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**Ultrasonographical examination of one humped camels (*Camelus
dromedarius*) liver with some haematological and biochemical
aspects**

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List of Abbreviations

AST	Aspartate Amino Transferase
ALT	Alanine Amino Transferase
ALB	Albumin
BIL	Bilirubin
ALP	Alkaline phosphatase
GGT	Gamma Gultamic Transferase
GLDH	Glutamic Dehydrogenase
TG	Triglyceride
RBC	Red Blood Cell counts
HB	Haemoglobin
PCV	Packed cell volume
MCV	Mean Corpascular Volume
MCH	Mean Corpascular Haemoglobin
MCHC	Mean Corpascular Haemoglobin Concentration
TWBC	Total White Blood Count
ICS	Intercostal Space
RP	Reference Point
IU/l	International unit per liter
mmol/l	Millimol per liter
G/l	Gram per liter
l/l	Liter per liter
T/l	Thousand per liter
Fps	Frame per second
Sec	second
M ²	Meter square
fmol	Femtamol
Fl	Femtoliter
Pg	Picogram
μmol/l	Micromole per liter
Cm	Centimeter
Mm	Millimeter
%	Percent

\leq
MHz

Less than or equal to
Megahertz

1 General Introduction

1.1 Introduction

One humped camels (*Camelus dromedarius*) are very important in many countries as they are used as food and draft animals. The ability of camels to utilize range in marginal areas and to survive and produce under harsh environmental conditions has been recognized over the years (KNOESS 1977, GAUTHEIR-PILTERS and DAGG 1981, HJORT and HUSSEIN 1986, ABBAS and TILLEY 1990, SCHWARTZ 1992). Camels play a vital role in the subsistence economy of pastoral peoples in diverse ecozones extending from the Gobi and India in central Asia (KOHLER-ROLLEFSON 1992, LAVAL et al. 1998, LENSCH 1999) to Mauritania in the west (ABIEDERRAHMANE. 1997) and Somalia and Ethiopia in the horn of Africa (WILSON et al. 1990, ABDURAHMAN and BORNSTEIN 1991, TEFERA and GEBREAH 2001). Camel exports also contribute significantly to the foreign currency income of two major camel producing countries, namely Somalia and Sudan (REUSSE 1982, CLARKE 1985, KHALIFA 1987, SAINT-MARTIN et al. 1992). Camels have also been tapped as an important sport and tourism resource in the Arabian Gulf countries (SNOW et al. 1992) and Australia (WILLIAMS 1992), a country into which camels were introduced in an effort to master the desert during the 18th century, and have been breeding freely as feral animals ever since (MCKNIGHT 1969).

The camel produces milk, meat, wool, hair and hides, serves for riding, as a beast of burden and as a draft animal for agriculture and short and long distance transport. Two thirds of the camel population of the world is located in Africa (FAO, 1989). The majority of camels in this region are kept by migratory pastoralists who rely on a nomadic life style for securing nutrition for their herds. Since pasture productivity in that area is marginal and forage yields are highly variable by season, camels under these systems undertake long seasonal migrations sometimes covering up to 600 km in one route (HAILLEY 1980, ABBAS and MUSA 1987, AGAB and ABBAS 1999). These migrations together with the poor range conditions during the long dry season a characteristic of arid zones, subject camels to severe stress (WESTERN 1982, ABBAS et al. 1993, AGAB 1993). Under these conditions, camels are the only reliable milk producers because of their unique adaptation to hot and arid conditions (SCHWARTZ 1992). The historical isolation of camel pastoralists, the underreporting of camel diseases outside city boundaries, scarcity of veterinary centres in the camel sphere, and the virtual lack of field studies have led several researchers to consider camels to be resistant to the diseases commonly affecting livestock in the same region (ZAKI 1948, DALLING et al. 1966,

MUSTAFA 1987). With increasing human population pressure and declining food production in Africa there is an urgent need to develop previously marginal resources, such as the semi arid and arid range lands, and to optimize their utilization through appropriate livestock production systems, of which camel production is certainly the most suitable one.

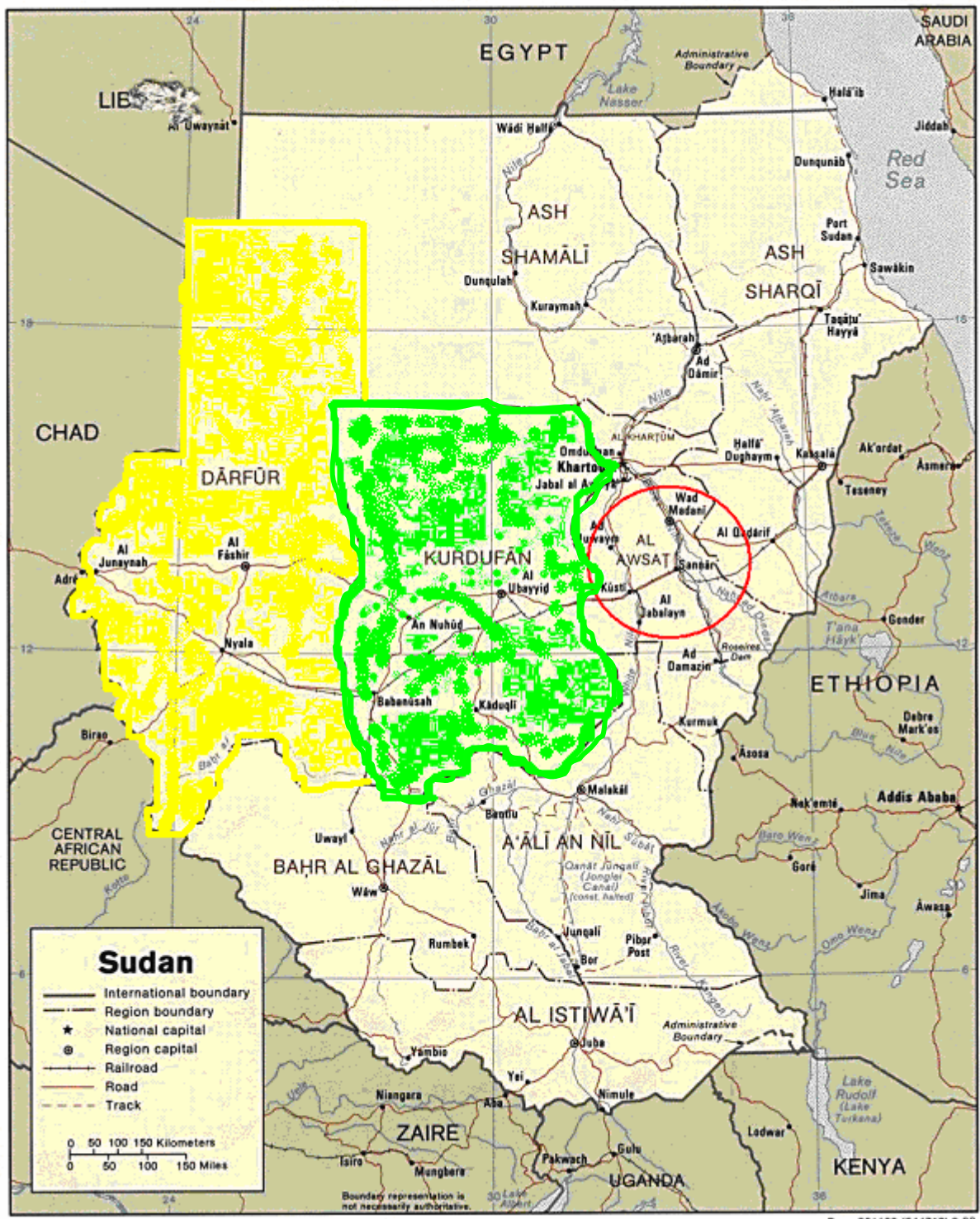
In Sudan, camel population varies between 2.7 million (National Statistics 1989) and 3.1 million. Camels occur mainly in Kordofan, Darfur and Butana. There is export of slaughter camels, mainly young males, and racing camels to neighbouring countries like Egypt, Libya, Saudi Arabia and the Gulf states (SCHWARTZ 1992).

Recent socioeconomic and agricultural developments in the main camel-keeping countries have led to modifications in the way camels are managed, with the evolution of several new forms of husbandry practices. These include dairies centrally located within the cities, as well as smaller peripherally placed farms. These managements practices aim towards the commercial production of fresh or pasteurized camel milk and include camel feedlots, and medium to large-sized (mobile) ranches, in which camels are mobilized seasonally to make use of crop residues. As a result of this upsurge of interest in the camel, more data and research are urgently needed in camel diseases, diagnosis and treatment.

1.2 Objectives of the study

The objective of this study was the examination of the liver in apparently healthy dromedary camels using transcutaneous ultrasonography with special emphasis on the following points:

- a. In which position can we perform this examination?
- b. In which intercostal space can we scan the liver and what are the hepatic structures (borders, caudal vena cava, portal vein and its branches) which can be visualized?
- c. What is the echo pattern of the liver parenchyma?



○ Butana Area
 Darfur State
 Kurdufan State

Figure 1: Camel breeding areas in the Sudan

2 Literature Review

2.1.1 Classification of the one humped camel

The one and two humped camels are known as old world camels and they are classified as follows

Class Mammalia

Order Artiodacyla

Sub-order Tylopoda/Camelides

Genus Old world: *Camelus dromedarius* (one humped camel)

Camelus bactrianus (two humped camel)

New world: *Lama glama* (llama)

Lama pacos (alpaca)

Lama guanicoe (guanaco)

Vicugna vicugna (vicuna)

2.1.2 Camel Breeds

New and old world camelides may be distinguished by colour, size, conformation as well as other characteristics (WILSON 1978). Dromedary camels have been defined into two types on the basis of weight and body build. These are the light riding or (racing) camel and the heavy (pack or baggage) type. Riding or racing camels are slender animals with a long and level shoulder, a smallish hump, a markedly tucked –in abdomen and long legs with small feet. The hair is short and fine, the skin is thin and supple. Heights may differ greatly, but live weights rarely exceed 350 kg in females and 450kg in males. The baggage type has a much heavier build with a more balanced appearance of fore and hind quarters. The hump is pronounced in well fed animals, shoulder and rump are relatively short and sloping steeply. The hair is often longer and coarse. The legs appear shorter and sturdier and feet are large. Live weight is around 500kg in female and over 550kg in males. The baggage type seems to dominate in eastern Africa whereas, Sudan is only country where a true riding camels can be found and it is called Anafi breed. However there are no exact breeds or local types of camels which can be distinguished from others by particular characteristics. Size, build, colour and production differ widely within herds and also within tribal, ecological, geographical or political boundaries. Low reproductive rates limit the potential for systematic selection within

local populations, and particularly so within the female portion of the herds, although preferences for certain phenotypes and/or high performances are expressed by all camel pastoralists (BEKELE et al.2002)

Somali camels, especially the Benadri type appear to be the only specialized dairy camel in the area. This breed presents a more uniform type than other breeds in the region. The animals conform basically to the heavy baggage type. They are mostly white, large and heavy. The reported milk yield reach up to 3500 kg in a prolonged lactation of 15 to 16 months (SCHWARTZ 1992).

2.1.3 Composition and characteristics of camel milk

Camel milk is a rich source of protein with potential anti-microbial and protective activity (WERNERY 2006). Tables 1 and 2 summarize the composition of camel milk in comparison with other species. It was shown that the relative amount of the main components of camel (milk protein, fat) and lactose are similar to those in cow milk and the percentage of the fat changes according to water contents. Furthermore, the fat in the camel milk does not form a layer when kept undisturbed and is evenly distributed throughout the milk in small micelles which make fat digestion easier. Camel fat contains much higher concentration of long chain fatty acids (C14-C18) than short chain fatty acids, and is therefore healthier (STAHL 2005). Milk yield varies with age, breed, feeding and management conditions, and the stage of lactation. It is difficult to estimate the daily milk yield of a camel under pastoral conditions because calves suckle throughout the lactation period and the variability of milking frequencies among different pastoral groups. WANGO et al. 1998 estimated the daily milk yield of dromedary camels in Northern Kenya as 21L in the 2nd week of lactation falling to 4.8-2.2 by the sixteenth week of lactation. BEKELE et al. 2002 stated that camels which calved in the dry season gave milk for a longer period and had a higher milk yield than those that calved during the rainy season. Camels that calved in the long wet season showed the highest daily yield between 9 and 19 weeks of lactation. The camel can produce an adequate amount of milk in drought areas where other domestic animals have very low production as shown in Table (3). It was shown that camels can be managed well in a closed farm and milked with an automatic portable milking machine (WERNERY et al. 2004). In that study, total milk yield was 21.96 Kg with an average daily milk yield of 4.8 Kg by each camel (n=16). Camel milk is generally opaque-white. It has a sweet and sharp taste and some times it may be salty depending on the fodder composition. For example, feeding on (*Atriplex*

canescens) results in a salty taste while feeding on *Schowia purpurea* gives the milk an odour similar to that of cabbage.

The pH of camel milk ranges from 6.5-6.7 with an average value of 6.56 whereas the density ranges from 1.025-1.032 with an average of 1.029. Both values are lower than those of cow's milk (REO et al. 1970, SAWAYA et al. 1984, FARAH and BACHMANN 1987).

One of the important factors that affect camel milk composition is the water. Water content of camel milk varies from 84%-90 %. One of the most remarkable features of dehydrated camels is the ability to continue lactation, and to secrete milk with over 90% water content, which could be a natural adaptation in order to provide necessary fluid to the camel calf (YAGIL and ETZION 1980).

Unlike bovines, the colostrum of camels is white like normal milk and slightly diluted. Only fragmentary data are available on colostrum composition in camel milk (FARAH 1993). Transformation from colostrum to milk occurs generally within 7-10 days in camel (WERNERY 2006). The most complete data on camel colostrum are those reported by SESTUCHEVA 1958 and ABU-LEHIA et al. 1989 for Russian and Saudi camels respectively, these data are summarized in Table 4.

Camel milk is unique in that it has the ability to inhibit the growth of micro-organisms because it contains protective proteins and enzymes with antibacterial and antiviral properties (EL-AGAMY et al. 1992) such as lactoferin, lactoperoxidase, peptidoglycan recognition protein (PGRP). Camel milk contains insulin and is therefore used to treat *Diabetes mellitus* (AGRAWAL et al. 2005). This insulin (42 μ U/ml) is not much higher than in cow milk but trial in rabbits and rats showed that the insulin is not destroyed in the stomach. It passes into the intestines causing reduction in blood sugar (WERNERY et al. 2006.)

2.1.4 General Biology

Camels are different from ruminants in many aspects; they walk on the pads of the two last phalanges instead of the sole of the claw, they have no horns or antlers, their blood cells are elliptical and small (6.5 μ) and the predominant white cell is the neutrophil. Even though camels ruminate; they are not considered as true ruminants, as they lack the four well defined stomachs of the ruminants (the rumen, reticulum, omasum and abomasum). The anatomy of all members of the *Camelidae* is considered to be similar but most of available data on the anatomy of the alimentary canal have been obtained mainly from the llama. Anatomical description of the camel remains a challenge because various authors use different nomenclature to describe the digestive tract, particularly with respect to the diverticula.

LEESE (1927) stated that the camel has only three stomachs, compared with the bovine's four compartments and that the missing part is the omasum or third stomach. HEGAZI (1950) describes the camel as having the same four compartments as other ruminants, but with the external constrictions between the omasum and abomasums being less well defined in the camel.

The first compartment (C1), the rumen is a glandular region divided by a transverse muscle pillar into a cranial and caudal sac (Fig. 2). The function of this compartment is the rapid absorption of solutes and water (ENGELHARD and RUBSAMEN 1979). The second compartment (C2), the reticulum is small and only partially separated from the first compartment. The reticulum is separated from the third compartment by a tubular sphincter. The third compartment (C3), the omasum/abomasum is an elongated tubiform organ (Fig. 2). However, ENGELHARD, RUBSAMEN and HELLER (1984) mentioned that it would be better to describe camelidae stomach as two compartments, with a forestomach (comprising the reticulorumen) and a tubular stomach, being the whole of the other part. The motility of the camelid stomach differs strongly from that of ruminants; the mean retention time of digesta is shorter in camels than in other ruminants, by about 20%. This could be due to the more rapid contractions and the shorter rumination cycle in the camel stomach (HOFMAN 1988).

Table 1: Water, fat, protein and lactose content (%) in milk of different animal species and man (WERNERY 2006)

Origin	Water	Fat	Protein	Lactose
Human	88	3.8	1.0	7.0
Cow	87	4.5	3.4	4.8
Buffalo	83	7.4	3.8	4.8
Sheep	82	7.1	5.8	4.6
Goat	87	4.1	3.4	4.6
Reindeer	67	18	11.0	1.5
Dromedary	87-91	2.0	3.0	4.0

**Table 2: General composition of camel milk in comparison with cow milk
(WERNERY 2006)**

Parameters	Units	Camel milk	Cow milk
Total solids	%	9-13	13
Water	%	87-91	87
Protein	%	2.7-4.0	2.7-4.7
Fat	%	1.8-3.8	3.8
Lactose	%	3-5	3.7
Calcium	mg/100 ml	100-160	100-140
Copper	mg/l	1.3-1.8	0.1-0.2
Phosphate	mg/l	580-1040	650-1100
Iron	mg/l	1.3-2.5	0.3-0.8
Potassium	mg/l	600-2100	1350-1550
Magnesium	mg/l	75-160	100-150
Manganese	mg/l	0.08-0.2	0.04-0.2
Sodium	mg/l	360-620	350-600
Zinc	mg/l	4.4-5	3.5-5.5
Vit C	mg/l	24-36	3-23
Vit B ₁₂	mg/l	0.002	0.002-0.007
Folic acid	mg/l	0.004	0.01-0.1
Niacin	mg/l	4.6	0.5-0.8
Pantothenic acid	mg/l	0.88	2.6-4.9
Vit B ₆	mg/l	0.52	0.4-0.63
Vit A	mg/l	0.1-0.15	0.17-0.38
Vit B ₂	mg/l	0.42-0.80	1.2-2
Vit B ₁	mg/l	0.33-.60	0.28-0.9
Vit E	mg/l	0.53	0.2-1.0

Table 3: Average milk yield of camels from different countries (FARAH 1993)

Country	Daily yield (kg)	Lactation length (months)
Egypt	3.5-4.5	9
Ethiopia	5-13	12-18
India	7-18	15
Kenya	2-12	11-16
Pakistan	8-10	12
Somalia	3-9	9-18
Sudan	5-10	10-12
Tunisia	4	12

2.1.5 Adaptation to hot and arid environments

The ability of the dromedary to adapt to the arid habitat is extremely unique amongst large herbivores (KING 1983). The most significant of these adaptations is the economic use of water in almost all metabolic functions (HOFMAN 1988). Water losses through urine are minimized by concentrating urine, by reducing renal urine flow and by retaining metabolites in the body fluid. Faecal water loss in camel is likewise comparatively low due to the efficient re-absorption of water in the colon. Camels can tolerate fluctuations of the internal body temperature from 34 to 42 °C and hence store considerable amounts of heat during the day and can dissipate this by non- evaporative mechanisms, radiation, conduction and convection during the cooler hours of the night. The highest deep body temperatures are usually reached during the early afternoon, with the additional beneficial effect of lowering the temperature gradient between environment and animal which results in reduced environmental heat gain (RUTAGWENDA et al. 1990).

Table 4: Average content of colostrum in camels studied in Kazakhstan and Saudi Arabia (FARAH 1993)

	Kazakhstan		Saudi Arabia	
	3hrs pp	2 days pp	At parturition	3 days pp
Total Solids	30.4%	18.4%	20.5%	13.6%
Fat	0.20%	5.8%	0.20%	1.5%
Protein	19.4%	3.6%	13%	4.7%
Lactose	7.2%	7.2%	2.7%	4.4%
Minerals	3.8%	0.1%	1.0%	0.8%

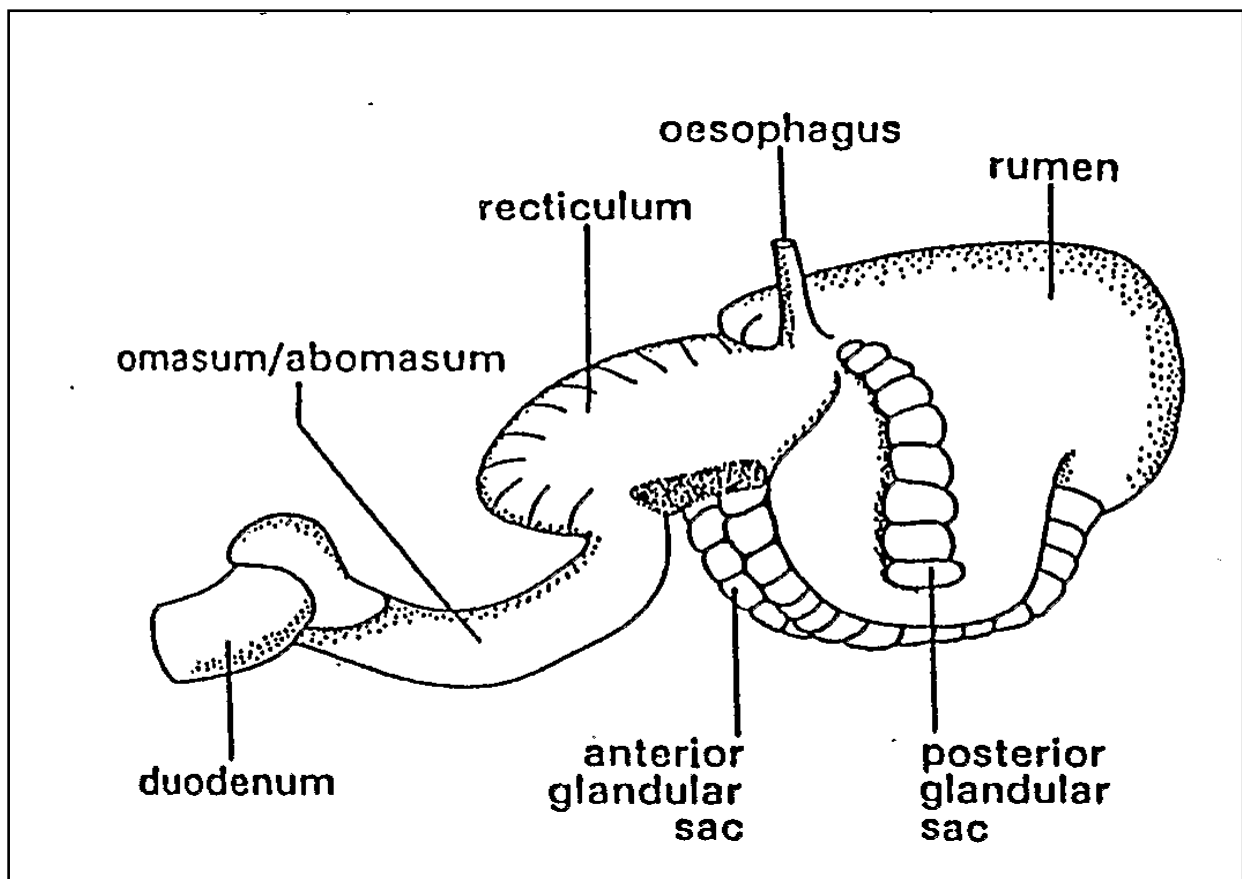


Figure 2: Schematic presentation of the stomach system of camelids (WILSON 1989)

2.1.6 Nutritional physiology

The usual habitat of the camel is not only characterized by high temperatures and scarcity of water, but also by considerable seasonal variation in available forage quantity and quality.

Camels can adapt to such fluctuation in forage quality by either increased selectivity for plants with higher quality or by more efficient digestion of plants of poor quality (HOFMAN 1988 and ENGELHART et al.2006) which leads to an increase in the habitat where camels can be kept profitably. Camels can recycle and utilize body urea for microbial protein synthesis much more efficiently than other ruminants (RUTAGWENDA et al. 1990).

2.1.7 Anatomy of the camel liver

The liver of dromedary camel is situated in the intra-thoracic part of the abdominal cavity, occupying most of the right hypochondriac and epigastric regions. The long axis of the organ extends cranioventrally from the second lumbar vertebra to the caudal border of the 5th rib. The cranial part of the organ curves ventromedially and caudally to the end on the left side at the level of the caudal border of the 5th rib (ABDALLA et al. 1971, NAGPAL et al. 1985, SMUTS and BEZUIDENHOUT 1987, FARAG, 1990, SIDDIG, 2002). In the foetus, the liver occupies most of the right abdominal cavity (ABDELI MONIEM et al. (2000) and HEGAZI (1945) stated that the long axis of the liver extends from the level of the 5th rib to the 11th rib.

