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Anatomy

Morphological and Diagnostic Imaging Studies on Pelvic Cavity of Egyptian Female Baladi Goat *(Capra hircus)*

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ABSTRACT

This presented study is designed to provide an in-detailed anatomic reference to the pelvic cavity of the female baladi goat through the topographical anatomy, cryo-sectional anatomy, computed tomographic examination (CT) and ultrasonographic evaluation. In addition to this, recording the different diameters of the pelvis. This study was set on thirteen healthy female baladi goats weighing 20–35 kg and age range from 8-18 months. The morphology of pelvic organs was particularly detailed through many CT scans and compared by cryo-cross sectional anatomy. The cadaver was frozen. then sliced at 3cm apart after that the cryo-sections were cleaned then photographed to be matched with the closest CT image to make it easy to identify accurately different structures. CT images were used to investigate female pelvis and its related viscera (part of rectum-uterus-vagina-urethra-urinary bladder- part of ureter). The dorsal boundary of pelvic cavity was long and it continued to third caudal vertebrae. The vesicogenital pouch was longer than vesicopubic and recto genital pouches. different pelvic diameters are recorded. Two-dimensional ultrasonographic evaluation considered complementary to other diagnostic modalities in pelvic cavity configuration. Ultrasonography can easily differentiate between different soft tissue depending on its characteristic components of basic tissue. Finally, it could be proved that the different diagnostic imaging as CT and ultrasonography contribute greatly in veterinary practice as the data obtained from diagnostic imaging can be used as a diagnostic tool and baseline data for educational ,clinical and research purposes .Beside that it can be used to evaluate the female goat reproductive performance specially in prediction of dystocia through examination of the pelvis.

Keywords: morphology, diagnostic imaging, goat, pelvic cavity.

INTRODUCTION

Goats have been the first to be domesticated as a meat producing-animal. Since increasing man-needs, the goats' populations are increased to be enough for human demands (Boyazoglu *et al.*, 2005). In Egypt, the baladi goats have been raised intensively across the Nile valley as well as Delta (Agha *et al.*, 2008). The villagers' herd of goats is above 90% of the goat population in Egypt (Mabrouk *et al.*, 2009)

Goat is a rapid reproducing animal with numerous kids' production and helps farmers increasing their wealth through selling their kids, milk as well as skin. Goats reach maturity early and with successful reproduction about 2 kids are produced each year with high percent of twinning. In developing countries, the goats are the most neglected and have no attention among different livestock (Gupta *et al.*, 2011).

Combination between the diagnostic imaging and the traditional way using dissection will add value to understand anatomical specifics (Seddek *et al.*, 2014). Different Imaging techniques contribute greatly in the formation of a standard database of normal existing

anatomical, physiological and functional parameters that will be helpful for anatomic researchers, veterinary medicine surgeons, specialist and practioners (Thomas and Pickstone, 2007).

Computed tomography (CT) is a valuable modality that provides a standard alive animals cross-sectional images review. It is a distinguish diagnostic tool for disease when compared to plain radiography (Prather *et al.*, 2005). recently computed tomography exceeds other modalities specially in the creation of a three-dimension model of various structures (Yamazoe *et al*., 1994).

CT is topping over radiography in getting rid of superimposed images in addition to exclusion of superior contrast resolution. These properties greatly guide specialists when radiograph is considered non-specific (Spann *et al*., 1998).

Ultrasound provides a non-invasive, cheap, accessible and substitute to many radiograph and CT procedures. However, these techniques considered integral to each other. ultrasonography can be used to instead of exploratory laparotomy to obtain details and information that was only available through the laparotomy (King, 2006; Crilly *et al.,* 2017).

Recently, the anatomy has become an interdisciplinary science thanks to imaging techniques development, it became much easier to combine between both traditional anatomical method and clinical disciplines. These data are greatly contributing in developing of a relatively new branch "Imaging Anatomy". this is the new anatomy contemporary trend, which examines the normal images of the anatomical objects. Anatomical scientific facts are interpreted by the imaging methods including ultrasound, CT "computed tomography" and MRI "magnetic resonance imaging" (Dilek *et al.*, 2019)

MATERIALS AND METHODS

Animals:

Thirteen normal, clinically healthy and not suffering from any pelvic disease female Baladi goat were obtained from department of veterinary anatomy and embryology faculty of veterinary medicine, Menoufia university. weight range from about 20–35 kg and aged between 8-18 months were included in this study.

