A SYSTEMIC REVIEW ON ULTRASONOGRAPHIC APPLICATIONS IN CAMELS

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ABSTRACT

Ultrasound is widely accepted as a safe noninvasive diagnostic imaging technique in animals and human. To date, ultrasonography has been used efficiently to study the ovarian status in she camels such as; follicular wave, spontaneous ovulation, optimum time for mating, ovarian vasculature, superovulatory response, ovarian follicular dynamics, ovarian follicular wave synchronisation and follicular deviation. Moreover, it has been applied for collection of cumulus oocyte complexes, pregnancy diagnosis, foetometry, foetal sexing, embryo transfer programmes, assessment of somatic cell nuclear transfer and evaluation of the quality and developmental ability of dromedary embryos. Uterine involution and various reproductive disorders such as; early embryonic death, endometritis, vaginal adhesions, ovarian cysts and ovarian hydrobursitis have been diagnosed by ultrasound. In male camels, ultrasonography is a useful tool in studying the developmental changes of testes and pelvic genitalia including; bulbourethral gland, prostate, and pelvic urethra and predicting puberty and future fertility. Normal pleura, heart, fore stomach, liver, small and large intestines, kidney, eye, udder and teat, foot, carpal and tarsal joints have been successfully imaged. However, very limited affections of these structures including; infectious pleuropneumonia, peritonitis, trypanosomiasis, John’s disease, intestinal obstruction and ruptured urinary bladder have been diagnosed ultrasonographically in camels. Therefore, ultrasonographic application in camels, compared to other farm animals, is still limited. In conclusion, ultrasonography is untapped in camel practice however, it can offer veterinarians the opportunity for more precise diagnosis and treatment of numerous disorders.

Key words: Camel, dromedary, foetometry, ovum pick-up, pregnancy diagnosis, ultrasonography

Ultrasonography is used extensively as a safe and non-invasive diagnostic technique in veterinary medicine (Fouad et al, 2000; Elnahas, 2008; Mostafa et al, 2014a; Abu-Seida et al, 2015) and as a method of choice for detecting reproductive disorders in large domestic animal species (Ali et al, 2013; Nagy et al, 2015). It is ideal for dairy production because it does not emit radiation that can be harmful to the pregnant herd and does not require anti-radiation shields, vests and building which can cause additional farm expenses.

Camel has several anatomical adaptations to survive the dry and arid climates. Therefore, numerous ultrasonographic differences have been recorded between camel and other ruminants especially on the foot, udder, optic dimensions and reproductive physiology.

In large animal practice, ultrasonography has been widely used with a great reliability for identification of several physiological and pathological conditions (Abu-Seida, 2012; Mostafa et al, 2014b and Mostafa et al, 2015).

The literature on ultrasonography in normal and diseased camels is quite scarce. Therefore, this review aims to shed the light on the current applications of ultrasonography in various organs of camels in a trial to find out the points of strength and weakness and future prospect of ultrasonographic applications in camels.

Ultrasongraphic examinations in camels:

In camels, ultrasound has been applied to identify the following organs

1. The reproductive organs:

Transrectal ultrasonography has been used to study the ovarian status in she camels such as; spontaneous ovulation (Nagy et al, 2005), follicular wave, optimum time for mating, ovarian vasculature (Rawy et al, 2014), superovulatory response (Vyas et al, 2004a and Nowshari and Ali 2005), follicular dynamics (Manjunatha et al, 2012a&b); follicular wave synchronisation for a timed breeding in both dromedary (Skidmore et al, 2009; Nagy and Juhasz,

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2012 and Manjunatha et al, 2015) and bactrian camels (Nikjou et al, 2008), follicular deviation (Manjunatha et al, 2014) and pre-ovulatory follicle during non-breeding season (Vyas et al, 2004b).

Both transrectal colour-Doppler and B-mode ultrasonography are used to detect changes in the ovarian structures and blood vasculature. Three phases of follicular development, those of growth, maturation, and regression, are observed during each follicular wave (Skidmore et al, 1996). The optimum time to mate or attempt to induce ovulation in she camels is when the growing follicle measures 0.9-1.9 cm in diameter.