2.1.7.1 Consistency and size of the liver

The liver contains a high amount of interlobular connective tissue leading to a firmer consistency than in other domesticated animals (LEESE 1927, HEGAZI, 1945, ABDALLA et al. 1971 and IBRAHIM 1983) but similar to that in swine. The weight of the camel liver varies with age and body weight and ranges from 8.1-13 kg (FARAG 1990). Other authors reported that the average weights of the camel liver were 10 kg, 15.2 lb, 6.5 kg, 5-8 kg, 6.5-10 kg or 10 kg as (DRONADI 1936, HEGAZI 1954, ABDALLA et al. 1971, IBRAHIM 1983, SMUTS and BEZUIDENHOUT 1987, SIDDIG 2002), respectively. However these differences corresponded with differences in the length and width as recorded by these authors; averages of 60-80 cm and 34-60 cm were reported for the length and width subsequently (Table 4). The liver represented 2.8% to 5.7% of the dressed carcass weight (FARAG 1990).

Table 4: Average weight and dimensions of the camel liver (*Camelus dromedarius*)

Authors	Weight	Length	Width
DROANDI (1936)	10 kg	60-80 cm	50-60 cm
HEGAZI (1954)	15-20.25 lb	70 cm	34 cm
ABDALLA et al (1971)	6.5 kg	60 cm	42 cm at base and 18 cm at apex
SMUTS and BEZUIDENHOUT (1987)	6.5-10 kg	-	-
FARAG (1990)	8.1-13.0 kg	-	-
SIDDIG (2002)	10 kg	67 cm	48 cm

2.1.7.2 Shape and surface of the liver

The camel liver has two surfaces, diaphragmatic (parietal) surface (*facies diaphragmatica*), and visceral surface (*facies visceralis*). However its shape has been classified by various authors according to different geometrical shapes. DRONADI (1936); HEGAZI (1954; ABDALLA et al. (1971) described it as triangular while FARAG (1990) considered it as an irregular quadrilateral. When it was considered to be triangular, the liver was assumed to have three borders and three angles. The borders are: caudal border (*margo caudalis*), ventral border (*margo ventralis*) and dorsal border (*margo dorsalis*). The angles are; caudodorsal angle (*angulus caudodorsalis*), caudoventral angle (*angulus caudoventralis*) and cranioventral angle (*angulus cranioventralis*). The caudal border which represents the base of the organ is thin and its upper two thirds are directed cranioventrally extending from the anterior border of the last rib to the distal end of the 10th rib. The ventral border is thin and irregular; extends interiorly from a point about 5 cm below the costal arch between the 10th and 11th, ribs up to the 5th rib, where it turns to the left side following the curvature of the cranial (left) lobe. It shows three main interlobular incisurae (*incisurae interlobares*), the caudal one at the level of the 8th, the middle one at the 7th, and the cranial one at the 6th intercostals space. The dorsal border is thick and is directed forward and downward following the curvature of the diaphragm. The caudal half of the border is 8-10cm thick and diminishes gradually to a thickness of 1cm then it forms a shallow wide groove (*sulcus venae cavae caudalis*). The

cranial half of the border is free and sharp. It presents a notch at the level of the ventral depression between the two subdivisions of the cranial (left) lobe (ABDALLA et al. 1971).

The caudoventral angle is situated about 5cm below the costal arch between the 10th and 11th ribs. While the cranioventral angle is situated at the level of the posterior border of the 5th rib, about 15cm from the sternum (ABDALLA et al 1971).

The diaphragmatic surface (*facies diaphragmatica*) is convex and is mainly adjacent to the corresponding surface of the diaphragm, except for a ventral part of the caudal (right) lobe which is in direct contact with the right abdominal wall. The convexity of the cranial (left) lobe is in contact with the diaphragm which is in turn adjacent cranially to the pericardium and dorsally to the base of the right lung (ABDALLA et al. 1971). This surface is mainly directed medially (ABDALLA et al. 1971, IBRAHIM 1983 and FARAG 1990).

The visceral surface (*facies visceralis*) is deeply concave at the central part of the papillary process below the *Porta hepatis* which is convex (NAGPAL 1985). It is very irregular in shape and is related to the rumen (C1), reticulum (C2), omasoabomasal complex (C3), right kidney, adrenal gland, pancreas, descending colon, duodenum and jejunum (HEGAZI 1945, ABDALLA et al. 1971, FARAG, 1990).

Both diaphragmatic and visceral surfaces of the liver are marked by several fissures which cut the surface in various directions and divide it into superficial lobes of variable sizes. These fissures are more abundant and deeper in both surfaces of the cranial part of the organ (left lobe), particularly on the visceral surface (ABDALLA et al. 1971, SMUTS and BEZUIDENHOUT 1987, SIDDIG 2002).

2.1.7.3 Lobulation of the liver

According to available literature, the liver of the camel is formed of two main lobes (FARAG 1990), three main lobes (LEESE 1927, DROANDI 1936, HEGAZI 1945, IBRAHIM 1983), four main lobes (ABDALLA et al. 1971, SMUTS and BEZUIDENHOUT, 1987, SIDDIG 2002), and five lobes (NAGPAL 1985). These opinions reflect difference between various authors in regards to what constitutes a lobe rather than actual anatomical variations in the described specimens.

2.1.7.3.1 Left Lobe (*Lobus hepatis sinister*) or Cranial lobe

This lobe constitutes the cranial and most ventral part of the liver and is directed entirely to the left of the median plane. It is related cranially and ventrally to the sternal portion of the diaphragm as well as the xiphoid cartilage and caudally to the rumen (C1). This lobe is sub-

divided by a wide ventral shallow depression into lateral (anterior) and medial (posterior) parts. The lateral (anterior) sub-division is larger than the medial (posterior) one and it represents the so called right hepatic lobe in the horse and the right medial hepatic lobe in the dog and pig whereas the medial (posterior) sub-division represents the so called left medial hepatic lobes in the same animals (ABDALLA et al. 1971, SMUTS and BEZUIDENHOUT 1987, FARAG 1990).

2.1.7.3.2 Right lobe (*lobus hepaticus dexter*) or Caudal lobe

This lobe forms the bulk of the organ. It constitutes the caudal two thirds of the organ and is situated at the right of the median plane in a sagittal direction, with its dorsal portion curved medially. Its parietal surface is related to both the right crus and costal part of the diaphragm, as well as the right abdominal wall. The visceral surface of the lobe is partially overlapped by the caudate and quadrate lobes and is also related to the right kidney and adrenal gland; at its dorsal part, it is related the descending colon at the middle and at its ventral part to the jejunum (ABDALLA et al. 1971, IBRAHIM 1983, SMUTS and BEZUIDENHOUT 1987, FARAG 1990).

2.1.7.3.3 Quadrate Lobe (*lobus quadratus*)

This lobe is represented by circumscribed mass of hepatic tissue extending from the visceral surface of the right lobe. It is divided into cranial and caudal subdivisions. The caudal subdivision projects ventrally beyond the contour of the ventral border of the liver at the level of the 8th costo-chondoral junction and comes to lie in contact with the right abdominal wall for about 10-15 cm, forming a quadrate process. This process was either tongue or heart shaped as observed by ABDALLA et al. 1971 and IBRAHIM 1983 or varied between triangular and rectangular shapes (FARAG 1990).

2.1.7.3.4 Caudate Lobe (*lobus caudatus*)

The caudate lobe lies in the dorsal part of the visceral surface of the right lobe, extending from the renal impression caudally to the esophageal impression cranially. It is formed dorsally by the ventral boundary of the sulcus venae cavae and projects ventrally to overlap over the dorsal portion of both the right and quadrate lobes. This lobe is represented by two processes, papillary and caudate with a connecting isthmus. The papillary process is the larger of the two processes and lies cranial to the *porta hepatis*. Its shape is circular or oval (FARAG 1990) but SMUTS and BEZUIDENHOUT (1987) described it as a flap -like shape.

The caudate process is situated caudal to the *porta hepatis*. Its shape is quadrilateral as described by IBRAHIM 1983 and FARAG 1990 while SMUTS, BEZUIDENHOUT 1987 observed it as pointed. ABDALLA et al. (1971) described this process as having an axe-handle shaped form.

2.1.7.4 Attachments of the liver

The liver of the dromedary as in other domestic animals is kept in position by the pressure of the neighbouring organs and two groups of ligaments, a visceral group (hepatorenal ligament and lesser omentum) and a parietal group (coronary, falciform, round, right triangular and left triangular ligaments).

2.1.7.4.1 The visceral group

2.1.7.4.1.1 Hepatorenal ligament (lig.hepatorenale)

This ligament connects the convex or the caudal border of the right kidney to the border of the renal impression in the liver (ABDALLA et al. 1971, FARAG 1990).

2.1.7.4.1.2 Lesser omentum (omentum minus)

The lesser omentum is represented by an extensive peritoneal fold, situated between the visceral surface of the liver and the concavity of the omasoabomasal complex (C3) (ABDALLA et al. 1971, IBRAHIM 1983, SMUTS and BEZUIDENHOUT 1987, FARAG 1990).

2.1.7.4.2 Parietal group

2.1.7.4.2.1 Coronary ligament (lig. coronarium hepatis)

This ligament closely attaches the diaphragm to the borders of the groove (*sulcus venae cavae caudalis*) (ABDALLA et al. 1971, FARAG 1990).

2.1.7.4.2.2 Falciform ligament (lig. falciforme hepatis)

Like in other ruminants (HABEL 1975), this ligament is attached to the liver along a vertical line, extending from the oesophageal impression dorsally to the umbilical fissure ventrally (FARAG 1990).

2.1.7.4.2.3 Round ligament (lig. teres hepatis)

The ligament is noticeable in the mature fetus and the neonate, but in mature animals, it is reduced to a barely noticeable cord (ABDALLA et al. 1971).

2.1.7.4.2.4 The right triangular ligament (lig. triangulare dextrum)

This ligament consists of two strong laminae which are fused with the corresponding part of the hepatorenal ligament, to be attached to the lateral border of the renal impression, the sublumbar region and the right crus of the diaphragm (ABDALLA et al. 1971, FARAG 1990).

2.1.7.4.2.5 Left triangular ligament (lig. triangulare sinistrum)

This ligament is considered absent in the camel (HEGAZI 1945, ABDALLA et al. 1971), in the ox (SISSON and GROSSMAN 1969), and in swine (EL-HAGRI 1967). In contrast, SMUTS and BEZUIDENHOUT (1987) and FARAG (1990) described this ligament in dromedary camels in a form of a short triangular fold, connecting the craniodorsal angle of the liver with the tendinous centre of the diaphragm.

2.1.7.5 Intrahepatic branches of the portal vein

In camels, the portal vein enters the liver at the portal fissure. It conveys blood from the stomach, pancreas, spleen and the intestine. At the porta hepatis, the portal vein divides into three main structures: the left, the right dorsal and the right ventral branches. The left branch which is the largest and main continuation of the portal vein (FOUAD and SAFWAT. 1986, SIDDIG 2002) supplies the papillary process, quadrate and left lobes. The right dorsal branch supplies the small dorsal part of the right lobe and caudate process. The right ventral branch supplies the majority of the right lobe.

In contrast, TADJALLI and AKHAVAN (2003) mentioned that the portal vein has four branches; right branch ramified in different parts of the right lobe, left branch passed to most parts of the liver such as right lobe, quadrate lobe, left lobe and papillary process of the caudate lobe. The caudal branch of the portal vein supplies caudate process and part of the right lobe while the dorsal branch supplies the caudate process and papillary process.

2.1.8 Functions of the liver

The liver possesses considerable functional reserve and regenerative capacity. In healthy animals including camels more than two thirds of the hepatic parenchyma can be removed without significant impairment of hepatic function and normal hepatic mass can be

regenerated in a matter of days (RADOSTITS 2000). Some of these functions include the following:

1. The smooth endoplasmic reticulum of the hepatocyte is responsible for the synthesis of cholesterol and bile acids, degradation of glycogen, and the metabolism and conjugation of bile pigments, xenobiotics or ingested substances, and steroid hormones before their excretion in bile or urine.
2. The rough endoplasmic reticulum of the hepatocyte produces plasma proteins such as albumin and fibrinogen; clotting factors V, VII, VIII, IX and X; and a variety of alpha and beta globulins.
3. Hepatocytes are responsible for the production of bile and specialized portions of their cell membranes form the wall of the canaliculi that carry bile from centrilobular areas to bile ducts within the portal areas. Bile consists of water, cholesterol, bile acids, bilirubin, and other constituents.
4. The liver provides a vast filter for blood entering the liver via the portal vein. Fixed macrophages (Kupffer cells) lining the sinusoids can phagocytose potentially injurious infectious agents before they access the systemic circulation. Hepatocytes can metabolize and render inactive many toxins absorbed into the portal circulation.
5. Mitochondria within the hepatocytes produce energy by oxidative phosphorylation and oxidation of fatty acids. Hepatocytes store glycogen as a readily available energy source (WILLIAM et al. 1995).

2.1.9 Hepatic dysfunction and liver failure

Liver disease is relatively common but often occurs in the absence of specific clinical signs. The liver has great powers of regeneration and more overt clinical signs associated with its failure do not appear until some 70-80% of the functional capacity is lost. Obscure signs of liver disease are therefore much more common than overt signs of liver failure. Signs of failure include central disturbances and are usually acute, even if the underlying liver disease has developed over a protracted period. This hepatic encephalopathy is associated with toxic blood levels of ammonia and intestinal amines, which would normally be detoxified by the liver (MUDRON et al. 2004).

In acute and chronic liver diseases there is occasionally an associated photosensitization. This is an injury of the cutaneous tissues resulting from activation of photodynamic pigments by ultraviolet light present in the sun rays. It is caused by the increased circulating concentration

of phylloerythrin, a photodynamic derivative of chlorophyll, which is normally excreted by the liver (GALITZER and OEHME 1978).

2.1.9.1 Toxic hepatitis

The liver is the most common site of toxic injury for two reasons: the liver receives approximately 80% of its blood supply from the portal vein which drains blood from the gastrointestinal tract. Thus, ingested toxic substances, including plant, fungal, and bacterial products, as well as metals, minerals, and other chemicals that are absorbed into the portal blood, are transported to the liver in high concentrations. Second, the liver possesses the enzymes capable of biotransformation of a variety of endogenous and exogenous substances for elimination from body; this process may also bioactivate some substances to a more toxic form, thereby causing hepatic injury. The common causes of toxic hepatitis in camelids and other animals are either inorganic poisons such as copper (JUNGE et al. 1989), phosphorus, arsenic, possibly selenium or organic poisons like carbon tetrachloride, hexachloroethane, Gossypol, creosols and coal tar pitch, chlorophorm and some anaesthetic agents (GROOM et al. 1995) and copper diethylamine quinoline sulfonate.

Poisonous plants include *Senecio*, *Crotalaria*, *Panicum effusum* and water-damaged *alfalfa* hay. The Fungus *Aspergillus flavus* has been associated with a specific respiratory and enteric syndrome in camels (EL-KHOULY et al. 1992). Alfatoxin contaminated stored camel food can also be toxic when its concentration is 2.5 mg/kg of feed and is considered lethal when found in a concentration of 6.2 mg/kg feed (OSMAN et al. 2004). Ingestion of some insects such as sawfly larvae (*Lophyrotoma interrupta*) can be toxic to the liver (DIVERS et al. 1983, MULLANEY and BROWN 1988, BYARS 2003).

2.1.9.2 Infectious hepatitis

Routes of infection into the liver are haematogenous, direct penetration, and ascending via the biliary system. The most common route is haematogenous because the liver receives both arterial blood and venous blood. The severity of inflammation is dictated by the nature of infectious agents which can be viral such as infectious canine hepatitis virus, rift valley fever virus which were reported in dromedary camels in Sudan, Egypt and Kenya (EISA 1981, ALI et al. 1979, ANONYMOUS 1998), herpes virus, Wesselsbron disease virus and infectious equine anaemia virus) or bacterial (Bacillary haemogloniaemia caused by *Clostridium haemolyticum*, infectious necrotic hepatitis caused by *Colistridium novyi* type B which was reported in dromedary camels by SEIFERT 1992, Tyzzer's disease caused by *Bacillus*

piliformis, leptospirosis caused by *Leptospira grippotyphosa* and liver abscesses which caused by *Fusobacterium necrophorum* or *Corynebacterium psuedotuberculosis* (ROSA et al. 1989).

2.1.9.3 Parasitic hepatitis

Hepatitis caused by migration of helminth larvae such as *Ascaris sp*, *Strongylus sp*, *Fasciola sp* and *Schistosoma sp*, through the liver is common in domestic animals. The migration of the larve throught out the hepatic parenchyma causes local tracks of hepatocelular necrosis accompanied by inflammation. The tracks are eventually replaced with connective tissue leading to the production of fibrous scars on the capsular surface. Some Cestode including members of the genus *Taenia* occur within the hepatobiliary system of domestic animals and may lead to hepatic infection (MALONE 1986). Hydatid liver disease is caused by *Echinococcus granulosus* is one of the most important liver problems in animals and man worldwide (TORGERSON and BUDKE 2003). An incidence of 59.8% of hydatidosis was reported in dromedary camels from different parts of Sudan (OMER et al. 2002, 2004, 2006). *Lamanema chavezii*, is a characteristic helminth of llamas and alpacas in Peru and Chile. However, its overall geographic range has not been well defined (CAFRUNE et al. 2001). The hepatic migration of the immature flukes of *Fasciola hepatica*, a trematode commonly found in sheep, cattle and occasionally other species including camleidae, produces haemorrhagic tracks of necrotic liver parenchyma (ELBIHARI 1985, ZUKOWSKI et al. 1992). These tracks are grossly visible and in heavy infestations are dark red. A variety of signs can follow this migration like acute peritonitis, hepatic abscesses and bacillary hemoglobinuria resulting from the proliferation of *Cloistridum hemolyticum* or *C. novyi* in the resulting necrotic tissue (the so called black liver disease). Mature flukes reside in the larger bile ducts and cause cholangitis or cholangiohepatitis which may lead to stenosis of the duct (BEHM and SANGSTER 1999).

2.1.9.4 Fatty liver

The presence of excessive lipid within the liver is termed fatty liver and occurs when the rate of triglyceride accumulation within hepatocytes exceeds either their rate of metabolic degeneration or their release as lipoproteins. It occurs in cattle, sheep cats, dogs and to a lesser extent in horses.

Fatty liver is not a specific disease entity but it can occur as a sequel to many perturbations of normal lipid metabolism which can be: excessive entry of fatty acid into liver, abnormal hepatocyte function, excessive dietary intake of carbohydrate, increased esterification of fatty

acids to triglycerides, decreased apoprotein synthesis and subsequent decreased production and release of lipoprotein from hepatocytes and impaired secretion of lipoprotein from the liver (SMITH 2002).

Some specific causes of syndromes associated with fatty liver in domestic animals include:

- a. Dietary causes include simple dietary excess in monogastric animals such as a high fat high cholesterol diet. Also deficiencies of cobalt and vitamin B12 have been implicated as causes of fatty liver in sheep and goats.
- b. Ketosis in cattle and pregnancy toxaemia in ewes (HALFORD and SANSOM 1983, EAST 1983).
- c. Endocrine disorders such as diabetes mellitus and hypothyroidism (HAYIRILI 2006).

Liver degenerative changes in camels including cloudy swelling, hydropic degeneration, fatty change and amyloidosis were reported by TEJ SINGH et al. 2006. Liver diseases such as hepatic lipidosis with biliary hyperplasia, cholangiohepatitis, hepatic necrosis, lymphoplasmacytic cholangitis, pericholangitis, septic phlebitis and hydrophic degeneration were reported in Llamas and alpacas (ANDERSON 1999). In a study of fatty liver in llamas and alpacas (TORNQUIST et al. 1999), females were more affected with fatty liver than males; however, the sex distribution was not different from that of the camelid population in the diagnostic laboratory's database. All affected females were either pregnant (54%) or lactating (46%). Most affected camelids were 6 to 10 years old. Anorexia and recent weight loss were common (51.6% of camelids) whereas an infective agent was found in only one llama, and toxins and mineral deficiencies were not recorded.

2.1.9.5 Tumours of the liver

Primary hyperplastic and neoplastic proliferation of the hepatobiliary system can arise from hepatocytes (e.g. hepatocellular nodular hyperplasia or hepatocellular carcinoma), epithelium of the bile ducts (cholangiocellular hyperplasia or carcinoma) and gall bladder (carcinoma), and mesenchymal elements such as connective tissue and blood vessels. Also the liver is a common site of metastasis for many malignancies in dogs (BERGMAN 1985) and in goats (HIGGINS et al. 1985). Multifocal lymphoma was reported in a 7-year old female dromedary camel (*Camelus dromedarius*) which was evaluated for inappetence, weight loss, polyuria, and polydipsia. Upon immunohistochemical staining the neoplastic cells in that animal were uniformly CD3-positive, indicating a T-cell lymphoma (SIMMONS et al. 2005). POTTER and YOUNG 1994 reported hepatic neoplasia in Llama.

2.1.9.6 Liver response to injury

The liver responds to any hepatic parenchymal destruction by three ways:

1. Regeneration of the parenchyma.
2. Replacement by fibrosis.
3. Biliary hyperplasia.

Liver regeneration is the most common response because the liver has an enormous functional reserve and regenerative capacity. However, prolonged regenerative effort often results in nodular proliferations of parenchyma that architecturally distorts the liver. Fibrosis occurs when the destruction of hepatocytes overwhelms the liver's regenerative capacity. This often occurs in the chronic toxic injury and metabolic disorders of hepatocytes. Biliary hyperplasia is a proliferation of new bile ducts within the portal tracts and periportal region and it results from a variety of insults in the liver. Biliary hyperplasia, nodular regeneration of parenchyma and fibrosis are considered to be characteristic features of the end stage liver or liver cirrhosis (WILLIAM et al. 1995).

2.1.10 Diagnosis of liver diseases

The liver is difficult to examine because of its location in the cranial abdomen and because obvious malfunction occurs only after the liver has lost approximately two thirds of its functional capacity. Therefore, hepatic failure is seen only when there is extensive damage to the hepatic parenchyma or there is obstruction to biliary drainage (PEARSON 1999; SCHROTTER et al. 2000). When liver disease is suspected after a general clinical examination, special techniques of palpation, biopsy, and biochemical tests of liver functions, ultrasonography and magnetic resonance image (MRI) can be used to determine further the status of the liver.

2.1.10.1 Palpation and percussion

A general impression of the size of the liver can be obtained by percussion of the area of liver dullness but accurate definition is not usually attempted. Deep percussion or palpation to detect the presence of hepatic pain can be carried out over the area of liver dullness in the posterior thoracic region on the right hand side. Percussion over the entire area is necessary as the pain of a discrete lesion may be quite localized. Palpation is relatively easy in ruminants and small animals but it is unrewarding in horses and pigs because of the thickness of the abdominal wall and the shortness of the flank (RADOSTITS et al. 2000). Palpation can also be applied directly to the liver as in intra-operative ultrasonography (DELLING 2000). In the

evaluation of the current literature there is no reference about palpation and percussion of the liver in the old world camelides.

2.1.10.2 Biopsy

Biopsy of the liver has been used extensively as a diagnostic procedure. It allows microscopic examination of a specimen of liver, which is useful to establish the type of lesion that, depending on the lesion and its cause, may or may not have diagnostic or prognostic value. The technique requires some skill and anatomical knowledge. The most satisfactory instrument is a long, small-calibre trocar and cannula to which is screwed a syringe capable of producing good negative pressure. An exact diagnosis is possible where the histological features are typical (e.g. neoplasia, pyrrolizidine alkaloid toxicosis). The major deficiency of the method lies in the small sample which is obtained, and unless the liver change is diffuse the sample may not be representative. The principal danger is that if the direction of the instrument is at fault it may approach the hilus and damage the large blood vessels or bile ducts. If the liver is shrunken and approach too caudal no sample is obtained. Peritonitis may occur if the liver lesion is an abscess containing viable bacteria. Biopsy can be guided by ultrasonography (MODRANSKY 1986).

2.1.10.3 Biochemical tests of liver functions

Hepatic disease is difficult to diagnose based on clinical findings alone and the use of laboratory tests is necessary. The results and interpretation of such tests, however, depend on the nature of the lesion, the duration and severity of the disease and species variation. Tests which specify the exact nature of the lesion are not available, and a combination of tests is usually necessary to make a diagnosis.

