterior surface shown on image 1a and 1b respectively. (LL: Left Lobe; CL: Caudate Lobe; RL: Right Lobe; QL: Quadrate Lobe)

The presence of Pons hepatis of variable dimension, joining the quadrate and the left lobes, was present in 3 (9.09%) specimens (Figure 2). Pons hepatis bridge the fissure for ligamentum teres and prevent normal visualization of the fissure and dimensions of the right and the left lobes. Study done in India with 50 formalin fixed livers revealed the presence of Pons hepatis in 5 (10%) specimens on the visceral surface of liver [16].

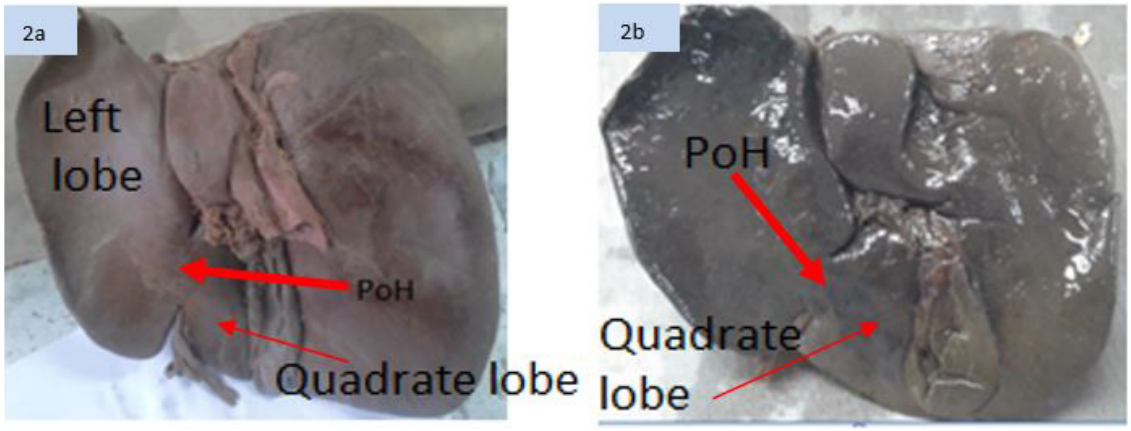

Figure 2 Pictures taken from Ethiopian cadavers IX and X in 2014 illustrating Pons hepatis (PoH) on the visceral surface that attaches left lobe and quadrate lobe shown images 2a and 2b

Morphological variations of liver lobe are commonly found in female than male guys and right lobe is predominantly affected however if left lobe changed from normal lobar pattern deformity is always associated with right enlargement [17].

Excessive or under expression of growth factors, malnutrition, post necrotic cirrhosis, biliary obstruction and veno-occlusive disease have been associated with atrophy or hypoplasia of a hepatic lobe. Whenever there is a defective liver lobe, it is better to examine the other organs as it might be associated with pathological conditional like diaphragmatic hernia, gastric volvulus, and portal hypertension.

Abnormal development of left lobe may predispose to gastric volvulus and diaphragmatic hernia while the right lobe might lead to portal hypertension [13]. But the current study was done on the cadaver and the history was not available, we couldn't verify that hypoplastic lobe of liver or segment under present study was due to various diseases, even though we tried to exclude pathological liver from the very beginning based on the morphological appearance.

Even though, we can't determine the sex and height of individual cadavers in the present study, variations in the lobar pattern were noted. There were enlarged right lobe with relatively small left lobe and enlarged left lobe with relatively small right lobe. There were 2 cases by which left lobe reach into the left side of upper abdominal cavity, up to the spleen and in the other 2 cases the quadrate lobes were totally absent and associated with absence of the fissure for the ligamentum teres.

Several studies said that among liver malformation, left lobe may be long and thin, having been extended downward and to the left onto the left upper abdominal cavity even though right lobe take approximately 65% of liver volume in normal occasion. Elongation of left lobe may seem like spleen after splenectomy or large spleen for the surgeon, but it was definable because of free movement during respiration as it connected to liver [18] (Table 3).