Transvaginal ultrasound guided ovum pick-up (OPU) technique is carried out in dromedary camels. For collection of cumulus oocyte complexes (COCs) the transducer is introduced through the vulva into the most cranial portion of the vagina. Then a 17-gauge, 55 cm single-lumen needle is placed in the needle guide of the ultrasound probe and advanced through the vaginal fornix and into the follicle. Follicular fluid is aspirated using a regulated vacuum pump into tubes containing embryo-flushing media. These aspirates are searched for COCs using a stereomicroscope and they are then denuded of cumulus cells by hyaluronidase and repeated pipetting. The developmental response, to chemical activation, of in vivo matured oocytes collected by ultrasound guided transvaginal (OPU) is better than in vitro matured oocytes obtained from slaughterhouse oocytes (Wani and Skidmore, 2010).

Ultrasonography is used in pregnancy diagnosis of mated dromedary and South American camels (Wright et al, 1998 and Ali et al, 2013). Ultrasonographic foetometry is a helpful tool for evaluation of foetal development, gestational age, and prenatal foetal sexing in camels. Intrauterine fluid accumulation is detected between the second and third weeks of pregnancy and the embryo is seen properly between the third and fourth weeks. Organisation and ossification of the embryo is first visualised at the 6th to 7th weeks and 7th to 9th weeks, respectively. The accessibility for crown-rump length, biparietal diameter, abdominal diameter, ruminal length, and eyeball diameter during the total gestational period are 10.6%, 10.6%, 12.8%, 12.8% and 38.3%, respectively. The best window for foetal sexing is found during the 11th week of pregnancy with an overall accuracy of 91.7% (Ali et al, 2013).

The conceptus is always observed by ultrasound through the left caudal abdomen approach (above the base of the udder) at the 6th to 12th week. Between the 13th and 27th week, the foetus is well visualised through the middle abdominal approach (from the base of the udder to the umbilicus). While from the 28th to 52nd week, the conceptus is mainly detected through the left cranial abdominal approach (from the umbilicus to the xiphoid cartilage) (Ali et al, 2015a).

Moreover, several foetal parameters including orbital diameter, biparietal diameter, abdominal diameter, chest depth and ruminal diameter are measured by ultrasound. Also, ultrasonography is used during the embryo transfer programmes (Skidmore and Billah, 2005; Khatir and Anouassi, 2006 and Skidmore and Billah, 2011), interspecies embryo transfer (Niasari-Naslaji et al, 2009), assessment of somatic cell nuclear transfer (Khatir and Anouassi, 2008 and Khatir et al, 2009) and assessment of the quality and developmental ability of dromedary embryos obtained by IVM/IVF, in vivo matured/IVF or in vivo matured/fertilised oocytes (Khatir et al, 2007). Moreover, ultrasonography is a beneficial tool for comparison of pregnancy rates in dromedary camels after deep intra-uterine versus cervical insemination (Skidmore and Billah, 2006).

Uterine involution is completed from 25 to 30 days postpartum and follicles (>1.0 cm diameter) can be imaged by ultrasound in only 52.7% of the examined she camels from 34 to 70 days postpartum. Half of these she camels had a confirmed pregnancy at 60 days after mating with virile studs (Vyas and Sahani, 2000 and Derar et al, 2014).

Regarding uterine pathologies, ultrasound has been used for diagnosis of various reproductive disorders such as; early embryonic death, endometritis, vaginal adhesions, ovarian cysts, ovarian hydrobursitis and during treatment with intrauterine therapies (Tibary and Anouassi, 2001; Ali et al, 2010a&b; Nagy et al, 2015 and Ali et al, 2015b). Ultrasonographically, ovarian hydrobursitis, is characterised by a collection of anechoic fluid within the ovarian bursa and hyperechoic encapsulation of the ovary (Tibary and Anouassi, 2001).

In male camels, ultrasonography is a useful tool in studying the developmental changes of the testes and pelvic genitalia including; bulbourethral gland, prostate, and pelvic urethra and predicting puberty and future fertility. Ultrasonographic testicular measurements including; testicular length, breadth, and depth as well as epididymal head and tail. All of these testicular and epididymal measurements show significant increase with age (Derar et al, 2012).
The normal ultrasonic appearance and seasonal changes in the testicular parenchyma in camels has been scanned using a B-mode real time ultrasound scanner connected with a 7.5-MHz linear-array transducer. The testicular tunics appear as hyperechoic lines surrounding homogenous, moderately echogenic testicular parenchyma. The mediastinum testis is seen as hyperechoic central line and as a spot in longitudinal and transverse scans, respectively. In winter, the testicular parenchyma appears as hyperechoic with a thin hyperechoic mediastinum testis. During spring, moderate echogenic parenchyma and a relatively thick hyperechoic mediastinum are scanned. In summer and autumn, less echoic testicular parenchyma and thick mediastinum are visualised (Pasha et al, 2011).