Topographic anatomy of the pelvic cavity

Three female baladi goat were used to study the normal anatomical structure of the pelvic cavity including the viscera and different pouches. first, the goats were sedated and sacrificed through bleeding from common carotid artery through cannula which was used in flowing the embalming fluid of 10% formalin for cadaver fixation. It was cut longitudinally using electric saw across midline for sagittal sections of pelvic cavity. The other cadavers were cut transversely into serial sections with 3 cm apart. It begins from level of last lumber vertebrae then each section was numbered, cleaned and photographed using Nikon Coolpix B600 (60x optical zoom lens) to be used as a model for assessing the anatomical features of pelvic cavity as whole. Then cadaver was kept in deep freezer at (-20 ^{o} C) on lateral recumbency.

Computed tomographic imaging

Three physically normal goat not suffering from pelvic distortion were used for CT scan. The images were taken in private diagnostic imaging center, Menoufia governorate, Egypt. Multi-slice helical of third generation 128- slice dual source CT scanner (Siemens Somatom Definition Flash, Siemens, Erlangen, Germany). Time of rotation .85 second. Tube size 7.0 MHU. Power 75 kW. mA up to 80 mA. the slice thickness is 0.2 cm in cross section. these scans were analyzed using Radiant DICOM Viewer software (Medixant, Poland) and compared with cryosections to asses different pelvic structure.

Ultrasonographic examination

Two female baladi were used for evaluation of female pelvic cavity. the Ultrasonography examination was done via transrectal approach by using portable ultrasound machine (Chison ECO3 Expert, Medical EXPO, China) with adjusted 8.5 MHz linear transducer).The coupling gel used to lubricate the transducer of ultrasound then was put in the rectum after removing fecal matter and was moved over the dorsal surface of the pelvic urethra and urinary bladder and laterally to image uterus.

gross anatomy of pelvic bone

five baladi goat from Menoufia governorate were euthanized and kept in sand for at least five months then was taken for studying the structure of bony pelvis and its characteristics. Also, a skeleton of baladi goat was obtained from department of anatomy and embryology, university of Sadat city were used in

morphological study of pelvic bone and internal pelvic diameters were measured. The nomenclature used in this study is adapted to Nomina anatomica Veterinaria (2017).

RESULTS

Gross anatomy

The pelvic girdle consisted of the union of three bones ischium, pubis and ilium and last three caudal vertebrae. The ilium consisted of two parts including wing and body. the iliac wing was broad with its gluteal surface direction dorsolaterally. the ventral surface is thicker. The gluteal line appeared as rounded crest. The iliac crest is concave dorsally and convex ventrally (figure2/5a). The body of ilium appeared in parallel to each other. The body of ilium was elongated (figure2/3a). The psoas minor tubercle is not clear. the pubis has two rami. Cranial ramus and wider caudal ramus. Iliopubic eminence was sharp and thin. There was deep greater ischiatic notch There was a lateral process extend from ischiatic tuberosity and directed ventrolaterally. The acetabulum was rounded. The obturator foramen was ovoid (figure 1a) and (figure 2a). These finding was perfectly represented in three-dimension model created with CT scan (figure 1b) and (figure 2b)