Changes of left lobe depend on many factors including, obesity, age of the patient, liver pliability, previous existence of splenomegaly and its duration that may mimic residual spleen after splenectomy, accessory spleen, mass lesion in the region of porta hepatis [19].

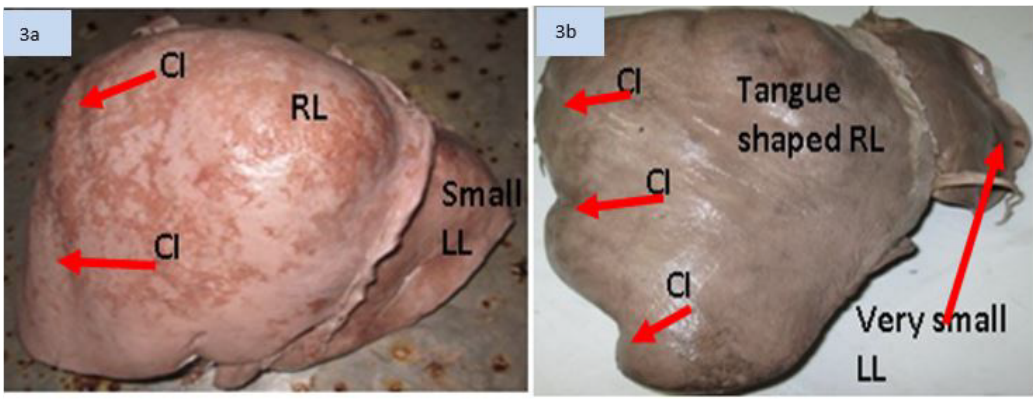

Figure 3 Pictures taken from Ethiopian cadavers XIV & VII in 2014 illustrating Netter's Type 1 liver showing very small left lobe with deep costal impressions (CI) on image 3a and 3b respectively and the right lobe of image 3b looks like tongue shaped (LL: Left Lobe; RL: Right Lobe)

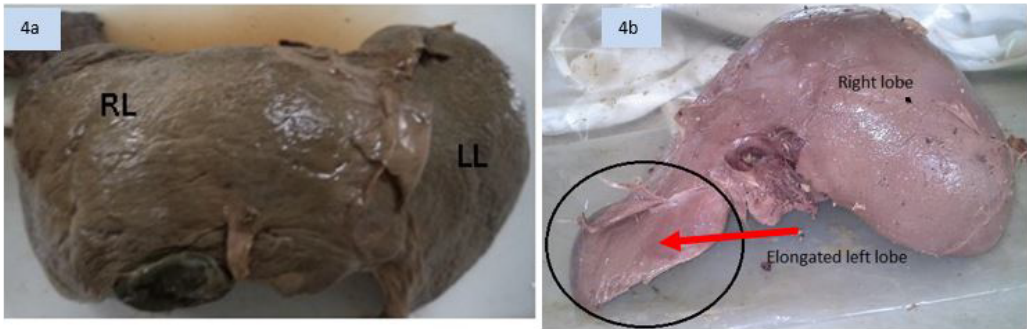

Figure 4 Pictures taken from Ethiopian cadavers VI and VIII in 2014 illustrating Netter's Type 3 liver - Transverse liver with relatively enlarged and elongated left lobe shown in image 4a and 4b respectively (RL: Right Lobe; LL: Left Lobe)

Two (6.06%) livers had elongated left lobe in the present study which is comparable research done in south India 5 (7.1%) and India 5 (10%) [7,16]. The comparability may be similarity in obesity, age of the patient, liver pliability and previous existence of splenomegaly (Figure 4).

Seven (21.21%) livers had very small left lobe with costal impressions which was very high as compared to study done India 1 (2%) and south India 5 (7%) [7,16]. The variation might be associated with biliary obstruction, post necrotic cirrhosis, malnutrition, and veno-occlusive disease.

Liver tissue continuous with the main liver is termed as accessory lobe of the liver but Liver tissue in the vicinity of the liver, without such communication termed as ectopic liver. Additional lobe of liver is congenital ectopic hepatic tissue most commonly due to organogenic hetroplasia however it may occur due to trauma or surgery [20].