Moreover, testicular ultrasonography can afford veterinarians the opportunity for more precise diagnosis and treatment of numerous dromedary infertility disorders (Waheed et al, 2014).

2. The respiratory organs (the lung and pleura)

Ultrasonographically, the different layers of thoracic wall appear as narrow bands of variable echogenicity in normal camels. Pulmonary parenchyma cannot be imaged due to its gas contents. Mostly, the right and left pulmonary surfaces are visualised at 5th-10th intercostal spaces (ICSs). Sometimes, it can be scanned at 4th and 11th ICS. The length of ventral lung border is largest at the 4th ICS and smallest at the 11th ICS. Moreover, the coastal and the parietal pleurae appear as echogenic line of 1-4mm thickness on the surface of the lung (Tharwat, 2013).

Abdominal and thoracic ultrasonography show severe bicavitory effusion, peripheral lung consolidation and intestinal hypomotility in a camel calf suffering from infectious pleuropneumonia and peritonitis (Stoughton and Gold, 2015).

3. The heart

Echocardiography is a helpful tool for determination of morphological and functional status of the heart. On the right side of camels, the caudal long-axis four-chamber view of the ventricles, atria, and the interventricular septum is imaged when the probe is placed in the right 5th or 4th ICS and when the probe placed more cranially in the 4th ICS, the caudal long-axis four-chamber view and the caudal long-axis view of the left ventricular outflow tract (LVOT) are scanned. The short-axis view of the ventricles is obtained at the 4th ICS when the transducer is rotated between 0° and 25°. When the transducer at the 3rd ICS, visualisation of the right ventricular outflow tract (RVOT) is achieved (Tharwat et al, 2012a).

On the left side, a four-chamber view is obtained when the probe is placed in the 5th or 4th ICS. The LVOT and RVOT are imaged from the 4th ICS and 3rd ICSs, respectively.

Echocardiography was helpful for diagnosis of a persistent ventricular septal defect (VSD) in a camel calf (Moore et al, 1999) and hypertrophic cardiomyopathy in a 9-year-old dromedary camel that showing thickening of left ventricular free wall and interventricular septum and small left ventricular lumen (Gutierrez et al, 2000).

4. The digestive organs:

Ultrasound has been used firstly to visualise the gastrointestinal tract and liver in healthy camels. On ultrasound examination, the rumen of normal camels has a smooth and echogenic ruminal wall.

The reticulum appears as a half-moon-shaped structure with a thick echogenic wall (1.17±0.27 cm) and a biphasic contraction. Mostly, the ventral part of the reticulum can be imaged from left and right paramedian region just behind the sternal pad.

The omasum can be viewed at the right 8th-6th intercostal spaces with a wall thickness of 1.1±0.7 cm and a transverse diameter of 8.74±3.4 cm.

The abomasum can be visualised at the right 9th-7th intercostal spaces (Tharwat et al, 2012a)

Small intestines can be imaged at the ventral part of the right paralumbar fossa and has a thin wall (0.43±0.14cm) and a diameter of 2.62±0.47cm. The caecum is imaged mainly in the caudal area of right flank. It has a thin wall (0.37±0.05 cm) and a diameter of 13.8±1.6cm. The proximal loop of the large colon appears as thick, echogenic, slightly curved and continuous lines. It has a thin wall (0.51±0.08cm) and a diameter of 3.5±0.8cm. The spiral colon can be imaged at the caudal ventral half of the abdomen and appears as a structure with thick echogenic walled and several echogenic arched lines next to each other. Mostly, free anechoic peritoneal fluid pockets can also be imaged in camels (Tharwat et al, 2012b). Percutaneous ultrasound-guided aspiration of peritoneal fluid (PF) is performed in healthy camels to study its constituents. Free anechoic PF is imaged in the triangular space between the dorsal ruminal sac and reticulum and 10-cm cranial to the umbilicus (Tharwat et al, 2013).

Ultrasoundography is a useful imaging tool for evaluation of abdominal distension in camels.
caused by trypanosomiasis, intestinal obstruction and ruptured urinary bladder.