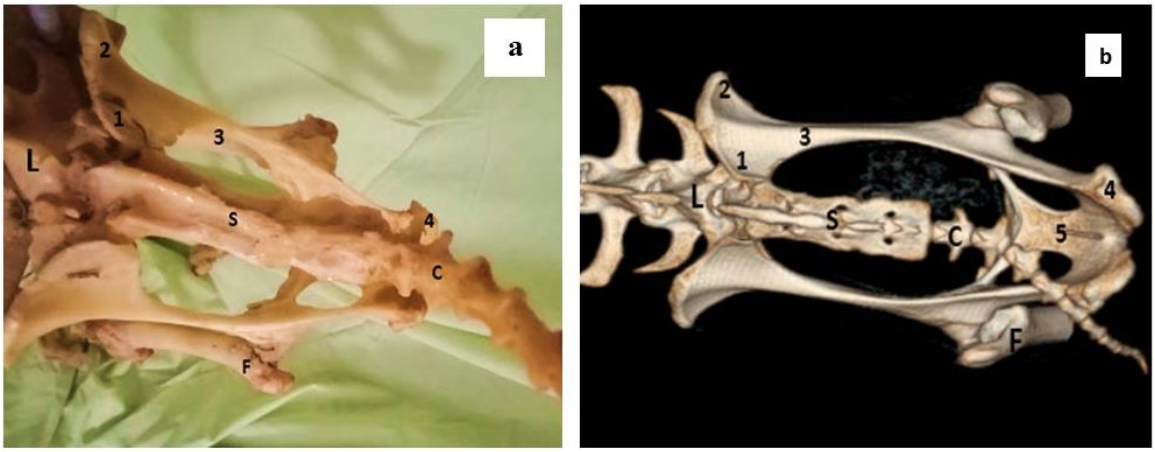

Figure (1): (a) Dorsal view of pelvic girdle and **(b)** its corresponding 3d model 1-sacral tuberosity, 2-coxeal tuberosity 3-body of ilium, 4- ischiatic tuberosity, L: lumber vertebrae, S: sacrum, C: caudal vertebrae, F: femur

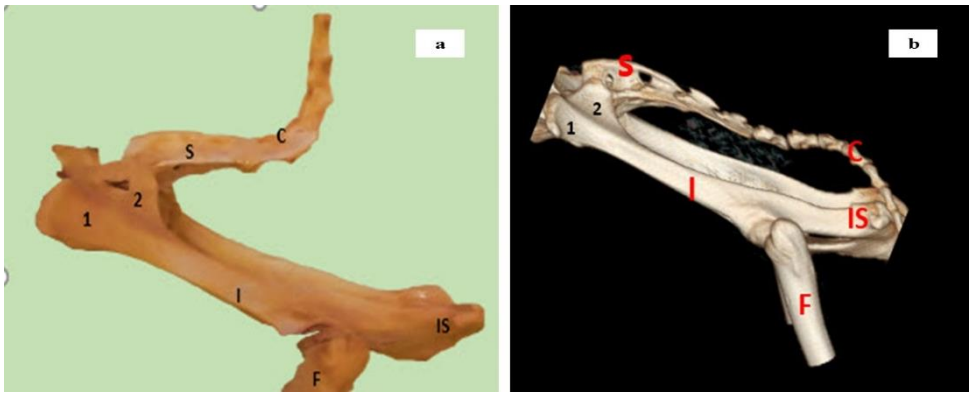

Figure (2): (a) lateral view of pelvis and **(b)** its corresponding 3D model 1- coxeal tuberosity, 2-sacral tuberosity, L: Lumber vertebrae, S: sacrum, C: caudal vertebrae, F: femur, IS: ischium

Pelvic measurement

Internal pelvic diameters including Conjugate diameter which was the distance measured from the most cranial end of the pelvic symphysis and promontory of sacrum , vertical diameter which was the distance measured from the pelvic symphysis cranial end and sacrum with being perpendicular to floor of pelvis and transverse diameter which extended across the greatest width of the pelvic inlet just above psoas tubercle from one side to the same opposite point the internal pelvic diameter mean value is shown in table (1), the transverse diameter mean value is 7.13 cm, the vertical diameter mean value is 8.18cm, the conjugate diameter mean value is 9.64 cm. The angle between conjugate and vertical diameter is pelvic angle or inclination and its mean is 12.6 °

Table (1): showing internal pelvic diameters

	Transverse diameter	Vertical diameter	Conjugate diameter	Pelvic angle
Mean value	7.13	8.18	9.64	12.6 °

