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ULTRASOUND IMAGING OF THE SPLEEN, STOMACH, LIVER, KIDNEYS, BLADDER, AND PROSTATE IN PIGLETS (*Sus scrofa domestica*)

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ABSTRACT

This study aims to describe ultrasonographic imaging of the spleen, stomach, liver, kidney, bladder, and prostate in piglets (*Sus scrofa domestica*). Ultrasonography was performed on six male piglets aged 1 month with a body weight of 4-8 kg. Ultrasonography of the spleen, stomach, liver, urinary bladder, and prostate was observed in the dorsal-recumbency position, and the kidney was observed in the lateral-recumbency position. The ultrasound examination used the Chison EBit 60, which is a linear type transducer with a frequency of 9 MHz, transverse and sagittal positions, and a gain of about 55-80. Ultrasonography of the spleen showed that the shape of the spleen head varied in each individual. The results of gastric ultrasonography showed the gastric lining clearly and the similarity of the position, shape, structure, echogenicity, and size of the stomach. The results of liver ultrasonography showed that the echogenicity of the liver tended to be hyperechoic, the kidneys were hyperechoic, and the bladder was hypoechoic due to the use of improper gain. The average length of the right kidney was 4.73±0.50 cm and the left kidney was 4.08±0.26 cm. The bladder wall thickness was 1.3±0.31 mm. Imaging of the bladder showed changes in wall size and echogenicity. Prostate ultrasound results obtained an average length of 2.68±0.45 cm, width 1.69±0.35 cm. The results of this study can be used as a reference for normal data on organ position, organ structure, and organ echogenicity of the spleen, stomach, liver, kidney, bladder, and prostate in piglets.

Key words: bladder, kidney, liver, prostate, spleen, stomach

ABSTRAK

Penelitian ini bertujuan untuk mendeskripsikan pencitraan ultrasonografi organ limpa, lambung, hati, ginjal, vesika urinaria, dan prostat pada anak babi (Sus scrofa domestica). Ultrasonografi dilakukan pada enam ekor anak babi jantan umur 1 bulan dengan bobot badan 4-8 kg. Ultrasonografi organ limpa, lambung, hati, vesika urinary, dan prostat diamati pada posisi dorsal-recumbency, sedangkan pada ginjal dilakukan pada posisi lateral-recumbency. Pemeriksaan ultrasonografi menggunakan Chison EBit 60, transduser tipe linear frekuensi 9 MHz dengan posisi transversal dan sagital dan gain sekitar 55-80. Hasil ultrasonografi limpa, terdapat bentuk kepala limpa yang bervariasi pada setiap individunya. Hasil ultrasonografi lambung menunjukkan lapisan lambung dengan jelas dan kesamaan posisi, bentuk, struktur, ekhogenitas, dan ukuran lambung. Hasil ultrasonografi hati menunjukkan ekogenisitas hati cenderung hiperekoik, ginjal hiperekoik, dan kandung kemih hipoekoik karena penggunaan gain yang tidak tepat. Panjang rata-rata ginjal kanan 4,73±0,50 cm dan ginjal kiri 4,08±0,26 cm. Ketebalan dinding kandung kemih adalah 1,3 ±0,31 mm. Pencitraan kandung kemih menunjukkan perubahan ukuran dinding dan ekogenisitas. Hasil ultrasonografi prostat didapatkan rata-rata panjang 2,68±0,45 cm, lebar 1,69±0,35 cm. Hasil penelitian ini dapat dijadikan acuan data normal posisi organ, struktur organ, dan ekhogenitas organ limpa, lambung, hati, ginjal, vesika urinaria, dan prostat pada anak babi.

Kata kunci: ginjal, hati, lambung, limpa, prostat, vesica urinaria

INTRODUCTION

The pig (*Sus scrofa domestica*) was one of the first animal species to be domesticated, with 500 different breeds distributed worldwide. Pigs are often used as biomedical model animals because they have similarities in anatomy and physiology to humans even though their systems are different. This physiological similarity allows for the results obtained in pigs to transfer to the human condition more accurately compared to other experimental animals such as rats and rabbits (Stembirek *et al*., 2012). Pigs have often been used as animal models in medical research, such as the study of laryngopharyngeal reflux, Staphylococcus aureus hepatic abscesses, and for the evaluation of drugs administered to humans (Yang *et al*., 2017).