Laboratory tests for diagnosis of hepatic disease can be divided into three categories. The first category includes tests which measure the excretory rate of parentally administered substances such as bromosulfalein. The second category includes tests for the assessment of the hepatic function such as blood glucose, serum proteins, clotting factors, and urinalysis. The third category includes tests for measuring the serum activity of certain enzymes which increase following hepatic injury (CRAIG et al. 1992 and WEST 1989). One of these enzymes is sorbitol dehydrogenase (SDH), which is liver-specific and is released early after hepatocyte damage. SDH has a short half life and therefore declines once the damage ceases. Unfortunately this enzyme is not stable in the blood and the assay must be undertaken immediately after sampling. A second enzyme is glutamic dehydrogenase (GLDH), another

liver specific enzyme with a short half life and whose presence indicates current tissue damage. Because it is nuclear in origin its serum elevation indicates extreme cell damage. It is relatively unstable and requires assay soon after collection. The third enzyme is gamma glutamic transferase (GGT) which is widely distributed in a variety of tissues. It is persistently elevated in both acute and chronic liver diseases and reflects damage to the biliary system. Other enzymes are aspartate amino transferase (AST) and alanine amino transferase (ALT); these enzymes are released early in cell disruption and clear slowly from the circulation. They are not liver specific enzymes because they are also released on disruption of other soft tissues such as skeletal and cardiac muscles. Serum alkaline phosphatase (ALP) levels are used as a test of hepatic excretory function in many animals (GOSSETT and FRENCH 1984).

Total serum bilirubin may be diagnostically useful when it increase in cases like haemolysis (HILALI et al. 2006), but normal values do not rule out liver disease (GRONWALL et al. 1980). Serum albumin analysis is not particularly useful in the diagnosis of liver diseases. However, one of the consequences of chronic liver failure is that the synthesis of albumin decreases. This would indicate that the synthetic function of the liver has been markedly diminished. Such findings usually suggest a diagnosis of liver cirrhosis. Malnutrition can also cause low albumin (hyboalbuminemia) with no associated liver disease PEARSON et al. 1992).

Lipid profiles have been used to predict periparturent problems, and for the diagnosis of metabolic diseases and the assessment of the nutritional status of animals. Serum total lipids, triglycerides and lipoproteins are helpful when interpreted in conjugation with history, clinical signs and laboratory tests (NAZIFI et al. 2002).

2.1.10.4 Ultrasonography

The benefits of ultrasound as a veterinary diagnostic imaging procedure are numerous. Routine examinations have been shown to have no harmful biological effects although constant review is undertaken to ensure this remains the case. Ultrasound is considered a safe procedure for the patient, the operator and nearby personnel, allowing it to be performed in any location without the need for specific safety precautions (PRESTON and SHAWA 2001). It is non-invasive and therefore well tolerated in unsedated animals, making serial examinations to monitor progression of the condition, response to treatment or to practice scanning techniques possible (NYLAND and MATTON 2002). A complete ultrasonographic assessment of the liver can provide detailed information about the size, position and the parenchymal pattern of the liver. Ultrasonography has become an essential imaging tool for

identifying abnormalities of the liver parenchyma, biliary tract and vascular system. In many cases ultrasonography has replaced radiology as the initial imaging procedure in screening for liver disease. Ultrasonography proved to be a useful tool for the diagnosis of many liver diseases in many animal species. The list includes liver tumours (BRAUN et al. 2005), thrombi in the caudal and cranial vena cava (BRAUN et al. 1992, BUENO et al. 2000, MOHAMED et al. 2004a), focal fatty liver (MOHAMED et al. 2003), and hepatic abscess (ITABISASHI et al. 1987) in cattle. A recent report (SCOTT et al. 2005) has described serial diagnostic imaging finding in hepatic fasciolosis using ultrasound in sheep. In dogs and cats many liver abnormalities can be diagnosed sonographically such as cholelithiasis (NYLAND and FISHER 1990) and nodular hyperplasia (LAMB 1998), in the dog and congenital portosystemic shunts (LAMB 1996) and biliary obstruction (LEVEILLI et al. 1996) in the cat.

2.1.10.5 Magnetic Resonance Imaging (MRI)

Advances in radiographic imaging using non-invasive techniques are valuable in establishing the diagnosis of hepatic lesions. MRI and CT have been successfully used as diagnostic tools of *Fasciola hepatica* in sheep (GONZALO-ORDEN et al. 2003). This method is not applicable in dromedary camels as they are too large animals. This method is also expensive.

2.1.11 Haematological and biochemical parameters of the one humped camel

Among the domestic animals, camel blood is unique because: a) it shows the highest total leukocyte count (SARWAR et al. 1993), b) MCHC is considerably high in relation to other species (JAIN 1986) and c) albumin is the predominant serum protein fraction (SARWAR et al. 1991). Haematological and biochemical determination of serum constituents can provide valuable information relating to nutrition, sex, age and physiological status of the animal (OSMAN et al. 2000). A review of the literature on camelids clinical pathology reveals that the available data is inconsistent, and has a wide range of values which are sometimes in disagreement with each other. Moreover, figures reported as normal reference values were obtained from relatively small and often undefined groups of animals with no reference to age, sex, nutritional status and environmental and management conditions. The number of parameters studied was sometimes limited. Tables 6 and 7 summarize the values for different haematological and biochemical parameters of camels recorded by different authors.

Table 6: Literature values for haematological parameters of the one humped camel (*Camelus dromedarius*)

Parameter	Range
Red Blood Cells (RBC) ($10^{12}/L$)	(7.0-10.55) ¹ , (6.0-12.0) ²
Packed Cell Volume (PCV) (L/L)	(0.16-0.42) ¹ , (24.0-32.0) ²
Haemoglobin (Hb) concentration (g/dl)	(11.0-16.0) ¹ , (8.4-14.3) ²
Mean Corpuscular Volume (MCV) (fl)	(14.0-48.4) ¹ , (36.0-55.0) ³
Mean Corpuscular Haemoglobin (MCH) (pg)	(11.8-20.78) ¹ , (16.0-22.0) ³
Mean Corpuscular Haemoglobin Concentration (MCHC) (g/dl)	(33.0-61.73) ¹ , (26.0-50.0) ³
White Blood Cells (WBC) (g/L)	(7.0-17.0) ¹ , (8.8-30.0) ²
Lymphocytes (%)	(45-70) ²
Neutrophils (%)	(27-50) ²
Eosinophils (%)	(0-2) ²
Monocytes (%)	(0-1) ²

1: MOHAMED and HUSSEIN 1999; 2: NYANG et al. 1997; 3: BOGIN 2000.

Table 7: Literature values for biochemical parameters of the one humped camel (*Camelus dromedarius*)

Parameter	Range
AST (IU/L)	(34.0-148.0) ¹ , (4.8-12.0) ²
ALT (IU/L)	(6.0-28.0) ¹ , (0.0-4.0) ²
ALP (IU/L)	(40.0-176.0) ¹ , (6.2-16.8) ²
GGT (IU/L)	(12.0-28.0) ¹
TG (mmol/L)	(0.17-036) ⁴
GLDH (IU/L)	(0.0-124.0) ⁵
ALB (g/L)	(30.0-44.0) ³
BIL (mmol/l)	(0-17.10) ¹ , (0.20-0.40) ³

1: MOHAMED and HUSSEIN 1999; 2: NYANG et al. 1997; 3: BOGIN 2000; 4: BENGOUMI et al. 1997 ; 5: FAYE et al. 1995.

2.2 Ultrasound

2.2.1: General principles

Diagnostic ultrasound has been used for more than 30 years without confirmed adverse effects neither to operator nor patient. It is accepted that the potential risk of ultrasound is far outweighed by beneficial imaging possibilities (NYLAND and MATTON 1995). This technique is normally used in evaluation of soft tissue, for assessment of the size, shape and location of static and non-static structures. The image represented by ultrasonography is usually a two dimensional one (2-D). A good knowledge of the anatomical cross-section of the three dimensional object is therefore a prerequisite for interpretation of the image (PARK et al. 1981, FEENY et al. 1991).

2.2.2 Properties of ultrasound waves

Diagnostic ultrasound employs high frequency sound waves (usually 2-10 megahertz, or millions of cycles per second) which are outside the range of human hearing (KREMKAU 1993).

2.2.3 Image definitions

Air, bone and mineralised structures have strong reflecting surfaces. That is, the ultrasound waves do not penetrate to the structures lying behind them. An acoustic shadow is thus created. The result of this is bright reflection known as the hyperechoic effect. In contrast, fluids produce an anechoic effect, a black image, since the reflection of the ultrasound waves is reduced or absent. Structures with densities lying between those showing effects of hyperechoicity and anechoicity produce a range of grey-scale images. These reflections are compared with hyperechoic effects and may be described as hypoechoic. Fat causes attenuation of the ultrasound due to an increased absorption of the ultrasonic ray resulting in a poor resolution (EBERSPÄCHER 1991).

The acoustic impedance of tissue is determined by density and stiffness of the medium (KREMKAU 1993). An increase in either the density or the stiffness of a medium increases the acoustic impedance. Increases in the propagation speed also increase the acoustic impedance. Only small differences in acoustic impedance occur between the various soft tissues and organs in the body, whereas large differences exist between the soft tissues and bone or structures containing air (NYLAND and MATOON 1995).

The acoustic impedance of tissue is shown in the Table (8).

Table 8: Acoustic impedance of different tissues (CURRY et al. 1990)

Tissue	Acoustic impedance (10^6) kg/m² sec.
Air	0.0004
Fat	1.38
Water (50)	1.54
Brain	1.58
Blood	1.61
Kidney	1.62
Liver	1.65
Muscle	1.70
Lens	1.84
Bone	7.8

2.2.4 Resolution

Three types of resolution are found in ultrasound imaging, axial resolution, lateral resolution and elevation resolution.

Axial resolution is the minimum reflector separation required along the direction of the ultrasound travel (scan time) to produce separate echoes (NYLAND et al. 1995). This resolution depends on the transducer frequency and it can not be more than half the pulse length because of the overlap of returning echoes reflected off interfaces spaced closely together (CURRY et al. 1990), (Table 9).

Lateral resolution refers to the ability to resolve adjacent point's perpendicular to the axis of the sound beam along the plane of the scan (MERRITT 1998), it depends on the ultrasound beams diameter (width) which varies with the transducer frequency and the distance from the transducer. Acceptable lateral resolution is usually found for several centimetres along the beam axis on either side of the focal point (focal zone).

Elevation (azimuth) resolution refers to the ability to resolve adjacent points perpendicular to the beam axis and scan plane (MERRITT 1998). This resolution is determined by the beams

diameter (height) which also varies with the transducer frequency and the distance from the transducer.

Table 9: Depth and axial resolutions obtained by different transducer frequencies

(NYLAND and MATTON. 1995)

Frequency	Imaging depth (cm)	Axial Resolution (mm)
2.0	30	0.77
3.5	17	0.44
5.0	12	0.31
7.5	8	0.20
10.0	6	0.15

2.2.5 Transducers

Ultrasound transducers are frequently referred to as probes or scan heads. At the hub of the transducer is a single or multiple piezoelectric (pressure-electric) crystals which are deformed (excited) by electric current, omitting ultrasound (RANTANEN 1993). Therefore ultrasound transducers convert electric voltage into ultrasound energy and incident ultrasound back into electrical voltage. There are several types of transducers which vary in image shape.

2.2.5.1 Linear array transducer

These are solid state transducers composed of a row of arrays of ultrasound crystals that are electronically fired in succession forming a rectangular image (REEF 1991). The width of the image is approximately equal to the length of the array.

2.2.5.2 Curvilinear array transducer

The curve linear array transducers are linear arrays shaped into convex curves. They produce a sector image that has a wider field of view than that of linear array.

2.2.5.3 Sector transducers

Sector transducers are designed with one or more crystals that are mechanically oscillated or rotated to form a pie-shaped image. In the sector transducers the focal zone is fixed and can not be electronically moved (CURRY 1990).

2.2.5.4 Phased array transducers

Phased array transducers are composed of multiple crystals in rectangular format that are electronically excited as a group with small time difference (phasing), which results in the sound pulse being sent out in a specific direction that is constantly changing. These transducers have a limited near field visibility compared with the linear array or curvilinear array transducer (POWIS 1993).

2.2.6 Transducers frequencies

A wide range of transducer frequencies is currently available from low frequency transducers imaging at 2.0 MHZ to high frequency transducers imaging at 10.0 MHZ. Ultra high frequency transducers exist for specialty imaging. The lower the transducer frequency the deeper the penetration, but less resolution. Routinely, 7.5 MHZ penetrates a depth of 4-6 cm, 5 MHZ penetrates 10-12 cm, 3.5MHZ penetrates 15-20 cm and 2.5 MHZ penetrates 25-30 cm. To reach superficial structures a stand off pad can be used to transfer the focal zone to a higher level (ALLEN and STONE 1990).The selection of the appropriate transducer for an examination depends upon the structure being evaluated, and the depth of the area from the transducer surface and the acoustic properties of the intervening tissues (POWIS 1986).

2.2.7 Focusing

Focusing the beam results in reduced beam diameter and improved lateral resolution (POWIS 1986). Focusing of the beam can occur only in the near field of the ultrasound beam. (KREMKAU 1993). Beam focusing characteristics are variable for each transducer and frequency and should be obtained from the manufacturer at the time ultrasound equipment is purchased. The focal distance and focal zone can be verified with an ultrasound test object. A number of devices are available commercially for testing imaging performance. Focusing can be performed dynamically or manually.

2.2.8 Modes of echo Display

There are three types of echo display; these are A mode, M (Time Motion) mode and B mode. The last two modes are used more frequently in clinical applications in veterinary medicine.

2.2.8.1 A mode

This mode refers to amplitude mode where amplitude of the returning echo is displayed as a spike from a vertical base line.

2.2.8.2 M Mode (Time motion mode)

This is a 1-D or ice-pick view of depth displayed against time. It is used in echocardiography to obtain high resolution images of the cardiac structures moving over time (REEF 1991).

2.2.8.3 B Mode

B mode or Brightness mode is a 2-D display of the returning echoes; the amplitude of the returning echo stored in memory is converted to the brightness of a dot that represents that returning echo (NYLAND et al. 1995). The location of the dot corresponds to the location of the echo reflector within the tissue cross section. This cross section may be obtained as a single frozen image (static B mode) or numerous frames can be acquired and displayed within one second and this is called (Real time B mode).

2.2.9 Artifacts

Imaging artifacts are displayed phenomena that do not properly represent the structures imaged (KREMKAU et al. 1986).

2.2.9.1 Reverberation artifacts

These types of artifacts are produced due to the sound pulses bouncing back and forth between two interfaces. The number of reverberation images depends on the penetration power of the beam and sensitivity of the probe (CURRY 1984).

Also reverberation differs according to the size, location, nature, and number of the reflectors encountered. Comet tail artifacts represent one type of reverberation artifact and it is easily recognized by series of closely spaced, discrete, bright and small echoes. Metallic objects in the gastrointestinal tract (pellets) or a biopsy needles can produce comet tail artifacts (WENDELL 1981).

2.2.9.2 Mirror image artifacts

These types of artifacts are produced when rounded strongly reflective interfaces such as diaphragm, lung interface are encountered (GARDNER et al. 1980).

2.2.9.3 Side-lobe artifacts

Side-lobe artifacts are produced by minor beams of ultrasound beams (LAING et al. 1982).

2.2.9.4 Slice thickness artifacts

It occurs when part of the ultrasound beam's width is outside a cystic structure and the echoes originating from this part of the beam are erroneously displayed within the cystic structure on the image (KREMKAU et al. 1986).

This type of artifacts occurs in urinary bladder and gall bladder and it mimics the presence of sedimentation (pseudo-sludge) in these organs (FISKE et al. 1982).

2.2.9.5 Refraction

The refraction of the ultrasound beam occurs when the incident sound wave transverses tissues of different acoustic impedance. Ghost artifacts or double image and split image artifacts are common artifacts in pelvic examination in women (SAUERBREI 1985).

2.2.9.6 Shadowing

Acoustic shadowing results from nearly complete reflection or absorption of the sound and this artifacts can be produced by gas or bone. The greater the amount of the beam's cross section attenuated, the greater the shadowing (KREMKAU et al. 1986).

2.2.9.7 Enhancement

Acoustic enhancement means that when the sound waves pass through certain tissue or other fluid filled structures, the image is brighter or more echogenic than expected. This kind of artifact is helpful in differentiating cystic structures from solid, hypoechoic masses (KREMKAU et al. 1986).

3 Animals Materials and Methods

3.1 Animals

The study was carried out using 45 (28 males, 17 females) clinically healthy one-humped camels (*Camelus dromedarius*). Their age ranged between 1.5 and 18 years old. These camels were studied in Egypt (27 camels, 17males, 10 females), Sudan (14 camels, 9 males, 5 females), and Germany (4 camels, 2 of each sex). Camels in Egypt and Sudan are considered were designed as Group I (n=41), whereas camels studied in Germany were designed as Group II (n=4).

Camels from Egypt were ultrasonographically examined for the purpose of establishing the image of the healthy camel liver. Blood samples were obtained before the camels were slaughtered (Kerdasa slaughterhouse). Livers were then examined post-mortem for abnormal lesions or colour change. Animals with gross liver lesions were excluded from the study. Haematological and biochemical parameters were not investigated in camels studied in Sudan.

3.2 Materials

3.2.1 Haematological and biochemical analyzers

Haematological and biochemical studies were conducted automatically (Hitachi 912 Automatic Analyser, Roche Diagnostics GmbH, Mannheim, and ADVIA 120 with software Bayer Diagnostics).

3.2.2 Test Kits

Test kits obtained commercially (Roche Diagnostics GmbH, Mannheim and Randox Laboratories GmbH, Krefeld) were utilized for the determination of biochemical parameters.

3.2.3 Ultrasound machine

Two ultrasound machines were used. Logic 100 from General electric (GE)[®] (Figure 3) was used to examine animals in Germany and Sudan whereas, ultrasound machine from Kontron medical company, Vetson color[®] (Figure 4) was used to examine animals in Egypt. This was a mobile, two dimensional imaging (2D) ultrasound machine with the following specifications:

- Real time (B and M) and in colour Doppler mode.
- Frame rates up to 200 fps in two dimensions and up to 25 fps in CFM (Colour Flow Mapping).
- High resolution (512x512 pixels) coloured monitor with a size of 10 inch.

- Cine mode image memory with up to 282 images depending on image resolution.
- Dynamic focusing and dynamic adjustment of receiver bandwidth of each depth.

3.2.4 Transducers

The transducer which was used for camel examination in Sudan and Germany was convex array transducers (C55) with a frequency of 3.5-5 MHz. The transducer for the Vetson color[®] was a convex array transducer (3.5 MC) with the following specifications:

- Bandwidth is 2-5 MHz.
- Maximum exploration depth is 30 cm.
- Scanning angle is 30-90°.



Figure 3: Ultrasound machine Logic 100 from General Electric (GE).



Figure 4: Ultrasound machine (Veston color®).

3.3 Methods

3.3.1 Pilot Study

This pilot study was made for the reason that ultrasonographic examination of the camel liver had never been described prior to this study. The aim of the pilot study were:

1. To choose the practical position to examine the camel liver ultrasonographically in order to obtain a good image in a safe way. Standing and sitting positions were tried.
2. To differentiate the various vascular structures, livers of slaughtered camels were ultrasonographically examined in a water bath.
3. To determine the area of liver examination, the right side of the abdomen was evaluated.

3.3.2 Restraining of camels

The sonographical examination study was done in sternal recumbency position because this position was the most satisfactory position for clinical examination. In this position animal movement is minimized and hence there is no risk to the examiner or to the examination

equipment. Animals were restrained by three ropes using the traditional method; that one rope was tied over the nostrum, a second rope crosses the neck and turns over the forelimb locking the carpal joint in a flexion position, a third rope was used for the hind limb, fixing each fetlock joint and passes over the lumbosacral region (Figures 5, 6 and 7).

3.3.3 Clinical examination

The temperature was taken with a rectal thermometer. The frequency of respiration was determined by inspection of the respiratory movements in the flank region and auscultation of the trachea, and was expressed as breath/minute. The heart rate was determined by auscultation of the cardiac area or from the pulse rate, determined by palpation of the tibial, middle cocccgeal or femoral arteries, was expressed as beats/minute.

3.3.4 Body weight estimation

The equation described by RAMADAN (1994) was used for determining the weight of each individual camel. Girth measurements were obtained after restraining the animals in the sternal recumbency position. The body weight was calculated as follows:

$$\text{Weight (Kg)} = 2.297 \times 10^{-5} \times (\text{Girth [cm]})^3 + 104.2$$

3.3.5 Measurement of the hump

The body condition of a camel was estimated by viewing the hump which reflects the internal fat reserve and provides a good correlation with total body fat. Circumference and height of the hump in each individual camel were measured using measuring tape.

3.3.6 Preparation of the camels

Hair was clipped from a rectangular area on the right abdominal side and the surface was subsequently washed with soap and water. The area was defined cranially by the 5th intercostal space (ICS), caudally by a handbreadth from the last rib, dorsally by a handbreadth below the tips of the vertebral spine and ventrally by the border of the sternum. Transparent gel (GYROLUX[®]) was then applied to this area for the purpose of the scan.

3.3.7 Blood collection and serum preparation

Approximately 20 ml of blood was collected aseptically from the jugular vein in two sets (10ml each). The first set was collected into vials (SARSTEDT[®]) containing ethylenediamine tetraacetic acid (EDTA) as anticoagulant for haematological studies. The second set was

collected into silicon-coated vacuum containers (SARSTEDT®) for biochemical analysis. Serum was separated in the latter samples by centrifugation at 2700g for 10-15 minutes and immediately assayed or stored at -20°C.

3.3.8 Haematological Studies

Haematological parameters were estimated with an automated haematological analyzer (ADVIA 120 with software from Bayer Diagnostics.). The analyzer determines the red cell count (RBC), packed cell volume (PCV), haemoglobin (HB) concentration, mean corpuscular volume (MCV) and total white cell counts (TWBC). The mean corpuscular haemoglobin (MCH) and the mean corpuscular haemoglobin concentration (MCHC) were then calculated according to the formulae of MILLS and VALLI (1988). Leukocyte differential cell count was performed microscopically.

3.3.9 Biochemical Studies

Biochemical parameters including alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), gamma glutamic dehydrogenase (GLDH), triglycerides (TG), bilirubin (BIL) gamma glutamic transferase (GGT) and albumin (ALB) were automatically analysed using a Hitachi 912 Automatic Analyzer (Roche Diagnostics GmbH, Mannheim) using kits from Roche Diagnostics GmbH, Mannheim and Randox Laboratories GmbH, Krefeld as shown in Table (10).

3.3.10 Ultrasonographic Examination

Ultrasonographic examination was performed in accordance with the following protocol:

- The liver was examined from caudal (flank region) to cranial (5th intercostal space) and from dorsal to ventral in every intercostal space.
- After application of transmission gel to the transducer, the area immediately caudal to the last rib (flank region) was examined for the location of the liver.
- The transverse process of the 2nd lumbar vertebra was considered as a reference point (RP).
- In the last intercostal space (11th) the transducer was placed dorsally and parallel to the rib and moved slowly ventrally to visualize the liver.
- Initially, the texture of the liver, hepatic and portal veins and visceral and diaphragmatic surfaces were examined.
- The dorsal margin was determined by measuring the distance between the dorsal

margin of the liver and the RP using a measuring tape.

- Determination of the ventral margin was obtained following the same procedure.
- The caudal vena cava, diameter of the caudal vena cava, the portal vein and its branches in the hepatic parenchyma, diameter of the portal vein, the thickness of the liver over these vessels, the depth of these vessels and thickness of the liver were also visualized.
- The distance between the point of the elbow joint and the point where the *porta hepatis* is clearly visible was measured.
- The ultrasonographic image was electronically stored for determination of the diameter of the caudal vena cava and the portal vein as well as the tissue thickness over these vessels.
- Appropriate measurement was then made electronically on the ultrasonogram by means of cursors.
- This procedure was repeated cranially to the level of the 5th intercostal space depending on the presence of each of the above mentioned structures (e.g caudal vena cava and portal vein).

All obtained images were stored in the memory card mounted in the ultrasound machine after labelling it with a number indicative of each camel.