Topographic anatomy of pelvic cavity

Bony boundaries of pelvic cavity are sacrum and first three caudal vertebrae dorsally and pubis and ischium ventrally and ilim laterally. The pelvic cavity enclosed part of rectum (figure 3a/R), uterus (figure 3a/U), urinary bladder (figure 3a/B), and ureters. The pretonium reflected on these organs creating pelvic pouches. It reflected between urinary bladder and pubis forming pubovesical pouch (figure 3a/4) then between urinary bladder and female genital tract forming vesicogenital pouch (figure 3a/3) and between female genital tract and rectum forming rectogenital pouch (figure 3a/2). On the two sides of the mesorectal dorsally the sacrorectal pouches which was divided into two pararectal fossa

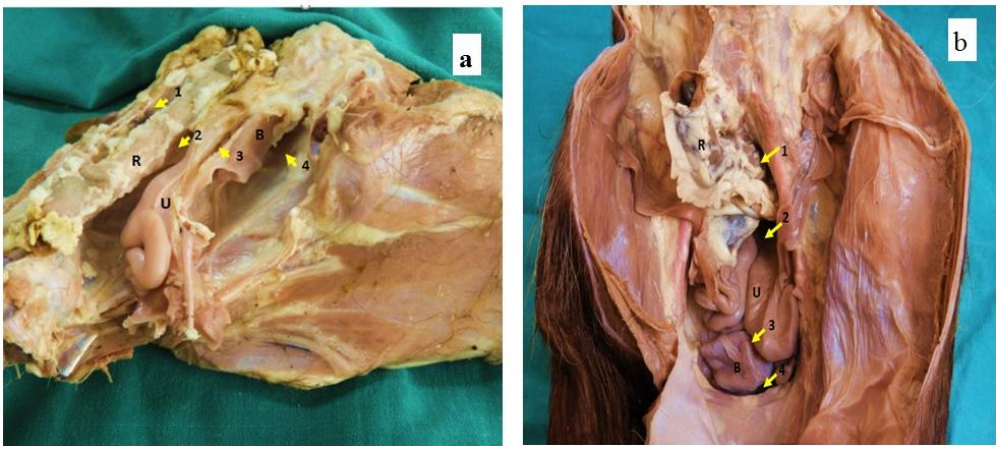

Figure (3): (a) cranial view of pelvic cavity pouches **(b)** lateral view of pelvic cavity pouches 1-sacro rectal pouch 2-rectogenital pouch**,** 3-vesicogenital pouch**,** 4- pubovesical pouch**,** R-rectum**,** U-uterus**,** B-bladder

computed tomography and Cross-sectional anatomy of the female pelvic cavity

At the level of the 3rd sacral vertebra

In anatomical cross-section, the rectum located dorsally and full of fecal matter (figure 4 a/3). uterus located medially (figure 4 a/1). Parts of sacrum
(figure 4 a/s) and shaft of ilium also appeared in cross section (figure 4 a/I).

In the CT image, the area of low density with moderate density circular parts represents rectum with fecal matter (figure 4 b/3). the uterus appeared with a moderate density (figure 4 b/1).

At level of 4th sacral vertebra

In anatomical cross-section, the rectum located dorsally full of fecal matter (figure 4c/3). Cervix located in the middle (figure 4c/12). Uterine horn located dorsal to cervix (figure 4c/1)and Urinary bladder which was shown dorsal to pelvic symphysis (figure 4c/4). Parts of sacrum (figure 4c/s), ilium , pubis and femoral head (figure 4c/6) also appeared in cross section (figure 4c/I).

In the CT image, the area of low density with moderate density circular parts represents rectum with fecal matter (figure 4d/3) and Urinary bladder which was shown dorsal to pelvic symphysis (figure 4d/4) appeared low-density.

At level of 4th caudal vertebra

In anatomical cross-section, the anal canal (Figure 4e/13) appeared dorsally. Vagina (figure 4e/8) appered dorsal to the pelvic urethra (figure 4e/9). ischiatic pelvic symphysis also appered (figure 4e/11). In CT images, the anal canal (Figure 4f/13) appeared low density .Vagina (figure 4f/8) appered dorsal to the pelvic urethra with moderate density.while pelvic urethra appeared low density (figure 4f/9). ischiatic pelvic symphysis also appered (figure 4f/11).