Additional lobes of liver occur very rarely because it is associated with an autosomal recessive gene with a very low frequency. A research done on 172 rats confirmed that accessory lobe of liver is due to genetic theory [21] but nowadays, there are two hypotheses in the mechanism of ALL: (I) embryonic liver curls outwards and forms an accessory lobe during the embryonic stage of development [22] or (II) accessory lobe arises from intra-abdominal hypertension caused by the development of the tunica muscularis and the enlargement of the liver [23].

Study done with 55 formalin fixed livers in southern Indian cadaver for occurrence of abnormal shape, lobes, fissures, and position of gall bladder, in 60% of cases the liver was normal, but 40% livers showed one or more variations. Additional lobes were found in 9.09% of cases which are small and situated in the vicinity of the porta hepatis, caudate and quadrate lobes and preoperative imaging of this lobe leads to the misdiagnosis as a lesser omental lymphadenopathy.

In the present study, 2 (6.06%) livers had additional lobes which may be formed by organogenic heteroplasia associated with an autosomal recessive gene or through trauma and surgery. The other cause for the development of additional is displacement of primitive bud at time of proliferation and error in segmentation of hepatic bud in the third month of intrauterine life [20,22].

Variations in the liver morphology can be classified as congenital or acquired but congenital variations of human liver are rare to found and they are rarer than almost any other organ of the body ever seen. Probably the variation may be very high in our population, but we do not notice them very often because these cases are usually asymptomatic [24,25].

Additional lobes of liver composed of similar cells and tissues which are found in the parenchyma of right or left lobe which had its own neurovascular structure and bile duct that connect in to the rest of liver. It is very important surgically and radiologically due to its small size, even it might be mistaken for a lymph node or any other tumour.

During surgeries around the porta hepatis, small additional lobe of liver may be suddenly removed that result bleeding into abdominal cavity [19,26]. One case in the present study, the accessory lobe found at right of gall bladder just inferior border of right lobe is bulge of tissue which commonly found in female exclusively [27]. The other one which was very small situated between left lobe and quadrate lobe. Similar study done in India by 2013 observed in one case a bulge of tissue which is referred to as Reidel's lobe, first described by French surgeon called Reidel [28].

But another study done in south India by 2013 with 55 livers, five livers (9.09%) had accessory lobes in which they were located in the region of porta hepatis, quadrate and caudate lobe [29]. This might be happened because of the differences in exposure to teratogen during embryonic period, sex, and age.

The causes of bulging hepatic tissue may be due to the influence of neighbouring organs on the right lobe like, gall bladder enlargement which push dawn right lobe the liver (Figures 5 and 6). The other possible causes of hepatic tissue bulging were adhesions to the anterior abdominal wall may drag dawn liver tissue, dragging dawn of prolapsed intestine or other abdominal viscera and presence of cyst at the edge of liver lobes [30-35].

Even if, inferior border of right lobe is hidden by abdominal organs which are found just inferior to it and making less palpable, presence of Reidel's lobe may be clinically detectable and results confusion with different pathological mass tumours [4,36-38].

So sound knowledge about the location of Reidel's lobe may be very important applications for diagnostic and imaging professionals, anatomists, and embryologists for new academic insights.