Camels with trypanosomiasis show accumulation of large amount of hypoechoic abdominal fluids with floating liver, intestine, kidney, spleen and urinary bladder. Mostly, no detectable abnormal ultrasonographic findings are imaged in liver, heart, major blood vessels and kidneys. The main ultrasonographic findings in camels suffering from intestinal obstruction include; distended intestinal loops, markedly reduced or absent intestinal motility and hypoechoic fluid with or without hyperechoic fibrin between intestinal loops (Tharwat et al., 2012c).

Ultrasonographic findings in camels with Johne’s disease are clumps of echogenic tissue interspersed with anechoic fluid pockets between the intestinal loops, various degrees of intestinal wall thickening and corrugation, excessive anechoic peritoneal fluid, severe enlargement of mesenteric lymph nodes with hypoechoic, heterogenic and echogenic contents, increased hepatic brightness, pericardial and pleural effusions. Sensitivity values of ultrasonography for detecting intestinal lesions and enlarged mesenteric lymph nodes are 95% and 84%, respectively (Tharwat et al., 2012d).

Hepatic ultrasonography can be carried out at the right 11th to 5th intercostal spaces (ICSs). The distance between the dorsal liver margin and the midline of the back is shortest (39.1 ± 7.4 cm) at the 11th ICS and increases cranially to 5th ICS. (Tharwat et al., 2012e&f). Sternal recumbancy position was the most suitable, practicable and safe position for liver ultrasonographic examination in camels. The long axis of liver extended from caudodorsal to craniaoventral in the right lateral side of the abdomen. The distance between the transverse process of the 2nd lumbar vertebra and the dorsal liver margin in camels ranged from 12.9 ± 3.9, 19.2 ± 4.4, 27.7 ± 6.2, 36.6 ± 7.2, 45.6 ± 6.7 and 52.7 ± 9.3 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 margin of the liver in the 11th, 10th, 9th, 8th, 7th and 6th intercostal spaces was found to be 21.9 ± 10.1, 24.7 ± 6.2, 36.9 ± 10.4, 42.6 ± 7.1, 49.9 ± 7.5 and 55.8 ± 9.2 cm, respectively. The normal camel liver parenchyma consisted of numerous medium echoes homogenously distributed over the entire area of the liver in all intercostal spaces. Fissures in the hepatic visceral liver surface were always observed in the 8th intercostal space and sometimes in the 10th, 9th and 7th intercostal spaces (Elnahas, 2008).

5. The urinary organs

As regards the application of ultrasound in the urinary system of camels, little information are available. Hence, further studies concerning the ultrasonographic diagnosis of urinary disorders in camels are recommended.

In camels, the right kidney is visualised from the right 10th and 11th ICSs and upper right flank. While the left kidney is imaged from the caudal left flank (Tharwat et al., 2012e). Ultrasound clearly differentiates the renal cortex from medulla.

Camels with ruptured urinary bladder show ruptured and collapsed urinary bladder, echogenic blood clots inside the urinary bladder and peritoneal cavity, thickened bladder wall, floating intestines in hypoechoic fluid and sometimes echogenic urethral calculi (Tharwat et al., 2012c).

6. The eye

Transcorneal ultrasonographic scanning of camels is performed using a 7.5-10 MHz transducer. Most of the performed studies are conducted on freshly enucleated eyes of camels by A-mode ultrasonography for measurement of optical dimensions after immersion of the eyes in distilled water kept at 20°C. The measured optical dimensions included the anterior chamber depth, lens thickness, vitreous chamber depth and axial length. Generally, A-mode ultrasonography is more accurate than B-mode for estimation of intraocular measurements. Thus, A-mode ultrasonography is the procedure of choice in ocular biometry while B-mode ultrasonography is used mainly for diagnostic aims. Compared to the average A-mode values, B-mode overestimates corneal thickness and anterior chamber depth and underestimates lens thickness, vitreous chamber depth and axial length (Hamidzada and Osuobeni, 1999).

In vitro, the average values of the anterior chamber depth, lens thickness, vitreous chamber depth and axial length are 5.27 mm, 10.93 mm, 14.85 mm and 31.05 mm, respectively. The uncorrected average corneal thickness is 0.76 mm (Osuobeni and Hamidzada, 1999). In vivo, all ocular measurements are slightly increased except anterior chamber depth which is slightly decreased. Axial globe length and vitreous chamber depth are larger in she camels than male camels while the lens thickness in male camels is larger than in females (Yadegari et al., 2013).