CT scan and sagittal section of the female goat pelvic cavity

In anatomical sagital section the anal canal located dorsally and was full of fecal pellets

(figure 5a/1). Uterine horn and cervix appeared dorsal to urinary bladder and pelvic urethra (figure 5a/5). vagina (figure5a/2). Both urinary bladder (figure 5a/3) and pelvic urethra was located dorsal to ischiatic

In CT image (figure 5), the low denisty anal canal was full of fecal pellets which appeared as moderate denisty circular area(figure 5b/1). Uterine horn and cervix appeared with moderate density(figure 5b/5). vagina appeared as moderate density (figure5b/2). Both urinary bladder (figure 5b/3) and pelvic urethra appeared with low density.

Three-diminsion reconstruction of pelvic girdle

First of all, the pelvic cavity bounderies were detected.coxeal tuberosity,sacral vertebrea amd coccegeal vertebrae were used as marks which limit pelvic cavity.then three diminsion image was genereted using CT softwares (figure 6)

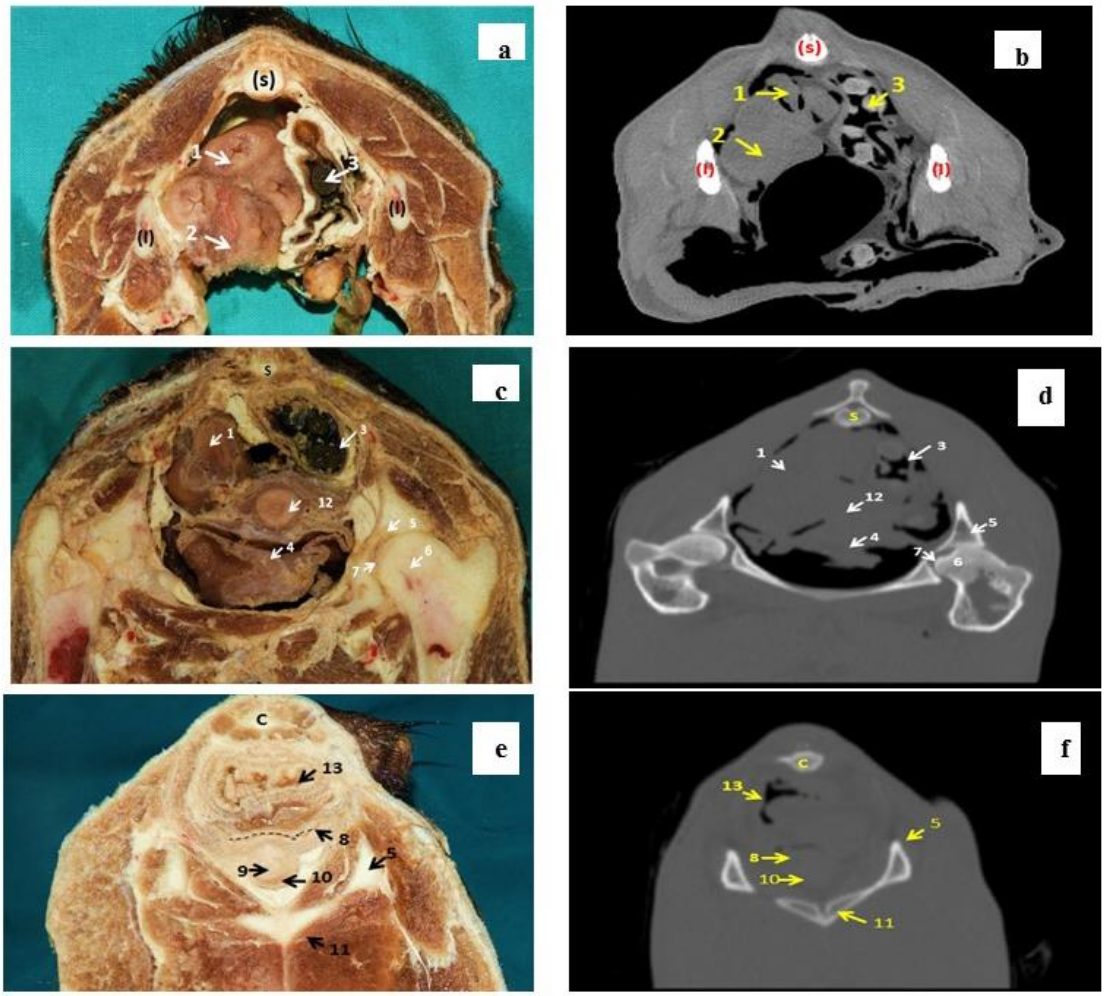