Figure 5: Camel in the sternal recumbancy position

Table 10: Summary of the methods and resources for biochemical tests

Parameter	Methods	Test kit
Albumin	Colored test with Bromcresol green	1
Bilirubin	Method after Jendrassik und Grof	2
Triglyceride	Enzymatic colored test after Wahlefeld, GPO-PAP-Methode	1
ALP	Colored test with p-Nitrophenylphosphat *	1
AST	UV-Test *	1
ALT	UV-Test *	1
GGT	Enzymatic colored test after Szasz	1
GLDH	UV-Test **	1

Note:

All tests were performed at 37°C

* Standardized Methods of the IFCC (International Federation of Clinical Chemistry) were applied.

** Optimized Standard methods of the GSCC (German Society of Clinical Chemistry) were performed.

Test kit: 1- Roche Diagnostics GmbH, Mannheim 2- Randox Laboratories GmbH, Krefeld.



Figure 6: Method of controlling the forelimb



Figure 7: Methods of controlling the hind limbs

3.3.11 Estimation of the liver size

Due to the fact that different camels have different hump sizes, we choose the transverse process of the 2nd lumbar vertebra as a reference point for measuring the dorsal and ventral liver margins. For the determination of the whole length of the liver which can be ultrasonographically examined, an imaginary triangle was obtained by drawing a line (representing the length of the liver) connecting the two ventral lines (Figures 8 and 9). The length of this line was calculated using the conventional Archimedian a geometrical theory that the square of the line facing the right angle is equivalent to the summation of the squares of the other two lines of a triangle.

3.3.12 Statistical analysis

Statistical package for social science (SPSS) program was used to analyse results of this experiment. Different tests within this program were used namely, descriptive statistics, correlation, one way analysis of variance (ANOVA) and regression depending analysis, (commercial name of package).

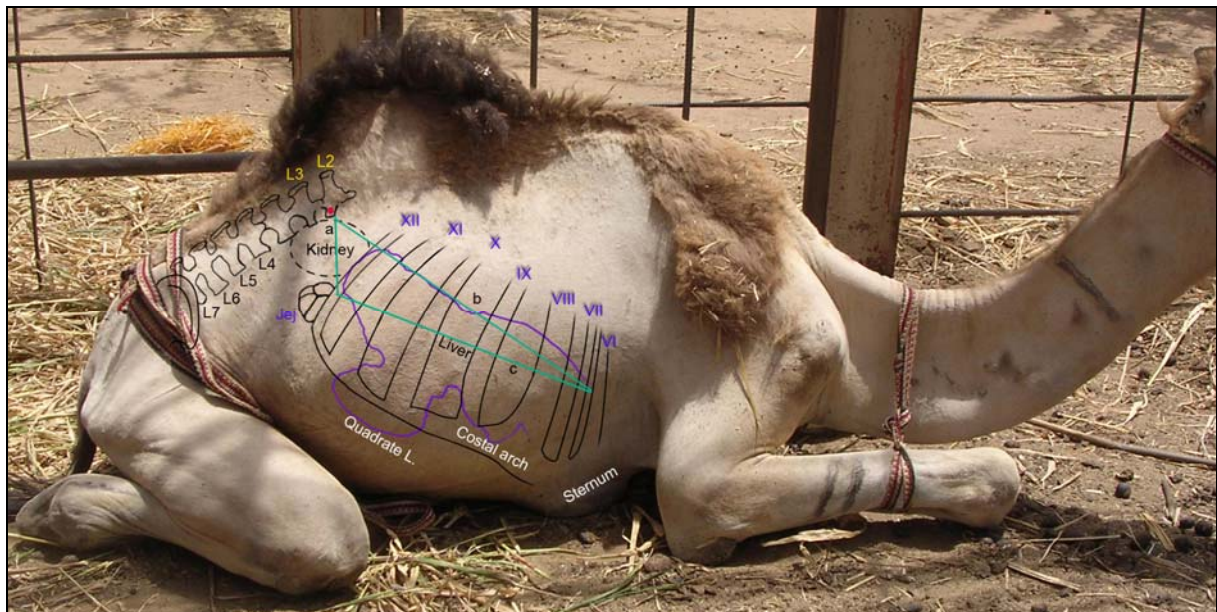


Figure 8: Schematic diagram showing area of liver examination in a sitting camel

a: Distance between the transverse process of the 2nd lumbar vertebra (RP) and the ventral margin of the liver in the 11th ICS.

b: Distance between the transverse process of the 2nd lumbar vertebra (RP) and the dorsal margin of the liver in the 6th ICS.

c: Imaginary line representing the length of the liver which can be ultrasonographically examined.

4 Results

4.1 Pilot Study

The following points were obtained from the pilot study:

1. Sternal recumbency position was found to be the most suitable, practicable and safe position to perform clinical examination, blood sampling and liver ultrasonographic examination.
2. Ultrasonographic examination of the liver in a water bath revealed that the organ is homogenous with a medium level of echogenicity. Hepatic vessels appear black (anechoic).
3. The area defined cranially by the 5th intercostal space (ICS), caudally by a handbreadth from the last rib, dorsally by a handbreadth below the tips of the vertebral spine and ventrally by the border of the sternum was the best area where most of the liver can be examined, (Figures 10-12).

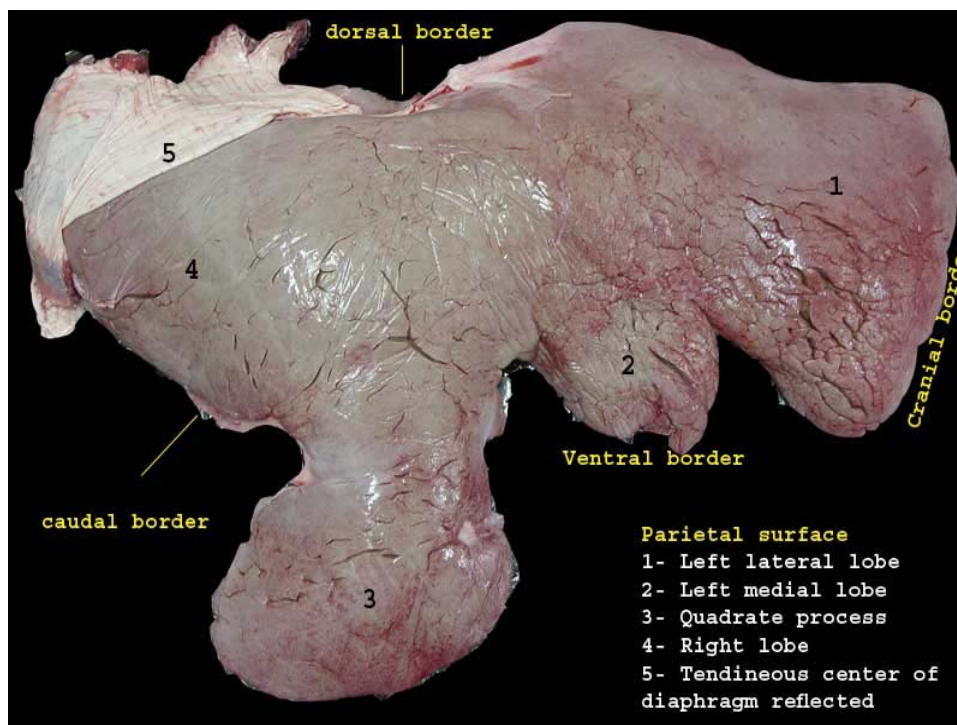


Figure 9: The diaphragmatic surface of the liver

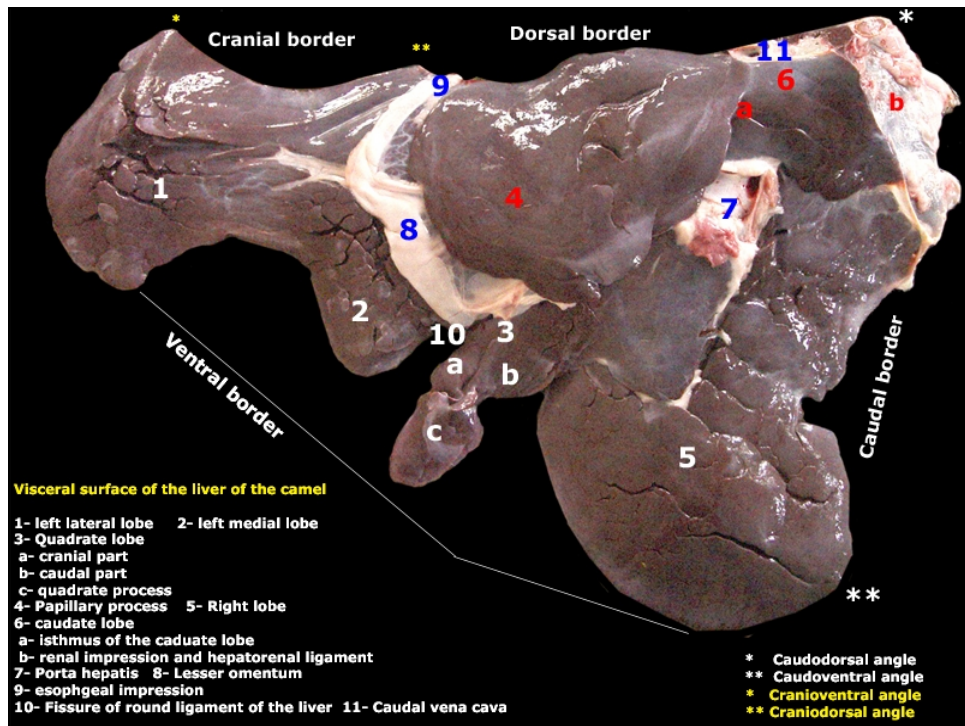


Figure 10: The visceral surface of the liver

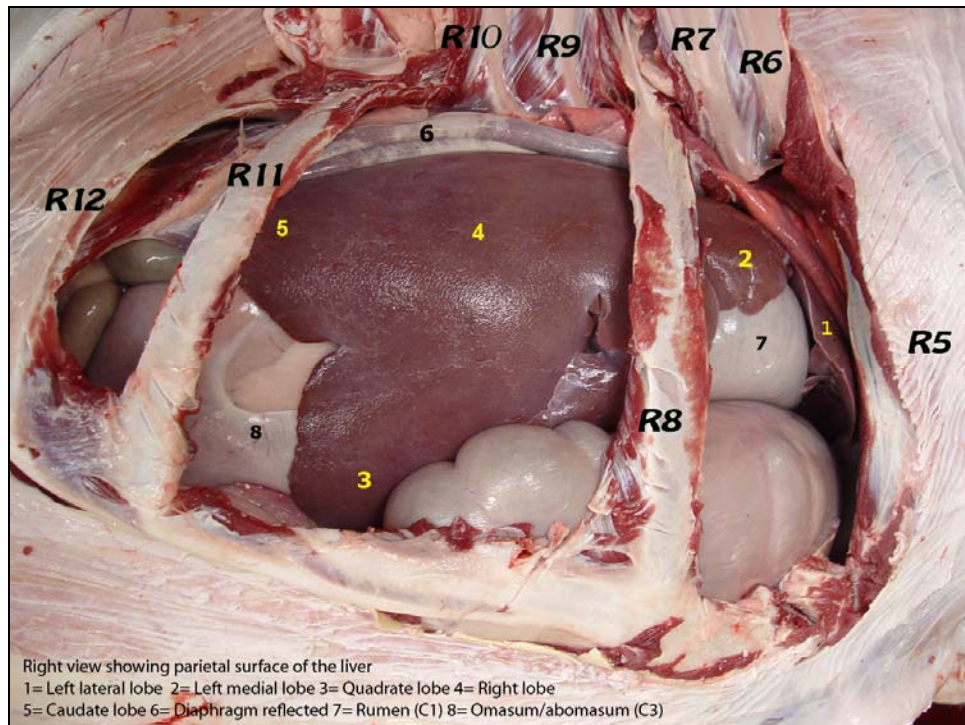


Figure 11: The liver in situ

4.2 Clinical examination

Table 11 summarizes the ranges of body temperature, pulse and respiratory rates in dromedary camels examined in Egypt and Sudan (group I) and in Germany (group II). As can be seen from that table, camels in group I had higher temperature, pulse and respiratory rates than those in group II

Table 11: Results of clinical examination (body temperature, pulse and respiratory rates) of dromedary camels in Groups I and II

Group Number	Body Temperature Range (°C)	Pulse Rate Range (beats/min)	Respiratory Rate Range (breath/min)
Group I (n=41)	35.8-40.0	35-55	10-22
Group II (n=4)	34.5-36.4	30-45	9-14

4.3 Estimation of bodyweight

Results of body weight estimation in Group I and II are summarized in Table 12. Group I camels were generally lighter than group II.

Table 12: Ranges of body weight estimation in dromedary camels in Groups I and II

Group Number	Body Weight Range (kg)
Group I (n=41)	350-550
Group II (n=4)	400-600

4.4 Hump height and circumference

There was a significant difference ($P \leq 0.05$) between the height and circumference of hump in the dromedary camels examined in both group as summarized in Table 13.

Table 13: Mean and standard deviation values (cm) of the height and circumference of the humps in dromedary camels in Groups I and II

Group Number	Height (Mean \pm SD) cm	Circumference (Mean \pm SD) cm
Group I (n=41)	23.1 \pm 6.1	87.6 \pm 35.9
Group II (n=4)	38.3 \pm 9.9	139.0 \pm 21.7

4.5 Haematological parameters of dromedary camels examined in Egypt and Germany

Tables 14 and 15 summarized the range, means, and standard deviation values of, RBC, Hb, PCV, MCV, MCH, MCHC, WBC, neutrophils, lymphocytes, monophils and eosinophils of dromedary camels examined in Egypt and Germany. In both groups there was a significant positive correlation between RBC, Hb and PCV values ($P \leq 0.01$).

Table 14: Haematological values of dromedary camels studied in Egypt (n=27)

Parameter	Range	Mean \pm SD
RBC (T/l)	9.90 – 19.38	12.15 \pm 2.22
Hb (mmol/l)	5.90 – 9.70	7.97 \pm 0.98
PCV (l/l)	0.30 – 0.54	0.45 \pm 0.006
MCV (fl)	35.50 – 44.40	39.34 \pm 2.64
MCH (fmol)	0.63 – 0.80	0.69 \pm 0.005
MCHC (mmol/l)	17.50 – 18.04	17.78 \pm 0.16
WBC (G/l)	5.80 – 31.40	15.20 \pm 7.11
Neutrophils (%)	37.0 – 57.0	68.0 \pm 4.56
Lymphocytes (%)	15.0 – 37.0	24.3 \pm 5.46
Monophils (%)	1.0 – 10.0	5.2 \pm 2.56
Eosinophils (%)	0.0 – 8.0	2.5 \pm 1.48

4.6 Biochemical parameters of dromedary camels examined in Egypt and Germany

Range, mean and standard deviation values of biochemical parameters including alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), gamma glutamic dehydrogenase (GLDH), triglycerides (TG), bilirubin (BIL) gamma glutamic transferase (GGT) and albumin (ALB) of dromedary camels studied in Egypt and Germany are summarized in Tables 16 and 17.

Table 15: Haematological values of dromedary camels studied in Germany (n=4)

Parameter	Range	Mean ± SD
RBC (T/l)	6.87 – 11.11	8.39 ± 1.96
Hb (mmol/l)	3.40 – 7.30	6.18 ± 1.86
PCV (l/l)	0.20 – 0.41	0.29 ± 0.09
MCV (fl)	29.20 – 37.40	34.15 ± 4.0
MCH (fmol)	0.49 – 0.77	0.66 ± 0.13
MCHC (mmol/l)	7.00 – 22.81	18.84 ± 2.68
WBC (G/l)	11–19.7	13.27± 4.28
Neutrophils (%)	35.0 – 55.0	67.7 ± 9.63
Lymphocytes (%)	19.0 – 41.0	28.1 ± 9.1
Monophils (%)	1.0 – 3.0	1.7 ± 0.96
Eosinophils (%)	1.0 – 3.0	2.5 ± 1.0

Table 16: Biochemical parameters of dromedary camels studied in Egypt (n=27)

Parameter	Range	Mean ± SD
Aspartate Amino Transferase (AST) IU/L	86.5 – 192.6	138.3 ± 39.4
Alanine Amino Transferase (ALT) IU/L	7.2 – 25.00	15.3 ± 5.9
Albumin (ALB) G/l	28.1 – 43.7	35.4 ± 4.1
Bilirubin (BIL) µmol/l	0.30 – 2.2	1.7 ± 0.43
Triglyceride (TG) mmol/l	0.12 – 0.87	0.38 ± 0.02
Alkaline Phosphatase (ALP) IU/l	31.0 – 87.0	55.5 ± 18.9
Gamma Glutamic Transferase (GGT) IU/l	6.0 – 33.5	12.14 ± 7.07
Glutamic Dehydrogenase (GLDH) IU/l	2.8 – 29.3	12.02 ± 6.8

Table 17: Biochemical parameters of dromedary camels studied in Germany (n=4)

Parameter	Range	Mean \pm SD
Aspartate Amino Transferase (AST) IU/l	100.0 – 185.0	139.3 \pm 36.0
Alanine Amino Transferase (ALT) IU/l	5.0 – 8.9	6.5 \pm 1.9
Albumin (ALB)G/l	26.0 – 34.4	30.1 \pm 3.4
Bilirubin (BIL) μ mol/l	1.4 – 1.9	1.6 \pm 0.24
Triglyceride (TG) mmol/l	0.4 – 0.8	0.6 \pm 0.02
Alkaline Phosphatase (ALP) IU/l	45.0 – 190.0	149.8 \pm 70.1
Gamma Glutamic Transferase (GGT) IU/l	0.22 – 9.88	5.9 \pm 4.07
Glutamic Dehydrogenase (GLDH) IU/l	5.2 – 13.1	9.5 \pm 3.3

4.7 Results of ultrasound examination

4.7.1 Liver location

The long axis of the dromedary liver extended from caudodorsal to cranioventral in the right lateral side of the abdomen. The distance between the transverse process of the 2nd lumber vertebra and the dorsal liver margin in camels examined in Group I (Egypt and Sudan) ranged from 12.9 \pm 3.9, 19.2 \pm 4.4, 27.7 \pm 6.2, 36.6 \pm 7.2, 45.6 \pm 6.7 and 52.7 \pm 9.3 cm in the 11th, 10th, 9th, 8th, 7th and 6th intercostal spaces respectively as shown in Table 18. Mean and standard deviation values of this distance in the same intercostal spaces ranged from 14.8 \pm 3.7, 26.3 \pm 3.4, 35.5 \pm 4.9, 50.8 \pm 10.8, 58.7 \pm 9.8 and 78 \pm 0.0 cm in camels examined in Group II (Germany) (Table 19). Variations between this distance in different intercostal spaces was found to be significant ($P \leq 0.05$) in all examined camels.

The distance between the transverse process of the 2nd lumber vertebra and the ventral margin of the liver in the 11th, 10th, 9th, 8th, 7th and 6th intercostal spaces was found to be 21.9 \pm 10.1, 24.7 \pm 6.2, 36.9 \pm 10.4, 42.6 \pm 7.1, 49.9 \pm 7.5 and 55.8 \pm 9.2 cm in Group I camels and 17.3 \pm 3.5, 33.5 \pm 7.0, 45.8 \pm 10.5, 63.8 \pm 4.3, 67.7 \pm 10.8 and 78.0 \pm 0.0 cm in Group II camels (Tables 20 and 21). Variations between the distance in different intercostal spaces were significant ($P \leq 0.05$) in all examined camels.

Mean and standard deviation values of the distance between the transverse process of 2nd lumbar vertebra and the dorsal and ventral liver margins in Groups I and II are shown in Figures 12 and 13.

Table 18: Mean and standard deviation values of the distance (cm) between the transverse process of the second lumbar vertebra and the dorsal margin in different intercostal spaces group I dromedary camels.

Number of the reference ICS	Number of camels	Mean ± SD
11 th	41	12.9 ± 3.9 ^a
10 th	41	19.2 ± 4.4 ^b
9 th	41	27.7 ± 6.2 ^c
8 th	41	36.6 ± 7.2 ^d
7 th	38	45.6 ± 6.7 ^e
6 th	27	52.7 ± 9.3 ^f

Small case letter indicates significant difference ($P \leq 0.05$)

Table 19: Mean and standard deviation values of the distance (cm) between the transverse process of the second lumbar vertebra and the dorsal margin in different intercostal spaces in dromedary camels studied in group II

Number of the reference ICS	Number of camels	Mean ± SD
11 th	4	14.8 ± 3.7 ^a
10 th	4	26.3 ± 3.4 ^b
9 th	4	35.5 ± 4.9 ^c
8 th	4	50.8 ± 10.8 ^d
7 th	3	58.7 ± 9.8 ^e
6 th	1	78.0 ± 0.0 ^f

Small case letter indicates significant difference ($P \leq 0.05$)

Table 20: Mean and standard deviation values of the distance (cm) between the transverse process of the second lumbar vertebra and the ventral margin of the liver in different intercostal spaces in Group I dromedary camels.

Number of the reference ICS	Number of camels	Mean \pm SD
11 th	41	21.9 \pm 10.1 ^a
10 th	41	24.7 \pm 6.2 ^b
9 th	41	36.9 \pm 10.4 ^c
8 th	41	42.6 \pm 7.1 ^d
7 th	38	49.9 \pm 7.5 ^e
6 th	27	55.8 \pm 9.2 ^f

Small case letter indicates significant difference ($P \leq 0.05$)

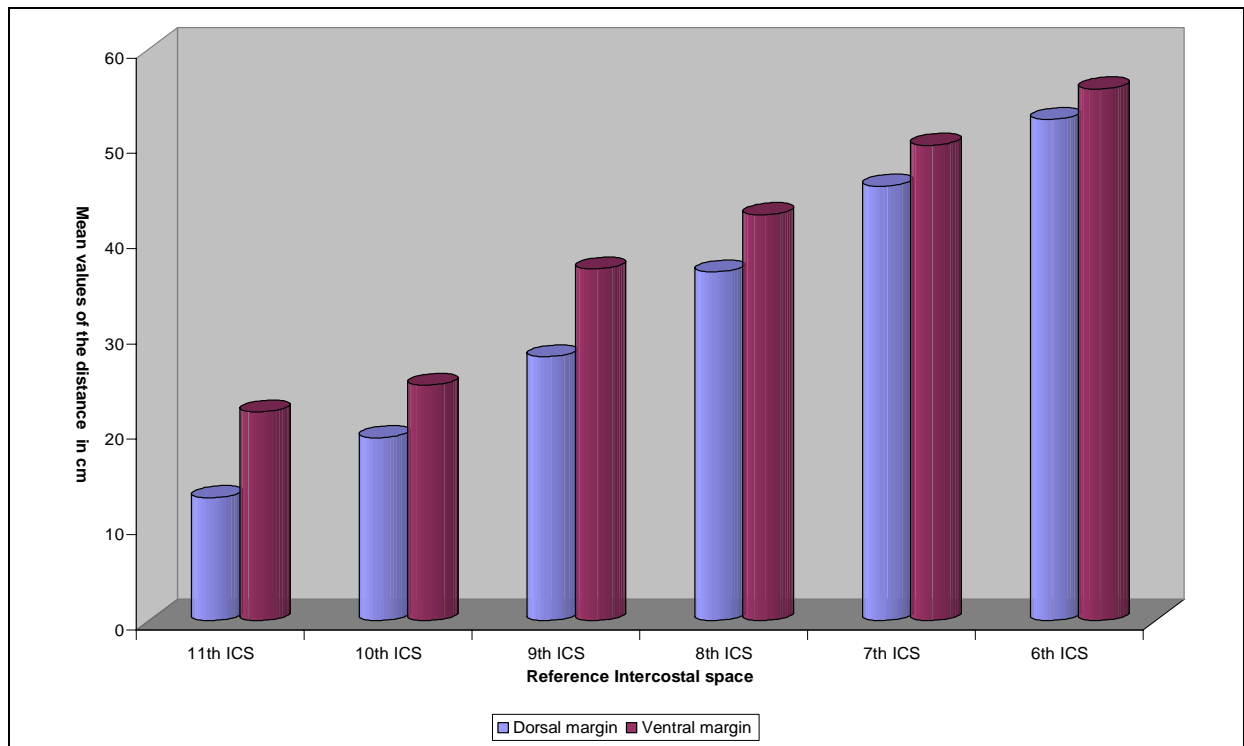


Figure 12: Mean values of the distance between the transverse process of the 2nd lumbar vertebra and the dorsal and ventral margins of the liver in Group I camels

Table 21: Mean and standard deviation values of the distance (cm) between the transverse process of the second lumbar vertebra and the ventral margin of the liver in different intercostal spaces in Group II dromedary camels .