The cornea, anterior and posterior lens capsule and iris appear hyperechoic. The axial length,
vitreous chamber depth (VCD), corneal thickness, lens thickness and scleroretinal rim thickness increase with the advance of age in camels (Kassab, 2012).

The average velocity of ultrasound through aqueous and vitreous humour samples derived from normal camels is 1,499 ± 23 m/s and 1,497 ± 24 m/s, respectively. These values are similar to that of cattle and pigs but slower than in humans (Hamidzada and Osuobeni, 1998). These ultrasonographic findings in normal camel’s eye are valuable for comparative ocular anatomy and ultrasonographic evaluation of ocular diseases in the future.

7. The udder and teats

Ultrasonography of udder and teats provides a good assessment of both normal and diseased udder (Kotb et al, 2014). In lactating camels, B-mode ultrasonographic examination of the udder in the water-bath was performed using 6.5-8.5 MHz linear array transducer (Abshenas et al, 2007). The streak canal, teat sinus, gland sinus and lactiferous ducts are imaged easily. The teat has a hyperechoic outer layer, a hypoechoic thicker middle layer and a less hyperechoic inner layer. The intercisternal wall of each teat can be divided into 3 layers: two outer thin hyperechoic layers and a thicker middle hypoechoic layer.

8. The musculoskeletal system

Several studies have been conducted on the normal carpal joint (Kassab, 2008), tarsus (Hagag et al, 2013) and foot (Abu-Seida et al, 2012) in camels. However, no available studies concerning ultrasonographic diagnosis of lameness are reported in camels.

The extensor carpi radialis, extensor digitorum communis and extensor digitorum lateralis tendons are easily identified by ultrasound at the dorsal aspect of the carpus and distal radius. Meanwhile, the extensor carpi obliquis tendon is difficultly identified and the ulnaris lateralis tendon is seen laterally. Moreover, the flexor carpi radialis, flexor digitorum superficialis and flexor digitorum profundus tendons can be observed at the palmar aspect (Kassab, 2008).

Ultrasoundography is a highly impressive cross sectional diagnostic imaging in camel’s digits. Transverse and sagittal ultrasonographical examinations are carried out on digits using a 6-8 MHz linear transducer. On the sagittal scan at the dorsal aspect of fetlock joint, common digital extensor tendon appears as a hyperechoic band of 9-15 mm width then bifurcates into medial and lateral hyperechoic branches of 8-10 mm width. Hyperechoic thick superficial digital flexor tendon of 15-20 mm width and thickness splits just below the fetlock joint to pass the hyperechoic deep digital flexor tendon (DDFT). On sagittal scan, DDFT appears as hyperechoic band while it appears as hyperechoic oval structure surrounded with anechoic synovial fluid and hyperechoic tendon sheath in transverse scan. The DDFT has 2 hyperechoic enlargements at the fetlock joint and under the second phalanx. The camel’s foot has three digital cushions (DC). The largest one is the middle digital cushion (MDC) that appears on sagittal scan of the solar aspect as a fish-like high echogenic homogenous structure. The abaxial (Abx DC) and axial digital cushions (Ax DC) are visualised as thin echogenic bands over the middle digital cushion. On transverse scan of the solar aspect, digital cushions appear as 3 high echogenic homogenous structures which are surrounded with a common hyperechoic capsule. The MDC appears as an oval or rounded echogenic structure surrounded by 2 crescentic echogenic Ax DC and Abx DC. The MDC is larger in the forelimb than hind limb and the Ax DC is thicker than Abx DC.

Transverse scan of the solar aspect at the interdigital notch shows 2 crescentic echogenic Ax DC of both claws which are separated by anechoic interdigital septum and 2 rounded echogenic MDC of both claws. The sole consisted of hyperechoic thin keratinised layer and thick anechoic layer. The thickness of the sole was 9-12 mm cranially and decreased gradually backward to be 6-7 mm at heel (Abu-Seida et al, 2012).

Tarsal ultrasonography is conducted in four planes including; dorsal, medial, lateral and plantar using a 7.5 MHz convex transducer to visualise all tarsal structures in camels (Hagag et al, 2013).

Conclusions:

Compared to other farm animals, ultrasonography is untapped in camel practice, however, it can provide veterinarians the opportunity for more precise diagnosis and treatment of numerous dromedary disorders.

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