Figure (4): anatomical cross section of pelvic cavity of female Baladi goat and its related CT scans. Where **(a)** Anatomical transverse cross section at level of 3rd sacral vertebra **(b)** CT scan transverse section at level of 3rd sacral vertebra **(c)** Anatomical transverse cross section at level of 4th sacral vertebra **(d)** CT scan transverse section at level of 4th sacral vertebra **(e)** Anatomical transverse cross section at level of 3rd caudal vertebra **(f)** CT scan transverse section at level of 3rd caudal vertebra.1-uterine horn, 2-uterine body, 3- rectum, 4-urinary bladder, 5-ischium bone, 6-head of femur, 7- hip joint, 8- vagina, 9-pelvic urethra, 10-neck of urinary bladder, 11-pelvic symphysis, 12- cervix, 13- anal canal

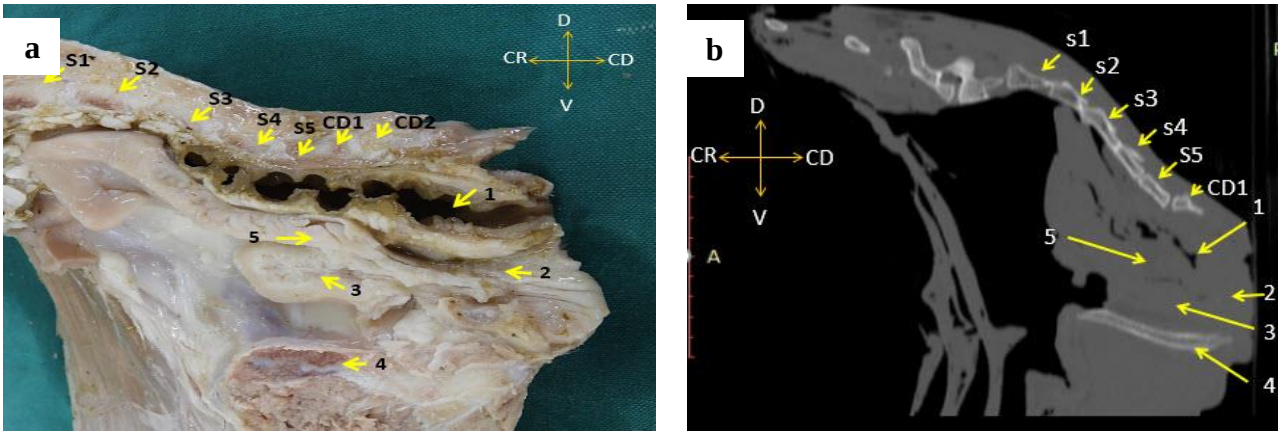

Figure (5): sagittal cryo-anatomical section of **(a)** pelvic cavity and **(b)** its related CT scan. 1-rectum, 2-vagina, 3-urinary bladder 4-Ischium, 5-uterus, S1-1st sacral vertebra, S2- 2nd sacral vertebra, S3-3rd sacral vertebra, S4-4th sacral vertebra, CD1- 1st caudal vertebra, CD2-2nd caudal vertebra.