Number of the reference ICS	Number of camels	Mean \pm SD
11 th	4	17.3 \pm 3.5 ^a
10 th	4	33.5 \pm 7.0 ^b
9 th	4	45.8 \pm 10.5 ^c
8 th	4	63.8 \pm 4.3 ^d
7 th	3	67.7 \pm 10.8 ^e
6 th	1	78.0 \pm 0 ^f

Small case letter indicates significant difference ($p \leq 0.05$)

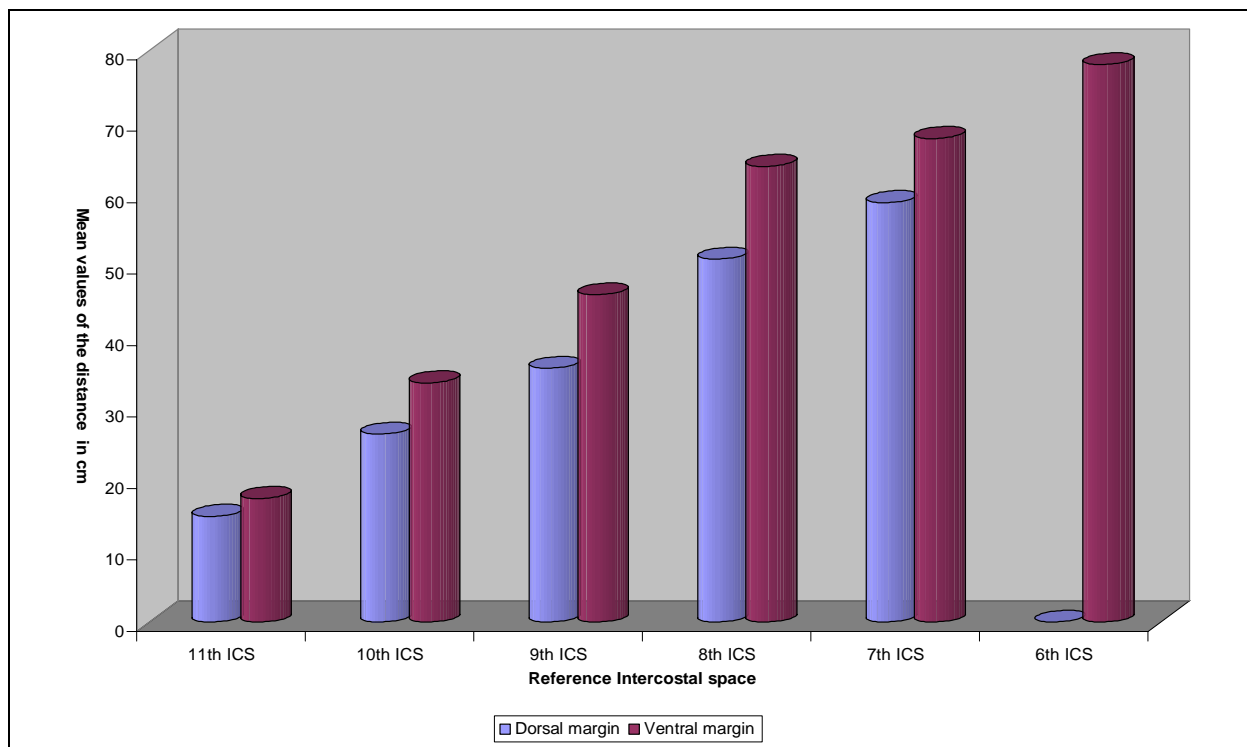


Figure 13: Mean values of the distance between the transverse process of the 2nd lumbar vertebra and the dorsal and ventral margins of the liver in Group II camels.

4.7.2 Hepatic Parenchyma

The ultrasonographic pattern of the normal camel liver parenchyma consisted of numerous medium echoes homogeneously distributed over the entire area of the liver in all intercostal spaces. The visible dorsal liver margin ran from caudodorsal to cranioventral. The ventral margin had a cranioventral course and was situated near the costal arch with a part extending below it in the 9th ICS (Figure 26). In the area from the 8th to the 10th intercostal spaces, the liver was adjacent to the omasoabomasal complex (C3) which was clearly recognizable as a thick echogenic line (Figure 25). Intestinal loops were situated adjacent to the liver in the 11th ICS (Figure 21). In some cases (n=4 in group I and 1 in group II) the right kidney could be imaged high dorsally in the 11th ICS (Figure 20). In all examined camels, the diaphragmatic (parietal) surface of the liver appeared as an echogenic (white) line with an even outline adjacent to the peritoneum. The visceral liver surface lays adjacent to the rumen (C1), omasoabomasal complex (C3) and intestines. This makes it difficult to assess the liver contours (Figure 28, 29). Fissures in the visceral liver surface were always observed in the 8th intercostal space (Figure 23). In some camels (18 in group I and 1 in group II) fissures were also observed in the 10th, 9th and 7th intercostal spaces (Figure 26). In the 9th ICS the lung shadow starts to appear, covering part of the liver and thus reducing its visible size (Figure 27).

4.7.3 Hepatic vessels

Portal and hepatic veins could be seen within the normal liver textures. The lumen of these vessels was anechoic and therefore appeared black. The hepatic veins could be differentiated from the portal veins by the lack of echogenic walls seen with portal veins and the ability to trace hepatic veins to the caudal vena cava. The caudal vena cava was characterized by an oval shape in cross section and runs from caudodorsal to cranio-ventral similar to the dorsal boundary of the liver (Figure 21, 22). It was always situated more dorsally and medially than the portal vein and could usually be visualized in the 11th and 10th intercostal spaces, rarely in the 9th intercostal space and could not be seen in the more cranial intercostal spaces (8th, 7th and 6th). The diameter of the caudal vena cava did not change significantly from the 11th to 9th intercostal spaces where it measured 24.6 ± 4.4 , 23.9 ± 4.4 and 23.6 ± 2.3 mm consequently (Group I) and 26.5 ± 4.9 , 27.1 ± 3.2 and 22.1 ± 1.1 mm (Group II). Depth of the caudal vena cava was found to be 94.4 ± 14.4 mm and 108.8 ± 8.9 mm in camels examined in Group I and II respectively (Tables 22 and 23, Figures 15 and 16). *Porta hepatis* lies at the level of the point of the shoulder joint at a distance of 70.3 ± 6.3 cm in both groups.

It could be visualized in the 10th ICS where the portal vein was characterized by star shaped ramification and hence could be clearly differentiated from the hepatic vein (Figure 21, 22). The portal vein was always situated ventrally and laterally to the caudal vena cava and it was best visualized in the 10th intercostal space. However, branches of the portal vein could also be visualized in the area from the 11th to the 7th intercostal spaces in both groups (Figure 24). Tables 24 and 25 summarize the values of the depth and diameter of the portal vein and its branches in the 11th, 10th, 9th, 8th and 7th intercostal spaces. These values are also plotted in Figures 17 and 18.

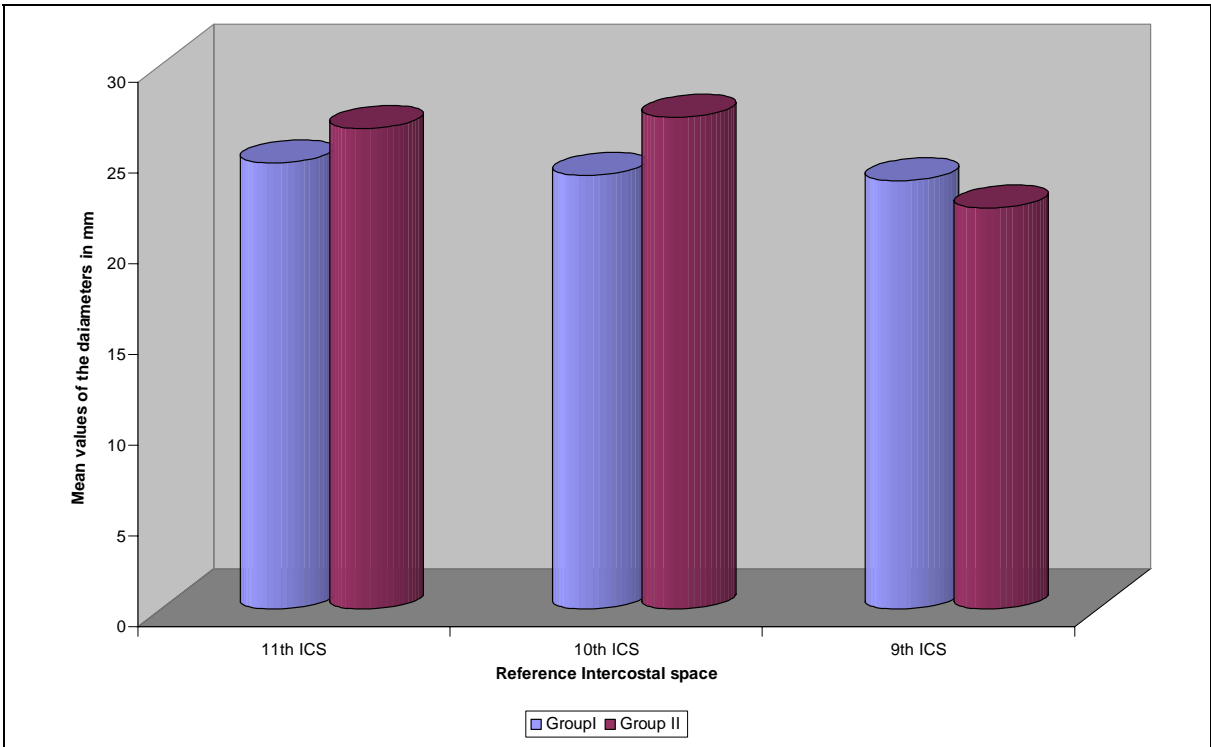


Figure 14: Mean values (mm) of the diameter of caudal vena cava in different intercostal spaces in Groups I and II camels.

Table 22: Mean and standard deviation of the diameter of caudal vena cava (mm) in Group I and II camels.

Group	Mean \pm SD in 11 th ICS	Mean \pm SD in 10 th ICS	Mean \pm SD in 9 th ICS
I	24.6 \pm 6.6 (n=40)	23.9 \pm 4.4 (n=35)	23.6 \pm 2.3 (n=27)
II	26.5 \pm 4.9 (n=4)	27.1 \pm 3.2 (n=4)	22.1 \pm 1.1 (n=3)

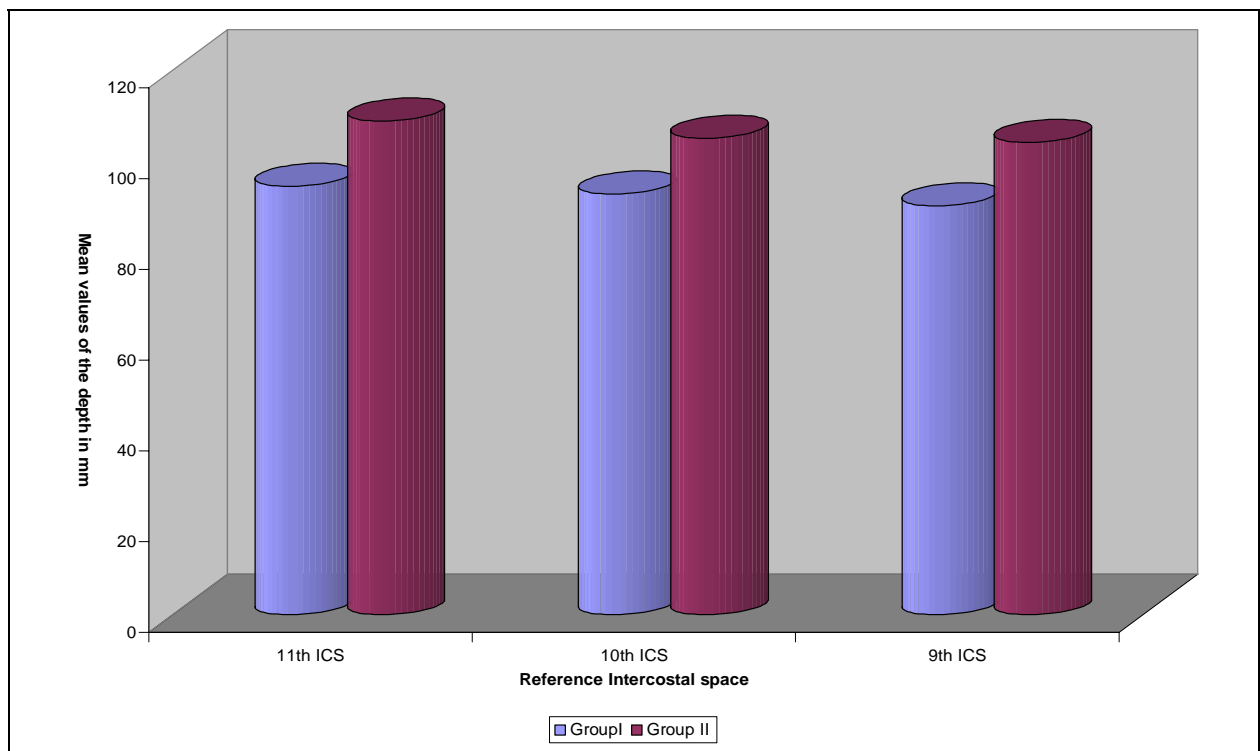


Figure 15: Mean values (mm) of the depth of the caudal vena cava in different intercostal spaces in Groups I and II camels.

Table 23: Mean and standard deviation of the depth of the caudal vena cava (mm) in Group I and II camels.

Group	Mean \pm SD in 11 th ICS	Mean \pm SD in 10 th ICS	Mean \pm SD in 9 th ICS
I	94.4 \pm 14.2 (n=40)	92.7 \pm 6.2 (n=35)	90.2 \pm 3.7 (n=27)
II	108.8 \pm 8.9 (n=4)	105.1 \pm 4.8 (n=4)	104.2 \pm 3.1 (n=3)

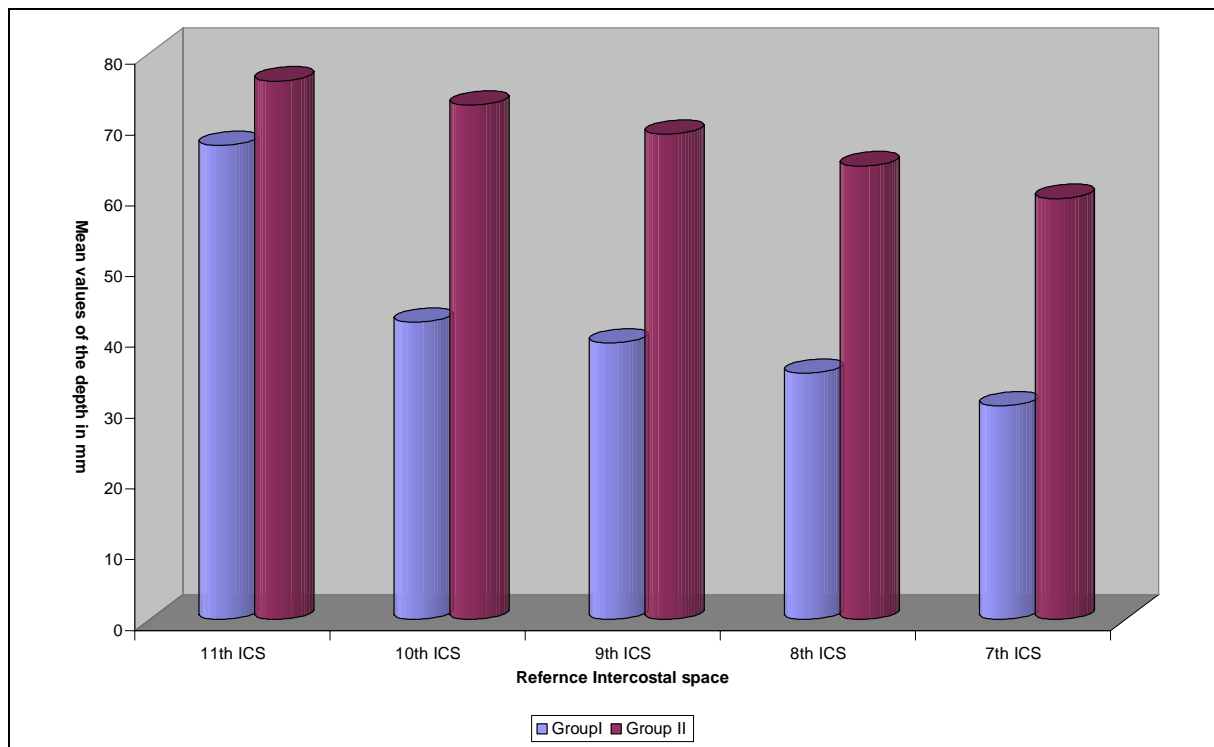


Figure 16: Mean values of the depth of the portal vein (mm) in different intercostal spaces in Groups I and II camels.

Table 24: Mean and standard deviation values of the depth of the portal vein and its branches (mm) in Groups I and II camels.

Group	Mean \pm SD in 11 th ICS	Mean \pm SD in 10 th ICS	Mean \pm SD in 9 th ICS	Mean \pm SD in 8 th ICS	Mean \pm SD in 7 th ICS
I	67.0 \pm 13.5 (n=38)	42.0 \pm 1.8 (n=41)	39.1 \pm 2.3 (n=40)	34.8 \pm 3.3 (n=31)	30.2 \pm 4.8 (n=29)
II	76.1 \pm 6.2 (n=4)	72.7 \pm 4.7 (n=4)	68.6 \pm 6.1 (n=3)	64.1 \pm 4.7 (n=2)	59.5 \pm 1.8 (n=2)

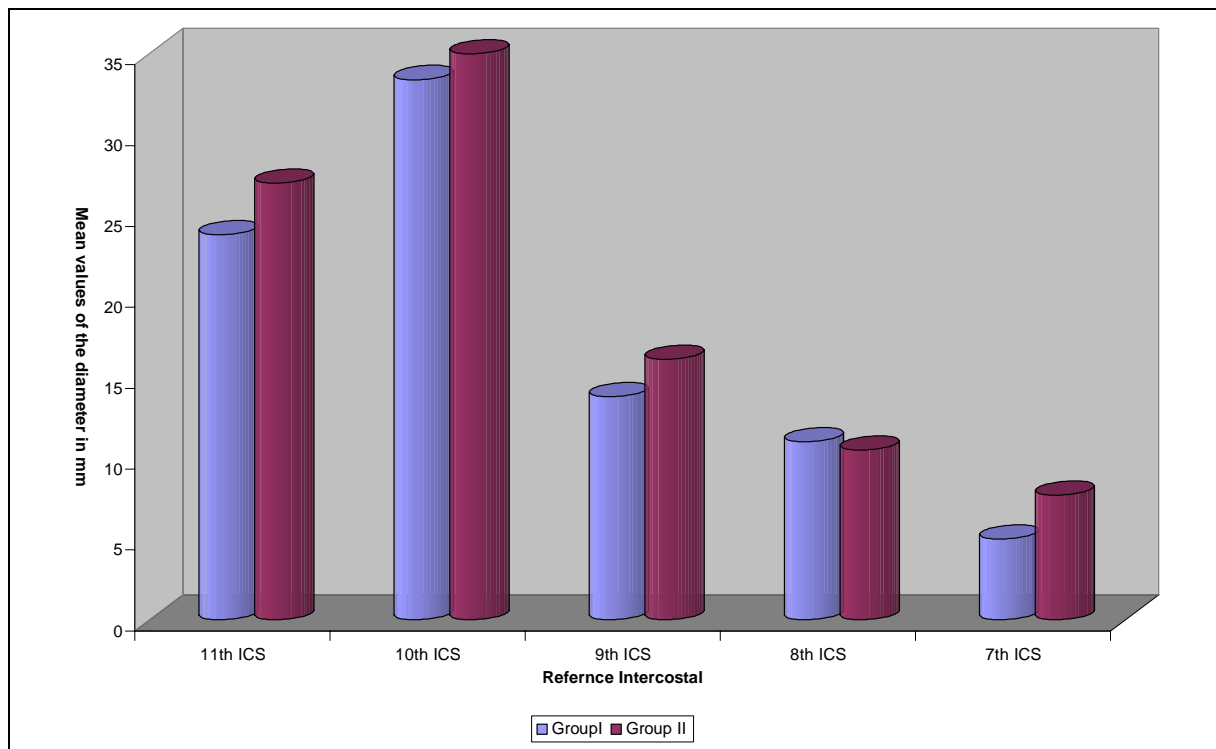


Figure 17: Mean values of the diameter of the portal vein and its branches (mm) in different intercostal spaces in Groups I and II camels.

Table 25: Mean and standard deviation of the diameter of the portal vein and its branches (mm) in Group I camels.

Group	Mean \pm SD in 11 th ICS	Mean \pm SD in 10 th ICS	Mean \pm SD in 9 th ICS	Mean \pm SD in 8 th ICS	Mean \pm SD in 7 th ICS
I	23.8 \pm 7.5 (n=38)	33.4 \pm 7.1 (n=41)	13.8 \pm 2.8 (n=40)	11.0 \pm 5.1 (n=31)	05.0 \pm 3.1 (n=29)
II	27.0 \pm 6.1 (n=4)	35.0 \pm 5.1 (n=4)	16.1 \pm 7.5 (n=3)	10.5 \pm 4.4 (n=2)	7.7 \pm 2.2 (n=2)

4.7.4 Thickness of the dorsal and ventral liver margins

The thickness of the dorsal and ventral liver margins varied in different intercostal spaces being thinner in the 10th ICS than in the 11th ICS and getting thinner cranially (Table 26 and 27, Figures 19 and 20).

Table 26: Mean and standard deviation of the thickness of the dorsal and ventral liver margins (mm) in Groups I camels.

Liver margin	Mean \pm SD in 11 th ICS	Mean \pm SD in 10 th ICS	Mean \pm SD in 9 th ICS	Mean \pm SD in 8 th ICS	Mean \pm SD in 7 th ICS	Mean \pm SD in 6 th ICS
Dorsal	124.7 \pm 16.6 (n=41)	137.2 \pm 29.6 (n=41)	132.1 \pm 26.2 (n=41)	101.1 \pm 22.6 (n=41)	80.0 \pm 32.3 (n=38)	29.1 \pm 10.3 (n=27)
Ventral	105.0 \pm 35.1 (n=41)	68.0 \pm 22.4 (n=41)	50.6 \pm 23.3 (n=41)	47.0 \pm 25.4 (n=41)	29.7 \pm 9.8 (n=38)	23.7 \pm 12.1 (n=27)

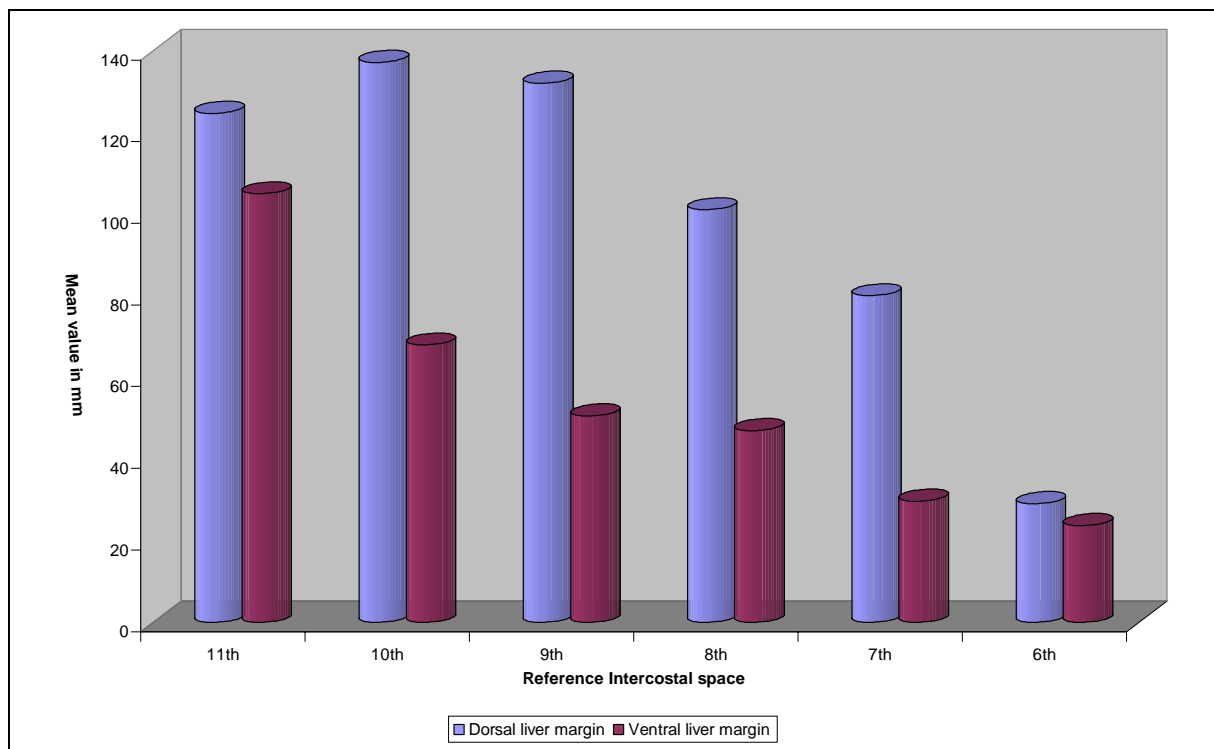


Figure 18: Mean values (mm) of the dorsal and ventral liver margins thickness in different intercostal spaces in Group I camels.