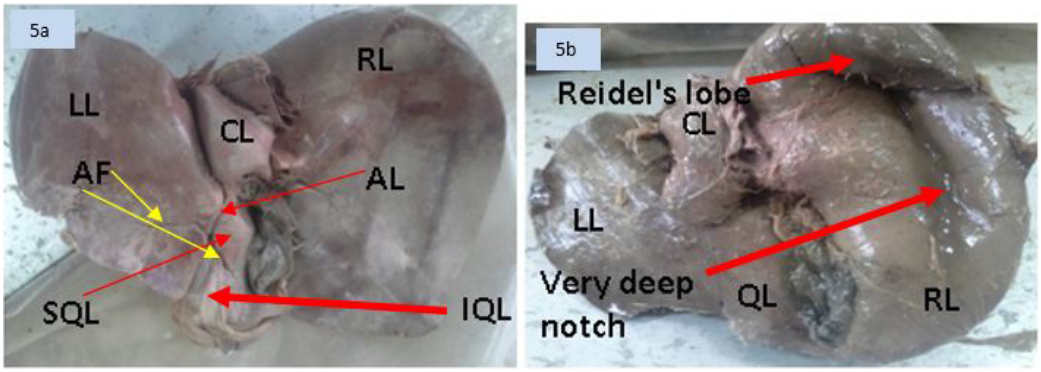

Figure 5 Pictures taken from Ethiopian cadavers XVI and XII respectively, in 2014 illustrating accessory lobe. Image 5a show AL around porta hepatis and Image 5b show Reidel's lobe with very deep grooves on the visceral surface which represent Netter's Type 4 liver (AF: Accessory Fissure; AL: Accessory Lobe; SQL: Superior Quadrate Lobe; IQL: Inferior Quadrate Lobe; LL: Left Lobe; RL: Right Lobe)

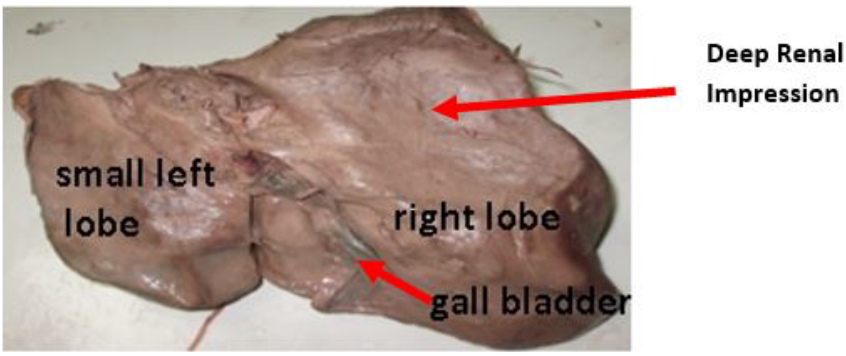

Figure 6 Picture taken from Ethiopian cadaver VII in 2014 illustrating Netter's Type 5 liver showing very deep renal impression and corset constriction

Table 3 Comparison of different studies on morphological variations of liver

Authors	Nagato, et al. [6]	Sachin, et al. [16]	Sangeeta, et al. [7]	Present study
Sample size	61%	50%	70%	33%
Netters type 1	8.19%	2%	7%	21.21%
Netters type 2	1.64%	0.0%	3%	0.0%
Netters type 3	6.56%	10%	7.10%	6.06%
Netters type 4	21.31%	2%	9%	3.03
Netters type 5	9.84%	2%	6%	9.09%

The findings in the present study correlate to some extent with the study by Nagato, et al. but in their study the frequency of tongue like projection of left lobe was high but in the current study Netter's type 1 was moderately high (Table 3).

CONCLUSION AND RECOMMENDATIONS

Morphological variations on the liver surface were accessory fissure, very small left lobe with deep costal impressions, pons hepatis, absence of quadrate lobe and mini accessory lobe, etc. Among the variations on the liver surface, 50% were accessory fissures and commonly located in the right lobe both visceral and diaphragmatic surface but other variations were mostly located on the visceral surface.

Recommendations

- In order to improve application and reliability on the anatomical foundation further research should be done in the morphological variation of liver in order to have better understanding of liver anatomy.
- Concert knowledge about liver anatomy avoids possible mistakes in the diagnostic imaging and help to plan appropriate surgical approaches.
- In order to generalize for the population further research should be done with increased number of specimen on prospective basis involving pathologist for morphological evaluation of liver pathology and cadavers before dissection.

DECLARATIONS

Competing interest

All authors declare that they have no conflict of interest associated with the publication of this manuscript.

Authors' contribution

Tsegaye Mehare conceived and designed the study and collected data in the field, performed analysis, interpretation of data, and draft the manuscript. Dr. Assegedech Bekele, Dr. Assefa Getachew and Yigrem Ali involved in the design, analysis, and interpretation of data and the critical review of the manuscript. All authors approved and read the final manuscript.

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