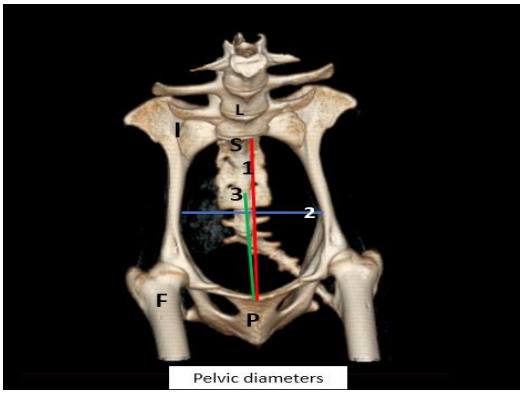

Figure (6): showing gross osteological boundaries of pelvic cavity and internal pelvic diameters using 3D model generated from CT scan1-conjugate diameter, 2-transverse diameter, 3-vertical diameter, L: lumber vertebrae, S: sacrum, P: pelvic symphysis, I: ilium.

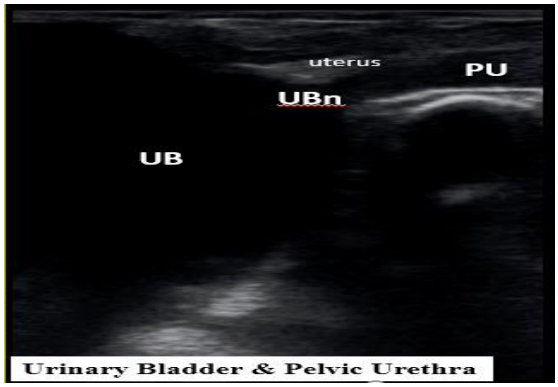

figure (7): ultrasonography of Baladi goat pelvic cavity showing urinary bladder and uterus, UB-urinary bladder, UBN-urinary bladder neck, PU-pelvic urethra

Ultrasonographic evaluation of female pelvic cavity

After the probe was introduced into rectum.it was diredcted prependicular to the abdominal wall to locat the urinary bladder which served as guide for evaluation of pelvic visera content.the urinary bladder appeared as an anechogenic structure (figure 6 UB). Dorsal to urinary bladder there was uterine body with two uterine horn on each respective side of uterine body (figure 6). In non gravid animal ,the uterus produced an echogenic image the dergree of echogenicity depended on the content of lumen.

The transverse diameter and conjugate diameter was easily observed while it was difficult to observe the verticle diameter because of the great length between cranial end of pelvis and 2nd sacral vertebra.

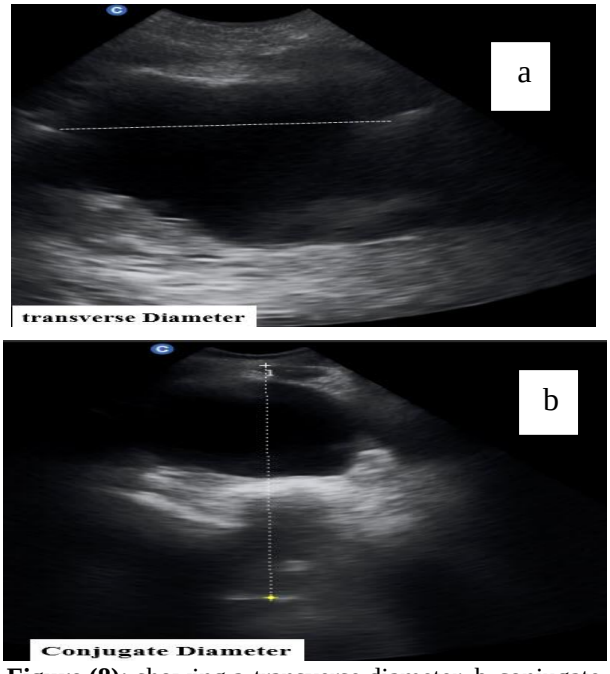

Figure (8): showing a-transverse diameter, b-conjugate diameter.

DISCUSSION

The pelvic girdle consisted of two pelvic bones each consisted of union three bones (ischium, pubis and ilium) . Bony pelvis is composed of two pelvic bones, sacrum and first caudal vertebrae

The ilium was divided into wing represented by slightly excavated fossa and body which carries the psoas tubercle. The dorsal border created the iliac crest which located between internal angle and external angle. the gluteal surface is dorsolaterally as in sheep but unlike deer where it was almost vertical. The gluteal line turned into rounded crest similar to deer but unlike to cattle where it was faint.