Table 27: Mean and standard deviation values of the thickness of the dorsal and ventral liver margins (mm) in Group II camels.

Liver margin	Mean \pm SD in 11 th ICS	Mean \pm SD in 10 th ICS	Mean \pm SD in 9 th ICS	Mean \pm SD in 8 th ICS	Mean \pm SD in 7 th ICS	Mean \pm SD in 6 th ICS
Dorsal	149.6 \pm 18.8 (n=4)	142.1 \pm 19.2 (n=4)	137.2 \pm 14.1 (n=4)	120.6 \pm 16.1 (n=4)	90.6 \pm 22.3 (n=3)	40.1 \pm 0.0 (n=1)
Ventral	117.0 \pm 25.1 (n=4)	88.2 \pm 33.3 (n=4)	68.0 \pm 20.8 (n=4)	55.7 \pm 19.4 (n=4)	37.6 \pm 12.3 (n=3)	32.1 \pm 0.0 (n=1)

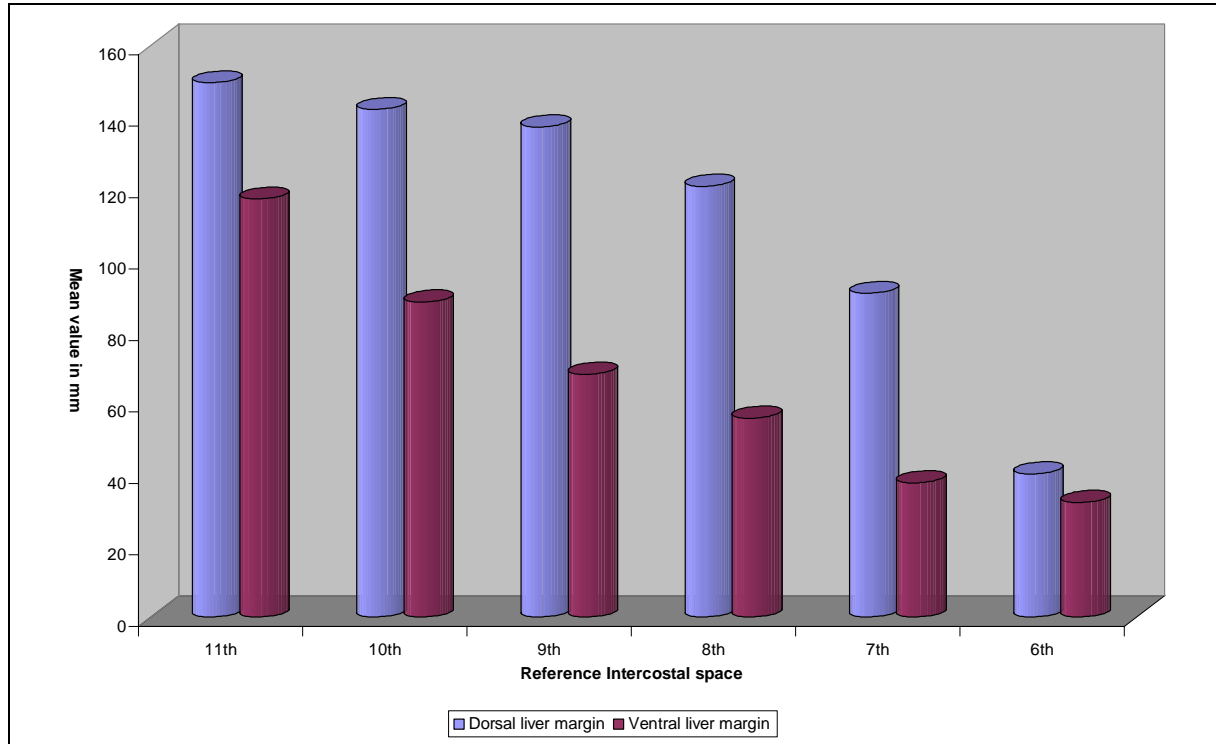


Figure 19: Mean values (mm) of the dorsal and ventral liver margins thickness in different intercostal spaces in Group II camels.

4.7.5 Liver size

The whole liver length which could be ultrasonographically examined in the area from the 11th to the 6th intercostal spaces in groups I and II were $(53.0 \pm 7.1 \text{ cm})$ and $(60.5 \pm 5.7 \text{ cm})$ respectively.

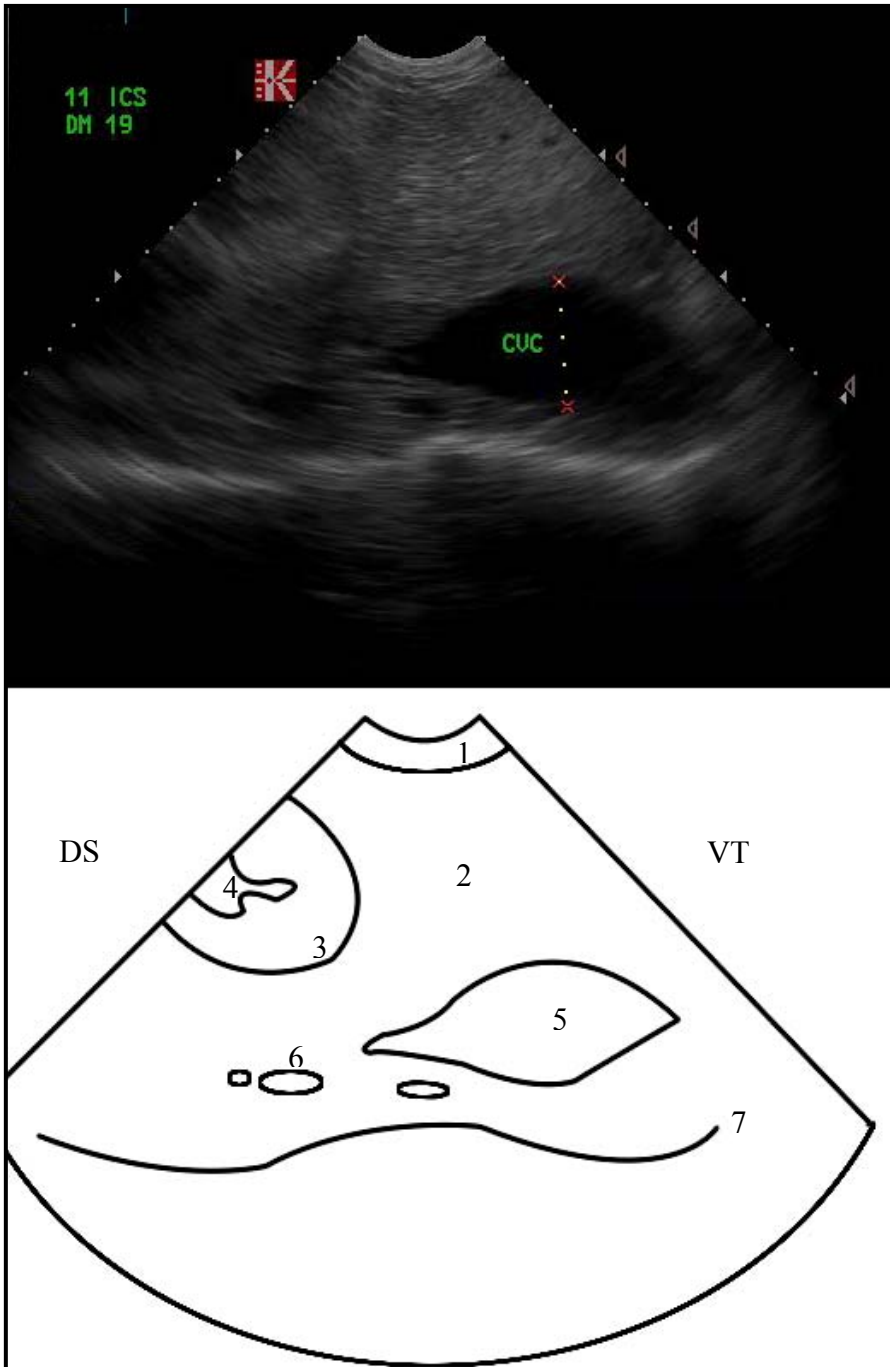


Figure 20: Dorsal margin of the liver at the 11th ICS, 19 cm from the reference point (RP). 1- Abdominal wall 2- liver parenchyma (caudate lobe) 3, 4 – cortex and medulla of the right kidney 5- caudal vena cava 6-branches of hepatic veins 7- Intestinal loops.
 DS= dorsal VT= ventral

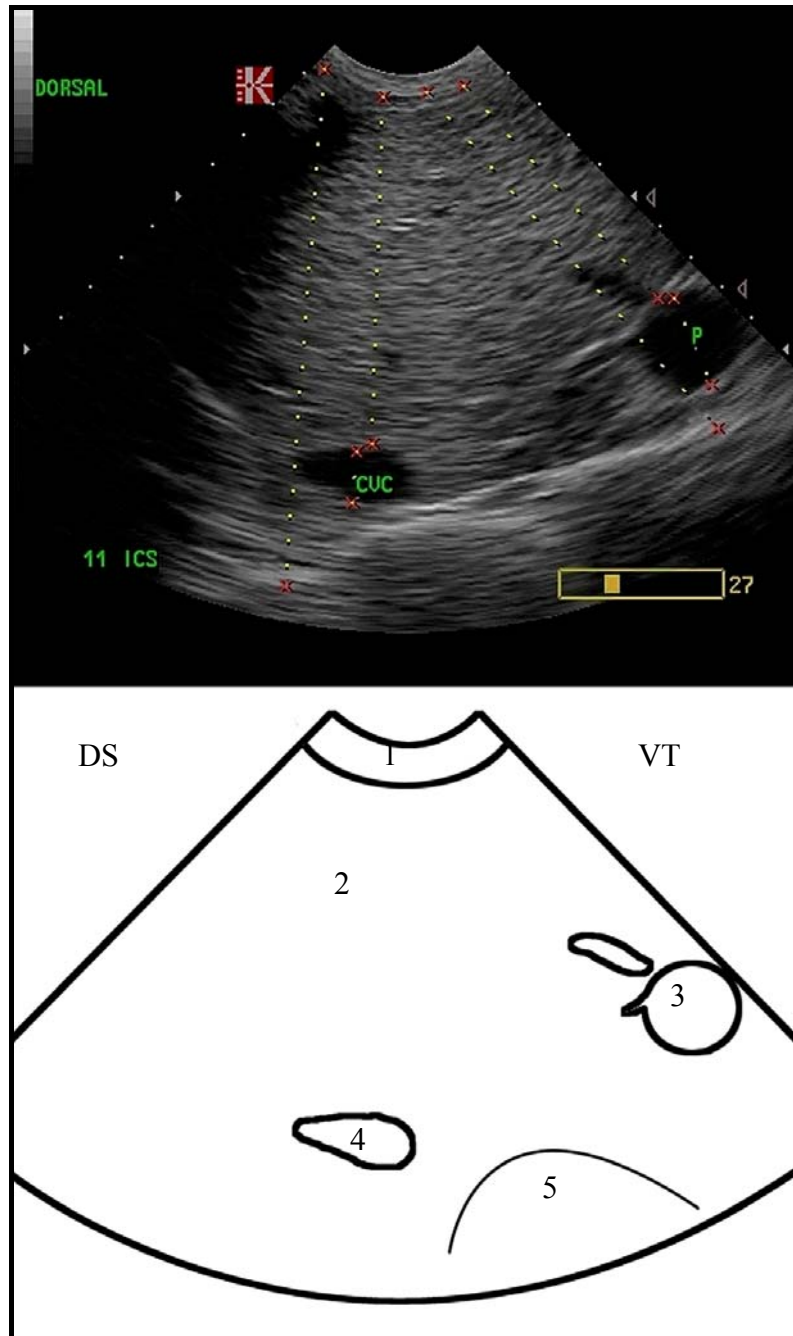


Figure 21: Dorsal margin of the liver at the 11th ICS. Abdominal wall 2- liver parenchyma 3- portal vein 4- caudal vena cava 5- Intestinal loops. DS= dorsal VT= ventral

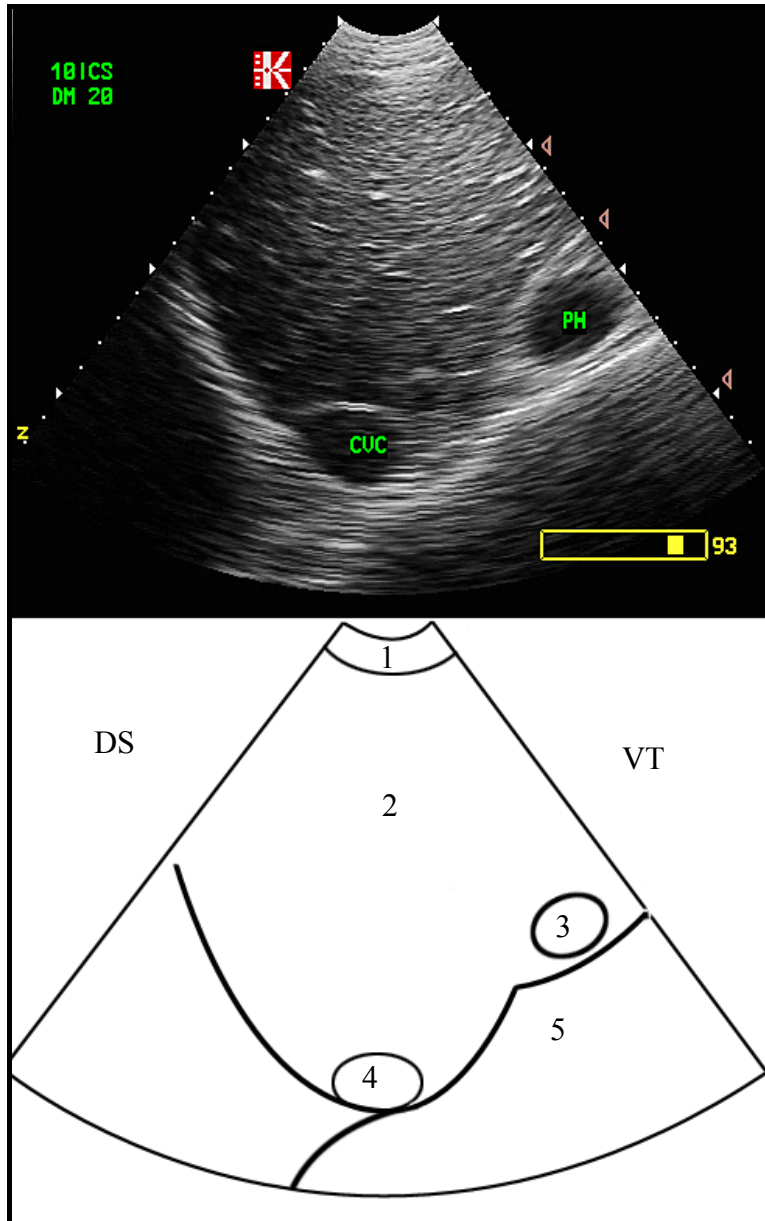


Figure 22: Dorsal margin of the liver at the 10th ICS, 20 cm from the RP. 1- Abdominal wall 2- liver parenchyma 3- portal vein 4- caudal vena cava 5- Third gastric compartment (C3) DS= dorsal VT= ventral

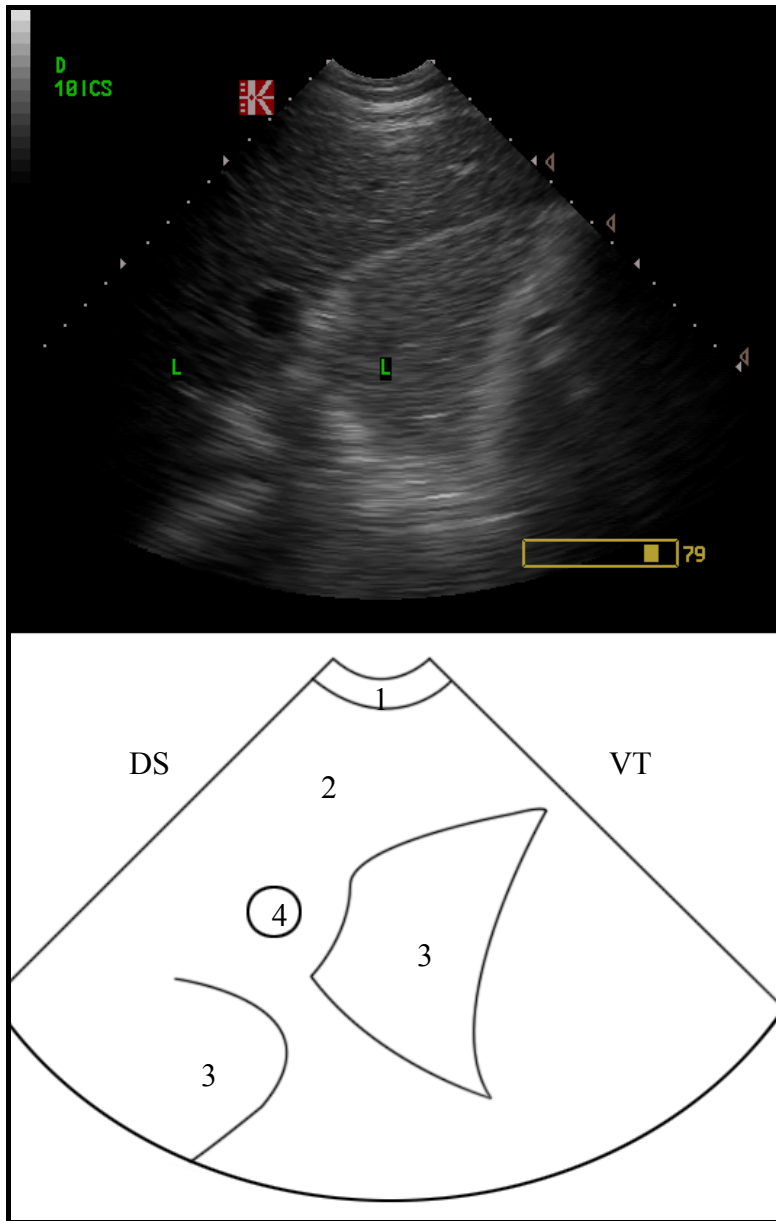


Figure 23: Ventral margin of the liver at the 10th ICS. 1- Abdominal wall 2- liver parenchyma 3- liver subdivision 4- portal vein DS= dorsal VT= ventral

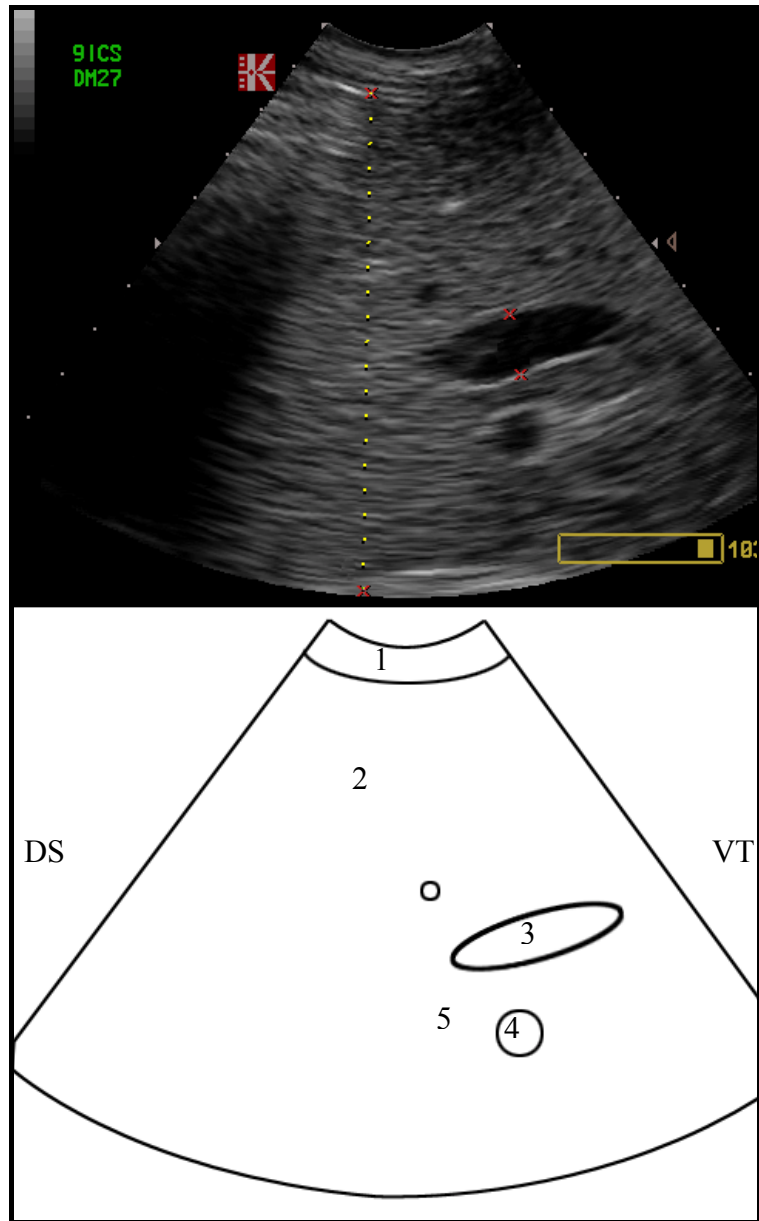


Figure 24: Dorsal margin of the liver at the 9th ICS, 27 cm from the RP. 1- Abdominal wall 2- liver parenchyma 3, 4-branch of portal vein DS= dorsal VT= ventral

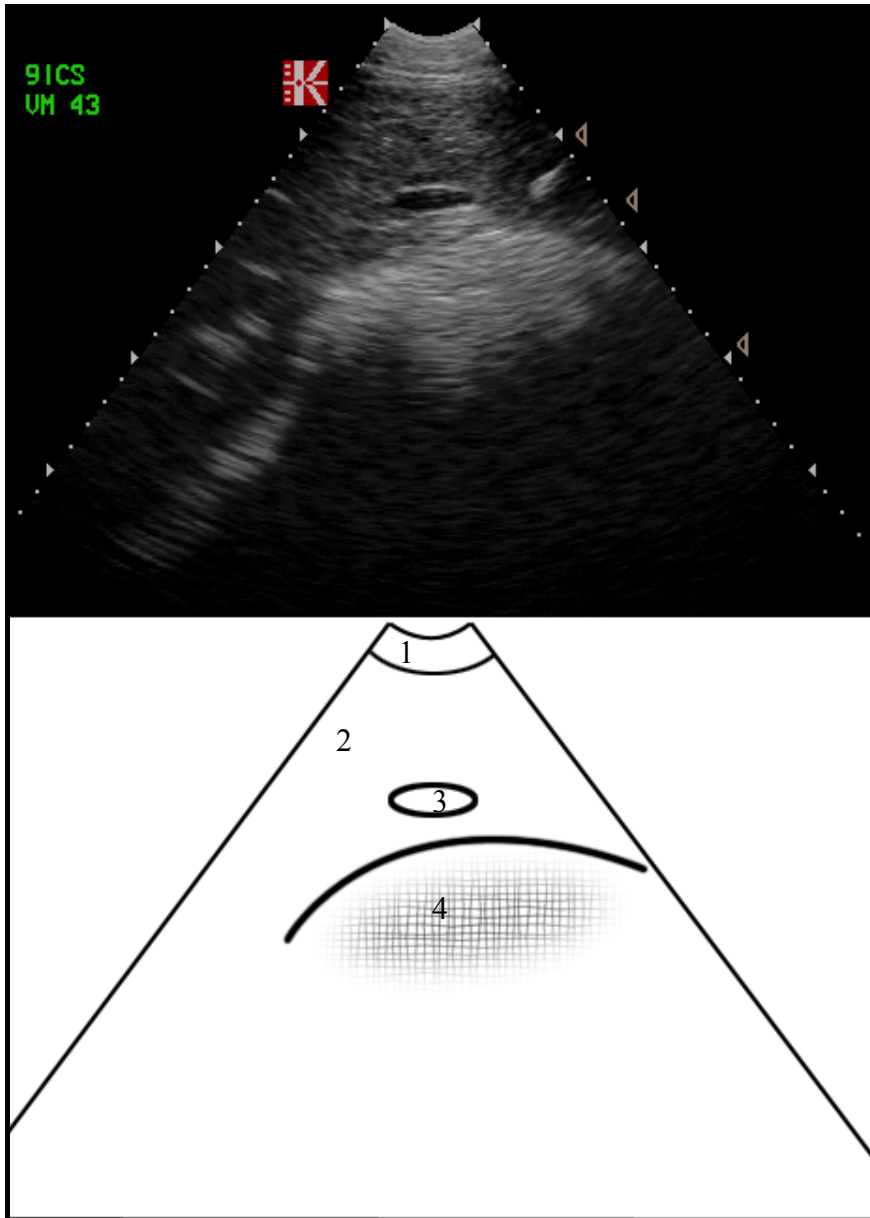


Figure 25: Ventral margin of the liver at the 9th ICS, 43 cm from the RP. 1- Abdominal wall 2- liver parenchyma 3-branch of portal vein 4- Third gastric compartment (C3) DS= dorsal VT= ventral