Organ transplantation saves the lives of patients affected by terminal organ failure and gives hope and new life to thousands of people (Deshmukh and Baheti, 2020). Pigs are the top choice for xenotransplantation. From an immunological point of view, the production of transgenic pigs has been shown to prevent hyperacute rejection. From a zoonotic point of view, xenozoonosis from pigs is considered to have low risk (Aristizabal *et al.*, 2017).

Healthy pigs are needed for transplantation, and ultrasonography (USG) is one of the diagnostic support tools that is often used for health examinations. Ultrasonography is a diagnostic technique that uses very high-frequency sound waves (ultrasound) that touch an organ or tissue, then reflect back to produce an image of the internal structure of an organ or tissue (Noviana *et al*., 2018). One ultrasound study on piglets (*Sus scrofa domestica*) placed a catheter directly into the respiratory tract of piglets for real-time visualization and evaluation of thoracic abnormalities. Another ultrasound study was on the reproductive

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system of pigs to observe pregnancy (Nishimura *et al*., 2017; Kauffold *et al*., 2019; Kaae *et al*., 2020).

Ultrasonographic imaging of normal pig organs in the abdominal cavity has not been widely performed. This study was conducted to determine normal structures in piglets so that it can be used as a reference in cases where internal structural abnormalities occur as well as a reference regarding the results of ultrasound imaging of each of these organs.

MATERIALS AND METHODS

All procedures carried out in this study had been approved by the Animal Ethics Commission, Faculty of Veterinary Medicine, IPB University with certificate number 158/KEH/SKE/XII/2019. The tools used were a portable type two-dimensional ultrasound machine (Chison EBit 60), linear transducer with a frequency range of 6-15 MHz, table, flash disk, digital camera, table mat or underpad, tissue, cage, feed container, drinking water container, and 10 mL syringe. The materials used were six male piglets aged 1 month and 1 day with bodyweights of about 4-8 kg, pig feed, drinking water, 70% alcohol, acoustic coupling gel, atropine sulfate 3% at a dose of 0.04 mg/kg, anesthetic drugs consisting of ketamine 10% at a dose of 10-20 mg/kg, xylazine 2% at a dose of 1-2 mg/kg, and zoletil 5% (tiletamine and zolazepam) at a dose of 6-10 mg/kg.

The piglets were fasted for 8-12 hours, after which they were transferred from the large pig pen to the operating room. The piglets were then subjected to a physical examination including pulse rate, respiratory rate, capillary refill time (CRT), and mucous membranes. The piglets were given premedication and then anesthetized. The fully anesthetized piglets were transferred to the table and placed in a dorsal-recumbency position for scanning the spleen, stomach, liver, urinary bladder, prostate, and then they were placed in a lateral-recumbency position to scan the kidneys. The scanning area was smeared with acoustic coupling gel. Ultrasound scanning was performed with a frequency of 9 MHz and a gain of about 55-80.

Spleen scans were performed in a dorsal-recumbency position with transducer in a sagittal position. The transducer was moved slowly over the left abdomen of the piglet until the spleen was visible. Once visible, the position of the transducer was changed to transverse to obtain sonograms with different fields of view.

The gastric scan was performed in the dorsal-recumbency position with the transducer in a transverse position. The transducer was placed caudal to the last rib in a dorsal direction. The transducer was moved slowly to the left lateral from the piglet position to view the cardiac and fundal portions of the stomach, and moved to the right lateral from the piglet position to view the pyloric portion of the stomach.

The liver scan was performed with the dorsal recumbency position and the transducer was positioned on caudal to the xiphisternum with the scan plane directed dorsocranially. The liver was scanned from left to right or from the ventral to dorsal side so that the examination of the entire liver could be completed.

The kidney scan was performed with the right and left lateral recumbency position. The frequency used was 9 MHz. The transducer was positioned perpendicular to the skin in a sagittal direction. The kidney is positioned superficially under the abdominal wall on both sides to facilitate scanning. The imaging of the left kidney was done by positioning the transducer on the caudal of the last costae sinistra and the imaging of the right kidney was done through the last two intercostals on the dextra.