The pubis consisted of two rami and body with caudal ramus thinner than cranial ramus. cranial part of pelvic symphysis is formed by pubis but, ischium forms caudal part of it and ends with ischiatic arch also, the ischiatic tuberosity had three branches. And these results were similar with (de Lima, 1915; Getty and Sisson, 1975; Poddar *et al*., 2018; Makungu, 2019; Salinas *et al*., 2020). the pelvic inlet line of demarcation was sacrum dorsally and body of ilium laterally and pubis ventrally and. pelvic outlet boundaries was coccygeal vertebrae dorsally and ischium ventrally. The pelvic inlet is oval in shape while pelvic outlet is rounded and this finding was like (Getty and Sisson, 1975; Rajani *et al.*, 2013).

Our results showed that the peritoneum was reflected between urinary bladder and the uterine cervix and forming the vesicogenital pouch at level of 5^{th} sacral vertebra but in dog at level of 2^{nd} sacral vertebra while the rectogenital pouch was located at the level of the 3^{rd} caudal vertebra while in dog at level of 1st caudal vertebra in dog (El-gendy *et al*., 2020). In addition to this the vesicopubic pouch reached the level of 2^{nd} caudal vertebra in female baladi goat.

In sagittal cross section we noted that the urethra of the female baladi goat runs dorsally to pelvic floor and ventral to vagina and open in vaginal vestibule with external urethral orifice which share it with sub urethra diverticulum and this result was similar to (Hartman and van de Watering, 1974) in the other hand in deer there is no sub urethra diverticulum.(Pérez *et al*., 2013)

Vagina located in pelvic cavity between rectum and urinary bladder and consists of cranial part and caudal part (vestibule). similar to (König *et al.*, 2004)

The uterus consisted of coiled uterine horn, short body and cervix. The uterus showed to be bicornuate, with tapered extremity of the horns. The horns were coiled but curved in deer and terminated in uterine tube. The cervix was a firm tube that could be easily distinguished by palpating. There was just one intercornual ligament in goats unlike cow there were 2 intercornual ligament but in deer there was only one and not always present (Pérez *et al.*, 2013)

computed tomography images at different levels were related with its corresponding cross-sectional anatomy slice. this helps greatly in creation of an atlas for female Baladi goat and to our knowledge there was no such literature comparing female caprine pelvic cavity using computed tomography as a diagnostic tool to cross sectional anatomy.

We found that CT was reliable in obtaining pelvic diameters with the help of special software because of avoiding superimposing that was produced during using X-ray technique

Also, it was efficient way in making 3D assessment of pelvic conformation, measurements and size. this will help prediction any difficulties during giving birth. And this is Compatible with (Dobak *et al.*, 2018) and can be applied for different species as cattle (Hiew and Constable, 2015), dog (Dobak *et al.*, 2018) and gazelle (Demircioglu *et al.*, 2021)

On the other hand, we noticed that the ultrasonography was difficult in obtaining the pelvic diameters than CT as conjugate diameter because of its great length about 10 cm but it was much easier in obtaining transverse diameter.

Ultrasonographic pelvimetry is most preferable in pregnant animal as it is a safe method in the other hand the radiography and computed tomography could have serious hazards and it is easy to use ultrasonography on examination of farm animal rather than other modalities because of the easy transportation and our finding totally agree with (De Amicis *et al.*, 2019)

CONCLUSION

We concluded that there were great similarities between diagnostic modalities such as CT scan and ultrasonography in examination the female Baladi pelvic cavity and this can serve as valuable and diagnostic tool specially in reproductive performance evaluation with the help of computed tomographic as well as ultrasonographic pelvimetry which will enable prediction of dystocia. also, it hands us a new tool of teaching anatomy and understanding anatomical specifics and foundation of standard digital database for normal animal parameters also CT scans can be useful in construction of three dimensions model of different organs

Ethical Approval

This study followed the guidelines for the care and use of laboratory animals and the animal welfare and ethics committee of the Faculty of Veterinary Medicine, University of Sadat City, Egypt.

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