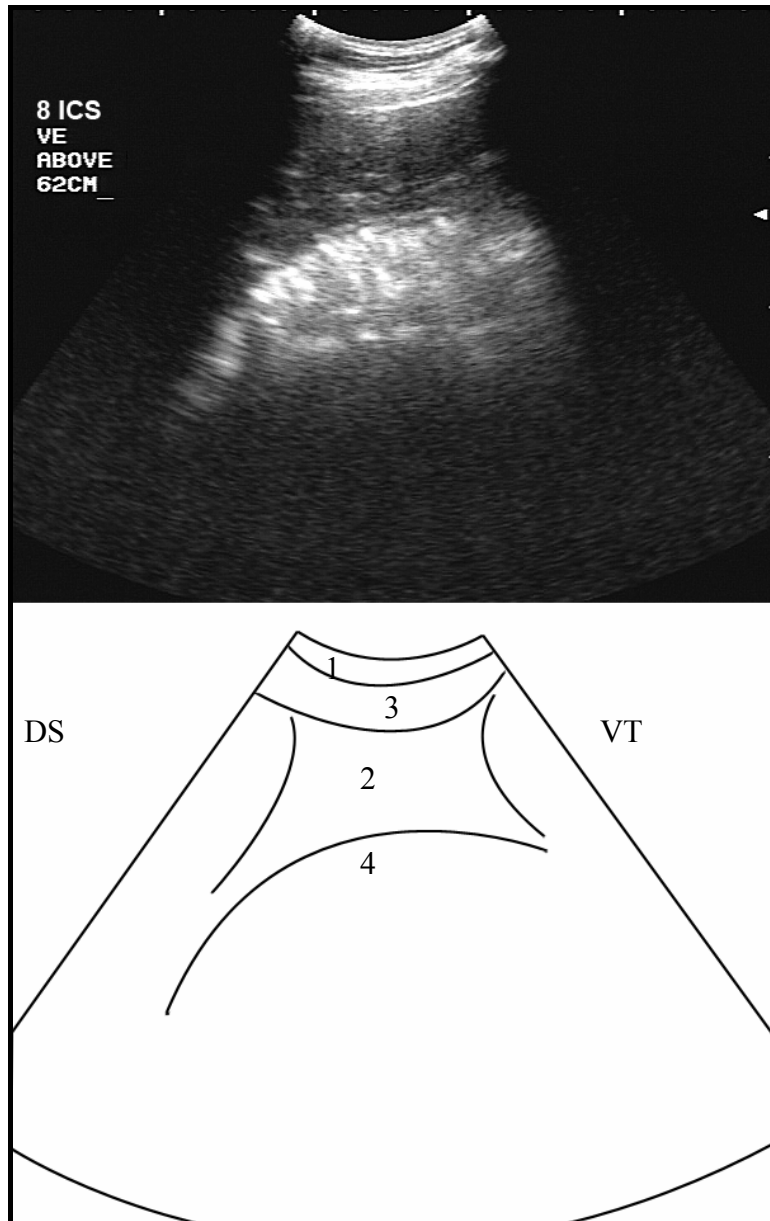


Figure 26: Ventral margin of the liver at the 8th ICS, 62 cm from the RP. 1- Abdominal wall 2- liver parenchyma 3- costal arch 4- Third gastric compartment (C3) DS= dorsal VT= ventral

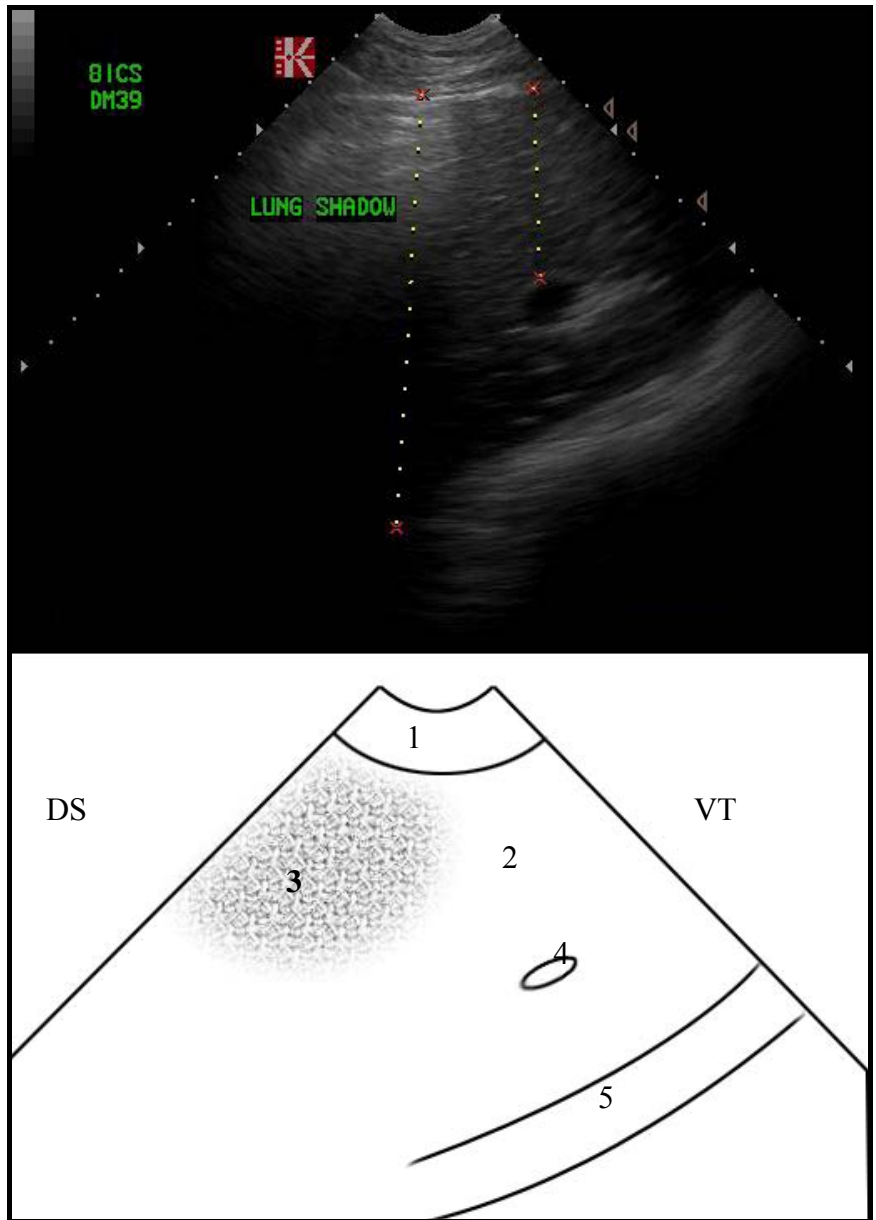


Figure 27: Dorsal margin of the liver at the 8th ICS, 39 cm from the RP. 1- Abdominal wall 2- liver parenchyma 3- lung shadow 4- branch of portal vein 5- Third gastric compartment (C3) DS= dorsal VT= ventral

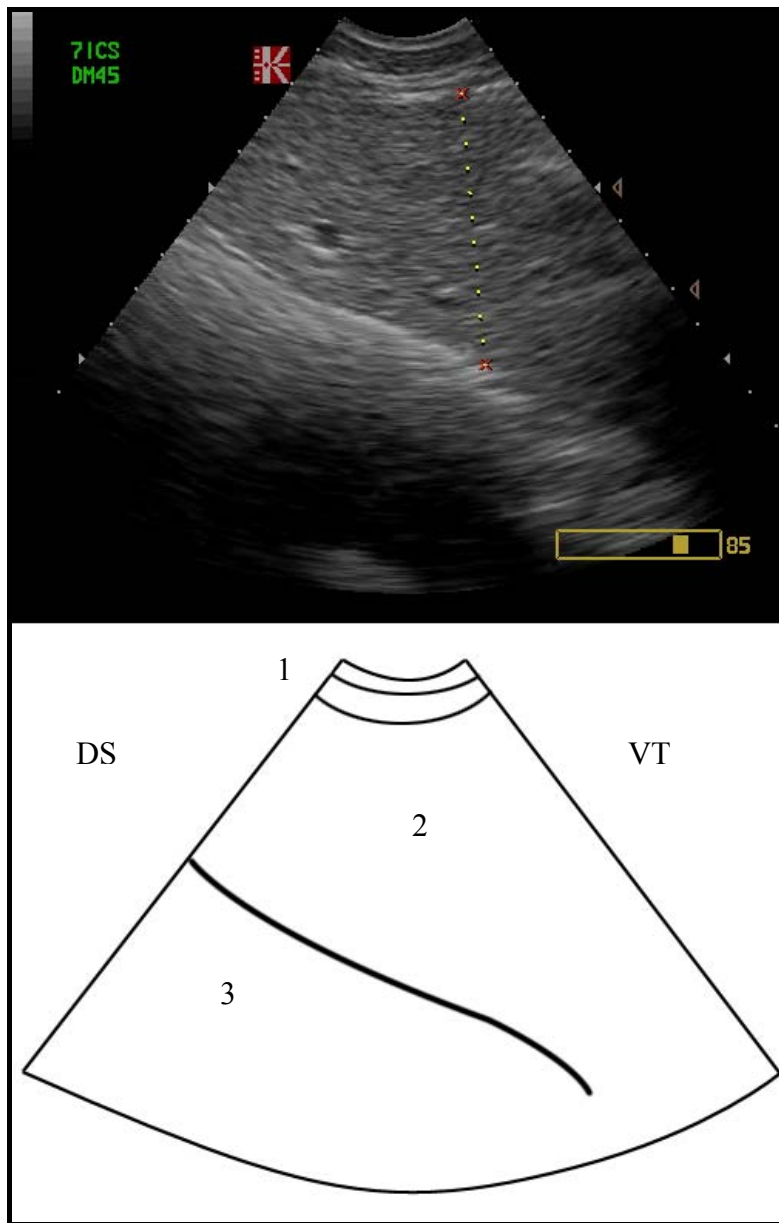


Figure 28: Dorsal margin of the liver at the 7th ICS, 45 cm from the RP. 1- Abdominal wall 2- liver parenchyma 3- rumen (C1) DS= dorsal VT= ventral

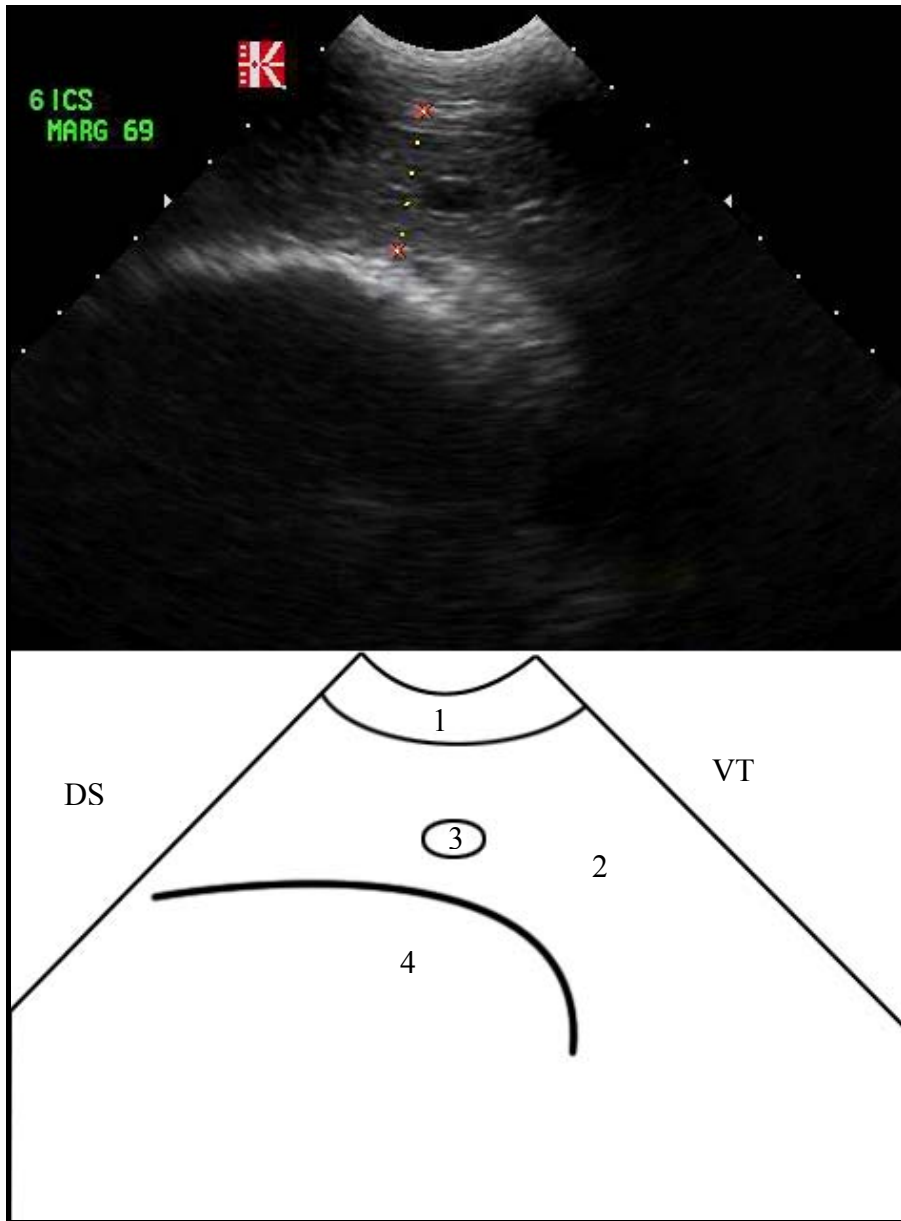


Figure 29: Margin of the liver at the 6th ICS, 69 cm from the RP. 1- Abdominal wall 2- liver parenchyma 3- branch portal vein 4- rumen (C1) DS= dorsal VT= ventral

5 Discussion

5.1 Pilot Study

The pilot study was performed in order to integrate the determination of different parameters in dromedary camels including haematology, biochemistry with liver ultrasonography for the first time. There is extensive data on the haematology and biochemistry of dromedary camels from different countries. These data vary considerably on ecological and logistical factors which makes it difficult to obtain reference values for comparison. Usage of abdominal ultrasonographic examination has never been described in dromedary camels according to our data search. Available data about gross anatomy of the camel liver is inconsistent and the nomenclature of different parts of the digestive tract, as for example C1, C2 and C3 for the rumen, reticulum, omasum and abomasums are neither universally accepted nor applied.

Animals used in this study were examined in different locations, namely Germany (Seeg in Bavaria), Egypt (Kerdasa Slaughterhouse) and Sudan (Tamboul Camel Market), with different environments, which in turn may affect the obtained results. Most of the work was conducted under field conditions and in most cases many nomads congregate around the examination area, which has an influence on both camel and the examiner. It was difficult to obtain the same number of camels in all areas and also to select animals of same age, size and sex. Due to performing the examination in different continents, two different ultrasound machines were used. As a result of differences in the height of the hump which may be affected by many factors such as nutritional status of the animal, the second lumbar vertebra was used as a reference point for measuring the dorsal and ventral margins of liver in all camels. These factors made it essential to do a pilot study so as to obtain some knowledge before conducting the main part of the study.

From the pilot study it was realized that the best position to perform the ultrasonographic examination in camel was the sternal recumbency position. BRAUN 1990 stated that the standing position was the best position for ultrasonographic examination in cattle whereas CEBRA et al. 2002 recommended a non-squeezing restraint chute for the ultrasonographic examination in llamas and alpacas. These differences in the examination positions described by different authors may be due to differences in animal size or behaviour that affect restraining of the animals and consequently the safety of the procedure to the workers. TEFERA (2004) mentioned that the standing position can be good for the clinical examination of young camels because they might not trained to kneel down whereas the

sternal recumbency position was the best position for the examination of adult camels because of their long body.

As was described by ABDALLA et al., (1971), NAGAPAL et al., (1985), SMUTS and BEYUIDENHOUT (1987), FARAG (1990) and SIDDIG (2002), the liver of the dromedary camel occupies the right hypochondric and epigastric regions with its long axis extending cranioventrally from the 2nd lumbar vertebra to the caudal border of the 5th rib. This was in agreement with our findings. In our work, the area defined cranially by the 5th intercostal space, caudally by a handbreadth from the last rib, dorsally by a handbreadth below the tips of the vertebral spine and ventrally by the borders of the sternum defines the best area for liver examination.

5.2 Clinical examinations

In this study clinical parameters including body temperature, pulse and respiratory rates were taken in both groups in order to assess the health condition of the animals and to compare them with the previously reported rates. Temperature ranged from 35.8-40.0°C and 34.5-36.4 °C in Groups I and II, respectively. Even though climatic conditions being different between countries (Sudan and Egypt for the animals in Group I and Germany for the animals in Group II), there were slight but non significant differences between the temperature ranges of animals in both groups. This can be explained by the fact that camels are homeothermic animals, as because there is a circadian cycle in the body temperature of dromedaries which permits their body temperature to fall to 35°C over night and increase to 40°C during the day (SCHMIDT-NIELSEN 1997). This cycling of body temperature permits much of the heat load of the day to be dissipated by non evaporative mechanisms, radiation, conduction and convection, during the cool hours of the night, so as not to lose water for thermoregulation (HILL and WYSE 1989). The temperature values in both groups are in agreement with ranges mentioned by TEFERA (2004). Even though determination of the heart rate by auscultation in camels is difficult due to vocalisation, pulse rates were found to range between 35-55 and 30-45 beats/min in Groups I and II, respectively. A pulse rate of 35-50 pulses/min was reported for dromedary camels by TEFERA (2004). Values reported in our study falls within this range but it was slightly higher in camels in Group I. This may be due to the fact that camels in this group could be excited as they were examined in the slaughterhouse. Respiratory rates of 10-22 and 9-14 breaths/ min were reported in Groups I and II respectively. In a similar study a range of 9-16 breaths/min was recorded in dromedary camels (TEFERA 2004). This is somewhat lower than the maximum value of respiratory rate reported in dromedary camels in

Group I (Sudan and Egypt) which may be again clarified by the fact that these camels were excited as they were in the slaughterhouse. These camels were located in Sudan and Egypt which are characterized by their higher environmental temperature. Heat causes an increase in thyroid activity, which in turn may increase respiratory rate (YAGIL 1985).

5.3 Estimation of body weight

Using the equation described previously we were able to estimate body weight in both groups. This method is an acceptable alternative for a scale balance, to facilitate work under field conditions. A similar method has been used to estimate body weight in equines (HALL and CLARK 1992) as they are also characterized by their heavy weights. Bodyweight ranged from 350 to 550 kg in Group I and from 400 to 600 kg in Group II

5.4 Hump height and circumference

The hump is the most important fat reserve in camel and represents 80% of the whole stored fat. Other fat depots in the camel include muscle, external pad, coastal part and shoulder (OLLIER et al. 1995). Stored fat represents mobilisable energy to cover maintenance and production requirements (BENGOUMI et al. 2005). Height and circumference of the hump were determined in dromedary camels in Group I (Egypt and Sudan) and Group II (Germany). Mean and standard deviation values for the former were 23.1 ± 6.1 cm and 38.3 ± 9.9 cm whereas mean and standard deviation values for the latter were 87.6 ± 35.9 cm and 139.0 ± 21.7 cm in Groups I and II respectively. There was a significant difference between these values in Groups I and II ($P \leq 0.05$). KAMILI et al. (2006) reported values of 0.53 m and 0.54 m for hump height and length in live animals respectively. There was some variation between this data and the data obtained in this study, which could be attributed to breed differences as well as variation in nutritional and physiological status of the camels (WILSON. 1978).

5.5 Haematological parameters

Haematological parameters including RBC, Hb, PCV, MCV, MCH, MCHC, were studied in dromedary camels examined in Egypt (n=27). Mean and standard deviation values for the camels examined in Egypt were: 12.15 ± 2.2 T/L, 7.97 ± 0.98 mmol/L, 0.45 ± 0.006 L/L, 39.34 ± 2.64 fl, 0.69 ± 5.16 fmol, 17.78 ± 0.16 mmol/L, respectively. Total and differential white blood cells count including neutrophils, lymphocytes, monophils and eosinophils were

also made and their mean and standard deviation values were: 15.20 ± 7.11 g/L, $68.0 \pm 4.56\%$, $24.30 \pm 5.46\%$, $5.2 \pm 2.56\%$ and $2.5 \pm 1.48\%$, respectively.

The same parameters were studied in dromedary camels in Germany (n=4). Mean and standard deviation values for RBC, Hb, PCV, MCV, MCH, and MCHC were 8.39 ± 1.96 T/L, 6.18 ± 1.86 mmol/L, $0.29 \pm .09$, 34.15 ± 4.0 L/L, 0.66 ± 0.13 fmol and 18.84 ± 2.68 mmol/L respectively. Total and differential white blood cells count including neutrophils, lymphocytes, monophils and eosinophils were also made and their mean and standard deviation values were: 13.27 ± 4.28 g/L, $67.7 \pm 9.63\%$, $28.1 \pm 9.1\%$, $1.7 \pm 0.96\%$ and $2.5 \pm 1.0\%$, respectively.

There was no significant difference in the mean and standard deviation values of the RBC, PCV and Hb obtained in our study in both groups. These values were in general agreement with literature values in case of camels studied in Germany, but disagreed with values reported by the same authors for the camels studied in Egypt. This may be due to stress condition as camels examined in Egypt were in the slaughterhouse as well as the nutritional status of the camel. The RBC, PCV and Hb values for camels studied in Germany were in agreement with the values reported by MOHAMED and HUSSEIN (1999) in Kuwait, NYANGO'AO et al. (1997) in Kenya, and ABDELGADIR et al. (1979) in Sudan, GHODSIAN et al. (1978) in Iran, and BANERJEE et al. (1962) in India. However, in Egypt only the Hb value was in agreement with these authors whereas RBC and PCV values were higher in our camels. The findings of MCV, MCH and MCHC obtained in both groups in this study were in agreement with those reported by GHODSIAN et al. (1978), REZAKHANI et al. (1997), SARWAR and MAJEED (1997), MOHAMED and HUSSEIN (1999) and BOGIN (2000). Nonetheless, all these parameters were a little higher than those presented by AL-HADRAMI (1997) in the United Arab Emirates. These minor differences could be attributed to difference in sampling techniques and analytical procedures.

The total white blood cell count obtained in this study from camels examined in Egypt and Germany are in agreement with the values reported by ABDALLA et al. (1988), NYANGO'AO et al. (1997) and MOHAMED and HUSSEIN (1999). The differential white blood cell percentages obtained in our study were similar to those mentioned by SARWAR and MAJEED (1997), WERNERY et al. (1999) and BOGIN (2000). The predominant white blood cells were neutrophils followed by lymphocytes. This is in disagreement with the results described by NYANGO'AO et al. (1997) and BANERJEE et al. (1962), who noted the predominant white blood cells in camel haemograms were lymphocytes followed by neutrophils.

5.6 Biochemical parameters

Documentation of the normal blood biochemical parameters is important as a tool for the determination of diseases or abnormalities. Since genetics, physiology, nutrition and environmental conditions may influence biochemical profiles, it is necessary to establish the normal reference values of these parameters. The literature on camelids clinical pathology reveals that the available data is inconsistent, having a wide range of values, which are inconsistent with each other. BOGIN (2000) had observed that the values, which were considered as a normal reference, were obtained from relatively small and undefined groups of animals. In this study, biochemical parameters including AST, ALT, ALB, BIL, TG, ALP, GGT and GLDH were examined in dromedary camels in both groups. In Group I (Egypt and Sudan), mean and standard deviation values were 138 ± 39.4 IU/l, 15.3 ± 5.9 IU/l, 35.4 ± 4.1 g/l, 1.7 ± 0.43 μ mol/l, 0.38 ± 0.23 mmol/l, 55.5 ± 18.9 IU/l, 12.14 ± 7.07 IU/l and 12.02 ± 6.8 IU/l, respectively, whereas mean and standard deviation values for these parameters in Group II (Germany) were 139.3 ± 36.0 IU/l, 6.5 ± 1.9 IU/l, 30.1 ± 3.4 g/l, 1.6 ± 0.24 μ mol/L, 0.6 ± 0.02 mmol/l, 149.8 ± 70.1 IU/l, 5.9 ± 4.07 IU/l and 9.5 ± 3.3 IU/l, respectively. There were no significant differences between these values in Groups I and II. The serum AST, ALT, ALB, BIL and GGT activities were similar to those reported by MOHAMED and HUSSEIN (1999). However, AST values encountered in this study were higher than those mentioned by FAYE et al. (1995), WERNERY et al. (1999), BENGOUMI et al. (1997), BOGGIN (2000) and CHOUDHARY et al. (2002).

ALT values encountered in Group I camels were higher than those mentioned by WERNERY et al. (1999) and SARWAR and MAJEED (1997). ALT values obtained in Groups I and II camels were higher than those mentioned by NYANGO'AO et al. (1997). Also ALT values in Group II camels were lower than those given by CHOUDHARY et al. (2002).

ALP values described by WERNERY et al. (1999) reported lower ALP values than those found in Group I camels and higher than the values in Group II camels. ALP values in Groups I and II camels were higher than those described by ELDIRDIRI et al. (1987) and NYANGO'AO et al. (1997). BIL values in Groups I and II camels were parallel to the levels established by WERNERY et al. (1999) and lower than those described by BOGIN. (2000).

ALB values in both groups of camels agreed with values mentioned by WERNERY et al (1999), BENGOUMI et al. (1997), SARWAR and MAJEED (1997). ALB values recorded for Group II camels were lower than the values mentioned by CHOUDHARY et al. (2002).

TG values obtained in both groups were in agreement with BENGOUMI et al. (1997). GLDH values in groups I and II camels were parallel to those mentioned by FAYE et al. (1995). GGT values obtained in the present study in both groups of camels were within the range given by WERNERY et al. (1999) and FAYE et al. (1995). Moreover, values reported in both groups of camels were lower than those mentioned by ELDIRDIRI et al. (1987).

The variations encountered between the results of this study and the findings of previous workers in serum enzyme activities may be attributed to breed variation, nutritional status, husbandry system, environmental conditions as well as analytical methods. This could explain the disparity noticed in the literature on biochemical profiles of camels, particularly in the regards to the establishment of standard (reference values) for the parameters. It could also be a reflection of the unique capability of this animal species to diverse ecological and management factors (YAGIL.1985).

5. 7 Ultrasound examination

5.7.1 Liver location

The information obtained from an abdominal sonographic examination is often not obtainable from other diagnostic procedures, and this information can often lead the clinician to the correct diagnosis (HILLYER. 1994). Liver diseases are of great importance in animals including camels. Disturbances of metabolism cause fatty degeneration diffuse changes in liver texture, enlargement of the organ, and obtuse rounded margins (BRAUN 1990).ultrasound examination enables the clinician to get an accurate assessment of most parts of the liver. It has been used in dogs (NYLAND et al. 2002), horses (REEF 1991) and cattle (BRAUN 1990) for years to diagnose focal and diffuse changes in liver structure.

To our knowledge, ultrasonographic examination of the size, shape and position of the liver and its vessels has not been reported in camels. The present study demonstrated that the liver location, liver can be visualized in an area extending from the 11th to the 6th intercostal spaces on the right side of the animal. From the available anatomical data about liver location in dromedary camel, our findings are in agreement with ABDALLA et al. (1971) and FARAG (1990). Both authors stated that the bulk of the liver is situated in the right side of the abdominal cavity and extends from the 5th to 12th rib (last rib). However, other authors mentioned that the liver extends cranioventrally from the 2nd lumbar vertebra to the caudal border of the 5th rib (HEGAZI 1945, NAGPAL et al. 1985, SMUTS and BEZUIDENHOUT 1987, ABDELMONIEM et al. 2000, SIDDIG 2002). In cattle, it was stated that the liver can

be ultrasonographically examined from the caudal to the cranial end, beginning from the last rib and ending at the 5th intercostal space. The organ at its largest part at the last three intercostal spaces i.e. 12th, 11th, 10th (BRAUN 1990, 1996). These findings are in agreement with our findings in that the liver in both animals (camel and cattle) can be best visualised at the last three intercostal spaces.

The distance between the transverse process of the 2nd lumbar vertebra and the dorsal liver margin in Group I camel was in the range of 12.9 ± 3.9 cm, 19.2 ± 4.4 cm, 27.7 ± 6.2 cm, 36.6 ± 7.2 cm, 45.6 ± 6.7 cm and 52.7 ± 9.3 cm in the 11th, 10th, 9th, 8th, 7th and 6th intercostal spaces consequently. The distance between the transverse process of the 2nd lumbar vertebra and the ventral liver margin in these intercostal spaces in the same group of camels was 21.9 ± 10.1 cm, 24.7 ± 6.2 cm, 36.9 ± 10.4 cm, 42.6 ± 7.1 cm, 49.9 ± 7.5 cm and 55.8 ± 9.2 cm respectively.

In Group II camels the distance between the transverse process of the 2nd lumbar vertebra and the dorsal liver margin ranged from 14.8 ± 3.7 cm, 26.3 ± 3.4 cm, 35.5 ± 4.9 cm, 50.9 ± 10.8 cm, 58.7 ± 9.8 cm and 78.0 ± 0.0 cm in the 11th, 10th, 9th, 8th, 7th and 6th intercostal spaces respectively. The distance between the transverse process of the 2nd lumbar vertebra and the ventral liver margin in these intercostal spaces in the same group of camels was 17.3 ± 3.5 cm, 33.5 ± 7.0 cm, 45.8 ± 10.5 cm, 63.8 ± 4.3 cm, 67.7 ± 10.8 cm and 78.0 ± 0.0 cm. From these results it was obvious that the distance between the 2nd lumbar vertebra (reference point) and the dorsal and ventral liver margins in dromedary camels examined in Groups I and II increases cranially which is in agreement with BRAUN (1990) and BRAUN and GERBER (1994) in cattle except that they considered midline of the back as the reference point. Difference in the reference point used in our study with that used in case of cattle is explained by the fact that, the mid back line is straight in cattle whereas the presence of the hump in camels makes it inconstant. The ventral liver margin on camels has a cranioventral course and is situated near the costal arch as in cattle (BRAUN 1990) and (BRAUN and GERBER 1994) but with a small part extending below it in the 9th intercostal space (ABDALLA et al 1971). Lung shadow started to appear from the 9th ICS which minimizes liver visibility. This has also been encountered by other workers (BRAUN 1990 and 1996, BRAUN and GERBER. 1994, DELLING 2000).

5.7.2 Hepatic Parenchyma

The parenchymal pattern of the normal camel liver consists of numerous medium echoes homogeneously distributed over the entire area of the liver in all intercostal spaces. The same

pattern was described in dogs (NYLAND and MATTOON 2002). In cattle, the parenchymal pattern of the normal liver consisted of numerous weak echoes (BRAUN 1990, BRAUN and GERBER 1994). This difference may be due to the fact that camel liver contains higher amounts of visible interlobular connective tissue leading to a firmer consistency than other domesticated animals (LEESE 1927, HEGAZI 1945, ABDALLA et al. 1971, IBRAHIM. 1993, LALLA and DORMMER. 1997). In the area from the 8th to 10th intercostal spaces the liver is adjacent to the omasoabomasal complex (C3). Intestinal loops are adjacent to the liver in the 11th intercostal space. This finding is in agreement with the observations of several workers on camels (HEGAZI 1945, ABDALLA et al 1971, NAGPAL et al. 1985, SMUTS and BEZUIDENHOUT 1987, FARAG 1990, ABDELMONIEM et al. 2000, SIDDIG 2002) as well as ultrasonographic findings in cattle (BRAUN 1990, BRAUN and GERBE 1994, DELLING. 2000).

Fissures were observed in the visceral liver surface in the 8th and in some camels also in the 10th, 9th, and 7th intercostal spaces. In some anatomical studies on the liver of dromedary camel, it was mentioned that liver surfaces are marked by several fissures cutting the surface in various directions and divide it into superficial lobes of variable sizes and that these fissures are more abundant and deeper in the cranial part of the liver particularly on the visceral surface (ABDALLA et al. 1971, SMUTS and BEZUIDENHOUT. 1987, SIDDIG 2002).

5.7.3 Hepatic vessels

Hepatic and portal veins were be visualized within the normal liver textures. The lumen of these vessels was anechoic and hence appeared black. It was mentioned that the portal veins are more echogenic than the hepatic veins in humans, dogs and horses (BYARS and HALLEY 1986, YAMAGA 1984, WU and CARLISLI. 1995). The portal veins are surrounded by connective tissue, whereas little or no connective tissue surrounds the hepatic veins (WU and CARLISLI 1995).The found in our study, the caudal vena cava was characterized by an oval shape in cross section and ran from caudo-dorsal to cranio-ventral similar to the dorsal boundary of the liver. The same was mentioned in some anatomical studies on camels' livers (HEGAZI 1945, ABDALLA et al. 1971, NAGPAL et al. 1985, SMUTS and BEZUIDENHOUT 1987, FARAG 1990, ABDELMONIEM et al. 2000, SIDDIG 2002). The caudal vena cava was always situated more dorsally and medially than the portal vein and could be visualized in the 11th and 10th intercostal spaces, rarely in the 9th intercostal space and could not be seen in the more cranial intercostal spaces (8th, 7th and 6th) because in

these intercostal spaces the caudal vena cava was hidden by the lung. A similar pattern was described in cattle (BRAUN 1996, MOHAMED et al. 2004) except that the caudal vena cava was triangular in cross section and could be visualized in the 12th, 11th intercostal spaces rarely in the 10th and never in the more cranial intercostal spaces. These could be attributed to anatomical differences between the two species considering the fact that cattle have thirteen ribs whereas camels have twelve. In some animals such as equines, the caudal vena cava is rarely imageable (REEF 1991). This also could be attributed to anatomical differences between species. The diameter of the caudal vena cava in the 11th, 10th and 9th intercostal spaces did not show significant difference in groups I and II. Mean and standard deviation values of 24.6 ± 6.6 mm, 23.9 ± 4.4 mm and 23.6 ± 2.3 mm were reported in group I for the diameter of the caudal vena cava in the 11th, 10th and 9th intercostal spaces respectively whereas these values were as 26.5 ± 4.9 mm, 27.1 ± 3.2 mm and 22.1 ± 1.1 mm in group II. BRAUN and GERBER (1994) stated that the diameter of the caudal vena cava in the last three intercostal spaces in cattle was 3.6 ± 0.6 mm, 3.7 ± 0.7 mm and 3.4 ± 0.8 mm respectively. This was comparatively greater than our results in case of dromedary camel. Depth of the caudal vena cava in Group I camels was found to be 94.4 ± 14.2 mm, 92.7 ± 6.2 mm and 90.2 ± 3.7 mm in the 11th, 10, and 9th intercostal spaces respectively whereas in Group II values of 108.8 ± 8.9 mm, 105.1 ± 4.8 mm and 104.2 ± 3.1 mm were reported in the same intercostal spaces. In cattle, values of 11.2 ± 1.5 mm, 12.4 ± 1.2 mm and 13.0 ± 1.2 mm were reported for the depth of the caudal vena cava in the last three ribs (BRAUN and GERBER 1994). This is in agreement with the anatomical fact stated by ABDALLA et al. (1971) that the caudal half of the dorsal border of the liver is thick and diminishes gradually as it goes cranially. The *porta hepatis* of the liver laid at the level of the point of the shoulder joint at a distance of 70.3 ± 6.3 cm and 73.2 ± 4.4 cm in Groups I and II respectively. Knowledge of this fact is important for portocentesis and is described for the first time in this study as far as we know. The *porta hepatis* could be visualized in the 10th ICS where the portal vein is characterized by a star-shaped ramification and can easily be differentiated from the hepatic vein. This star shape can be attributed to the fact that upon entering the porta hepatis, the portal vein divides into three branches (ABDALLA et al. 1971) namely *ramus dorsalis dexter*, *ramus ventralis dexter* and *ramus sinister* (FOUAD and SAFWAT 1986). The same anatomical finding was described in buffalo (ANIS 1977) and sheep (HEATH 1968). However, the initial branches of the portal vein in dogs are the right and left branches (SLIEGHT and THOMFORD 1970). In cattle, *porta hepatis* could be visualized in the 11th intercostal (BRAUN 1996).

The portal vein was best visualized in the 10th intercostal space in all examined camels in Groups I and II. The diameter of the vein in that intercostal space diameter was 33.4 ± 7.1 and 35.0 ± 5.1 mm in Groups I and II camels respectively whereas its depth in the same area was 42.0 ± 1.8 and 72.7 ± 4.7 mm in both groups. These findings are in agreement with the anatomical fact that the left branch of the portal vein is the largest and main continuation of the portal vein distributed into the papillary process, quadrate and left lobes (FOUAD et al. 1986, SIDDIG 2002). Ultrasonographic studies in cattle mentioned the 2nd intercostal space from the flank region as the best location for visualizing the portal vein (LECHTENBERG et al. 1989, BRAUN 2000, BRAUN et al. 2003) which is also similar to our findings as the 10th intercostal space in camel is the 2nd from the flank region.

5.7.4 Thickness of the dorsal and ventral liver margins

The thickness of the dorsal and ventral liver margins were found to be thinner in the 10th intercostal space (137.2 ± 29.6 mm and 142.1 ± 19.2 mm for the dorsal margin in Groups I and II respectively) and 68.0 ± 22.4 mm and 88.2 ± 33.3 mm for the ventral margin in both groups. Mean and standard deviation values of the thickness of the dorsal and ventral margins in Groups I and II camels were decreasing towards the cranial intercostal spaces. The dorsal margin is usually thinner than the ventral margin in all intercostal spaces in both group which is in agreement with the anatomical findings described by ABDALLA et al. (1971) and FARAG (1990) that the dorsal border (*margo dorsalis*) is thicker than the ventral border (*margo ventralis*).

5.7.5 Liver size

In all examined camels, the liver was ultrasonographically visible until a length of 53.0 ± 7.1 cm in the 11th intercostal space, whereas in the 6th intercostal space the visible liver size was 60.5 ± 5.7 cm. In previous gross anatomical studies a length of 60-80 cm was described for dromedary livers (DROANDI 1936, HEGAZI 1954, ABDALLA et al. 1971, SMUTS and BEZUIDENHUT 1987, FARAG 1990 and SIDDIG 2002) which is in agreement with our findings keeping in mind the fact that we could not view the whole liver ultrasonographically.

6 Summary

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Ultrasonographical examination of one humped camels (*Camelus dromedarius*) liver with some haematological and biochemical aspects

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Keywords: Dromedary, Liver, Transcutaneous Ultrasonography, Blood

The main objective of this study was to determine the suitable site to examine the liver by transcutaneous ultrasonography and to describe the echo pattern of the hepatic parenchyma and hepatic vessels in apparently healthy dromedary camels. The study was conducted on two groups of camels; Group I consisted of forty-one camels from Sudan and Egypt with the weight range of 350-550 kg. Camels in Group II (four camels) were studied in Germany their body weight ranged 400-600 kg.

Body temperature, pulse, heart and respiratory rates, blood haematology and biochemistry, hump height and circumference were determined.

Sternal recumbancy was found to be the most suitable and safer position to perform all the above mentioned examinations. Mean and standard deviation of the hump height and circumference in Group I were 23.1 ± 6.1 cm and 87.6 ± 35.9 cm respectively, and 38.3 ± 9.9 cm and 139.0 ± 21.7 cm, respectively in Group II.

Body temperature ranged 35.8°C to 40°C (Group I) and 34.5°C to 36.4°C (Group II); pulse rate ranged 35 to 55 beats/min (Group I) and from 30 to 45 (Group II) beats/min; respiratory rate was 10 to 22 breaths/ min (Group I) and 9 to 4 (Group II) breaths/ min.

Blood parameters including total and differential (neutrophils, lymphocytes, monophiles and eosinophils) white blood cell count as well as Hb, PCV, MCV, MCH and MCHC were measured in both groups. There was no significant difference in these values in animals in both groups. Blood biochemistry including AST, ALT, ALB, BIL, TG, ALP, GGT and GLDH was also measured in both groups. There were no significant differences between these values in Group I and Group II.

The liver could be ultrasonographically visualized in the area extending from the 11th to the 6th intercostal space (ICS) on the right side of the animal. The transverse process of the 2nd lumbar vertebra was considered as a reference point. The mean distance between the RP

and the dorsal and ventral liver margins was measured in both groups. The difference between these values in both groups was not significant.

The parenchymal pattern of the normal camel liver consisted of numerous medium echoes homogenously distributed all over the area of the liver. Fissures were observed in the visceral liver surface in the 10th to the 7th ICS. Hepatic and portal veins could be visualized within the normal liver textures. The caudal vena cava was characterized by an oval shape in cross section and visualized in the 11th and 10th ICS. *Porta hepatis* was found at the same level of the point of the shoulder joint at a distance of 70.3 ± 6.3 cm and 73.2 ± 4.4 cm from it in Group I and Group II, respectively. The portal vein was best visualized in the 10th ICS with diameter and depth of 33.4 ± 7.1 mm (Group I) and 35.0 ± 5.1 mm (Group II) and 42.0 ± 1.8 mm (Group I) and 72.7 ± 4.7 mm (Group II), respectively.

The thickness of the dorsal and ventral liver margins at the 10th ICS was thinner as it progressed cranially. The dorsal margin was usually thinner than the ventral margin in all intercostal spaces in both groups of camels.

The whole liver length which could be ultrasonographically examined in the area from the 11th to the 6th intercostal spaces in Group I and Group II were (53.0 ± 7.1 cm) and (60.5 ± 5.7 cm), respectively.

This work represents the first study on ultrasonographical examination of the liver in the one humped camel. The presented data can form base line values for future use of ultrasound in diagnosis of liver diseases in the dromedary camel. The technique is non-invasive and has the advantage that it can be applied in sitting non-tranquilized animals.

7 Zusammenfassung

Ayman El Nahas

Sonographische Untersuchung der Leber von Dromedaren (*Camelus dromedarius*) in Verbindung mit ausgewählten hämatologischen und biochemischen Parametern

Chirurgische Tierklinik der Veterinärmedizinischen Fakultät der Universität Leipzig

81 Seiten, 29 Abbildungen, 27 Tabellen, 202 Literaturangaben

Schlüsselworte: Dromedar, Leber, Transkutane Sonographie, Blut

Zielsetzung der vorliegenden Arbeit war die transkutane, sonographische Darstellung der Leber bei klinisch gesunden Dromedaren. Im Speziellen sollte die zur Sonographie geeignete Körperseite des Tieres, die Echogenität des Leberparenchyms und der Gefäße untersucht werden. Die einhöckrigen Kamele wurden für diese Studie in zwei Gruppen unterteilt: Gruppe I (n=41, 350-550kg) [aus dem Sudan und Ägypten], Gruppe II (n=4, 400-600kg) [aus Deutschland].

Bei allen Tieren wurden vor der sonographischen Untersuchung die Körpertemperatur, Puls – und Herzfrequenz, die Atemfrequenz und die Höhe und der Umfang des Höckers gemessen. Zusätzlich wurden Blutparameter labordiagnostisch ausgewertet.

Die sternale Lage des Tieres stellte die am besten geeignete Position zur Sonographie dar und erwies sich als die sicherste für den Untersucher. Klinisch konnten Höckerhöhen von 23.1 ± 6.1 cm (Gruppe I) und 38.3 ± 9.9 cm (Gruppe II) festgestellt werden. Der Höckerumfang betrug bei Gruppe I 87.6 ± 35.9 cm und bei Gruppe II 139.0 ± 21.7 cm. Die innere Körpertemperatur variierte in Gruppe I von 35.8°C bis 40°C und in Gruppe II von 34.5°C bis 36.4°C . Die Pulsfrequenz lag bei 35 bis 55 Schlägen / Minute (Gruppe I) und in Gruppe II bei 30 bis 45 Schläge / Minute. Es konnten Atmungsfrequenzen von 10 bis 22 Atemzüge / Minute (Gruppe I) und von 9 bis 4 (Gruppe II) ermittelt werden.

Zur Feststellung des Blutstatus wurden zunächst die Leukozyten – und Erythrozytenzahl und anschließende Differenzierung (neutrophile, monophile, eosinophile Granulozyten, Lymphozyten) bestimmt. Daraus leiteten sich die Werte für das Hämoglobin, der Hämatokrit, MCV, MCH und MCHC ab. Es waren keine signifikanten Unterschiede zwischen den Tieren aus Gruppe I und Gruppe II feststellbar. Die Blutchemie wurde an folgenden Parametern durchgeführt: AST, ALT, ALB, BIL, TG, ALP, GGT und GLDH. Zwischen beiden Kamelgruppen konnten bezüglich dieser Parameter keine signifikanten Unterschiede festgestellt werden.

Sonographisch konnte die Leber der Dromedare in einem Gebiet auf der rechten Körperseite zwischen 11. und 6. Interkostalraum (ICS) dargestellt werden. Als Referenzpunkt zur Vermessung der Leber wurde der Proc. transversalis des zweiten Lendenwirbels festgelegt. In beiden Gruppen wurde der jeweilige Abstand zum dorsalen Rand und ventralen Rand der Leber, ausgehend vom Referenzpunkt in den Interkostalräumen gemessen. Es bestanden keine signifikanten Längenunterschiede zwischen den Tiergruppen.

Das parenchymatöse Gewebe der Leber stellte sich mit vielen, mittelgroßen, homogen verteilten Echos dar, die sich regelmäßig über das gesamte, darzustellende Gebiet verteilten. Zwischen dem 10. und 7. Interkostalraum hatte die Leber auf der viszeralen Seite ein zerklüftetes Aussehen. Eingebettet in das homogene Parenchym konnten Abzweigungen der Pfortader und der V. hepatica erkannt werden. Die V. cava caudalis war im 11. und 10. Interkostalraum darstellbar und hatte ein querovales Aussehen. Die Porta hepatis ist auf der Höhe des Schultergelenkes in einem Abstand von 70.3 ± 6.3 cm (Gruppe I) und 73.2 ± 4.4 cm (Gruppe II) darstellbar. Am besten konnte die Pfortader mit ihren Aufzweigungen im 10. Interkostalraum in einer Tiefe von 42.0 ± 1.8 mm (Gruppe I) und 72.7 ± 4.7 mm (Gruppe II) erkannt werden. Der Durchmesser dieses Gefäßes betrug 33.4 ± 7.1 mm in Gruppe I und 35.0 ± 5.1 mm in Gruppe II. Weiterhin wurde die Breite des dorsalen und ventralen Leberrandes im 10. Interkostalraum bestimmt. Die Breite beider Leberränder verringerte sich in kranialer Richtung. Grundsätzlich war der Dorsalrand in allen untersuchten Interkostalräumen bei beiden Gruppen dünner. Die Gesamtlänge des sonographisch darstellbaren Leberabschnitts betrug in Gruppe I 53.0 ± 7.1 cm und in Gruppe II 60.5 ± 5.7 cm.

Diese Arbeit stellt eine erste Studie sonographischer Untersuchungen der Leber bei einhöckrigen Kamelen dar. Diese nicht invasive, leicht durchzuführende Technik hat den Vorteil, Untersuchungen auch am nicht sedierten, sitzenden Tier vornehmen zu können. Die vorgestellten Daten stellen eine Grundlage für die zukünftig Diagnostik von Lebererkrankungen der Dromedare dar.

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