The bladder scan was performed with the dorsal recumbency position. The transducer was in a sagittal position to the body axis and placed in the cranial pubis in the dorsal transducer direction. The prostate scans were performed in a dorsal-recumbency position with a sagittal transducer position. The transducer was placed in the cranial pubis on the right or left lateral side of the penis. A bladder search was performed as a reference for performing a prostate search. The bladder was filled to facilitate the search for the prostate. The transducer of the bladder was moved slowly along the neck of the bladder because the prostate was caudal to the bladder. Then after the prostate was found the transducer was rotated 90° into a transverse position and the examination was carried out from one end to the other.

Sonograms were interpreted in real-time. The Sonograms were observed to see the position, shape, echogenicity, margination, and the presence or absence of abnormalities in the spleen, stomach, liver, kidney, bladder, and prostate. The results were then discussed descriptively.

RESULTS AND DISCUSSION

Spleen

The sonogram of piglet spleen that can be seen in this study is the head and body of the spleen. The head of the spleen is the cranial part adjacent to the stomach and the body of the spleen is the middle or behind after the head of the spleen. Figure 1A and 1B shows anechoic tubular splenic vein on the head of the spleen and Figure 1C and 1D shows anechoic tubular splenic vein that came out of the hilum at the head of the spleen. The splenic vein will be shown more clearly when interpreted in real time or using color-doppler imaging. The splenic parenchyma had a homogeneous hypoechoic echogenicity and at the capsule, there was a hyperechoic layer surrounding the spleen.

The echogenicity of the spleen in the parenchyma was homogeneous hypoechoic, the splenic vein appeared tubular anechoic in the splenic parenchyma and emerged from the hilus in the spleen, and the capsule showed a hyperechoic layer surrounding the spleen. The hyperechoic layer was composed of connective tissue with a highly reflective interface (Penninck and d'Anjou, 2015; Noviana *et al.*, 2018). The visible splenic vein had anechoic echogenicity or was black in color because the contents of the splenic vein were blood. The splenic vein was located in the cranial part of the spleen or head of the spleen and acted as a blood supply to the proximal half of the spleen. (Fossum, 2013).

Sonogram of the piglet spleen in Figure 1E shows that the head of the piglet's spleen was triangular. Figure 1F shows that the head of the piglet's spleen was oval or round and elongated. Based on the sonogram results of 6 piglets, the shape of the spleen in these piglets varied in each individual.

The spleen is usually different shape in each animal and also varies in size and position (Noviana *et al*., 2018). The spleen in pigs is typically oval, with the head of the spleen being larger and the tail of the spleen being smaller (Nawal and Maher, 2018).

Stomach

The echogenicity of the gastric lumen varied in each individual pig. This can be seen in Figure 2A and 2C, where it had a hyperechoic gastric lumen, and in Figure 2D and 2F, where it had an anechoic to the hypoechoic gastric lumen. The echogenicity of the gastric lumen depends on the contents of the stomach itself. The contents of the gastric lumen can be air, gas, liquid, or food. The results of the gastric sonogram of the piglets showed that the gastric lumen of piglets 1-3 was filled with gas, and piglets 4-6 was also filled with gas but there were artifacts in the form of acoustic shadowing with inhomogeneous anechoic echogenicity or "dirty shadowing".

Acoustic shadowing is a condition in which the reflected sound waves are absorbed by bone, air, gas, rock, or tissue with a dense composition so that strong echogenic lines appear on the surface of the tissue structure. This results in no detectable tissue or organ below the echogenic line and only anechoic shadows being visible. Homogeneous anechoic images are called "clean", whereas anechoic shadows that are not homogeneous are called “dirty shadowing” (Penninck and d’Anjou, 2015; Noviana *et al*., 2018).

The lining of the stomach wall consists of subserosa/serosa with hyperechoic echogenicity, tunica muscularis with hypoechoic echogenicity, submucosa with hyperechoic echogenicity, and mucosa with hypoechoic echogenicity. These layers can be seen on a sonogram of a pig's stomach. Figure 2B and 2D and Figure 3A and 3B show the layers of the stomach wall

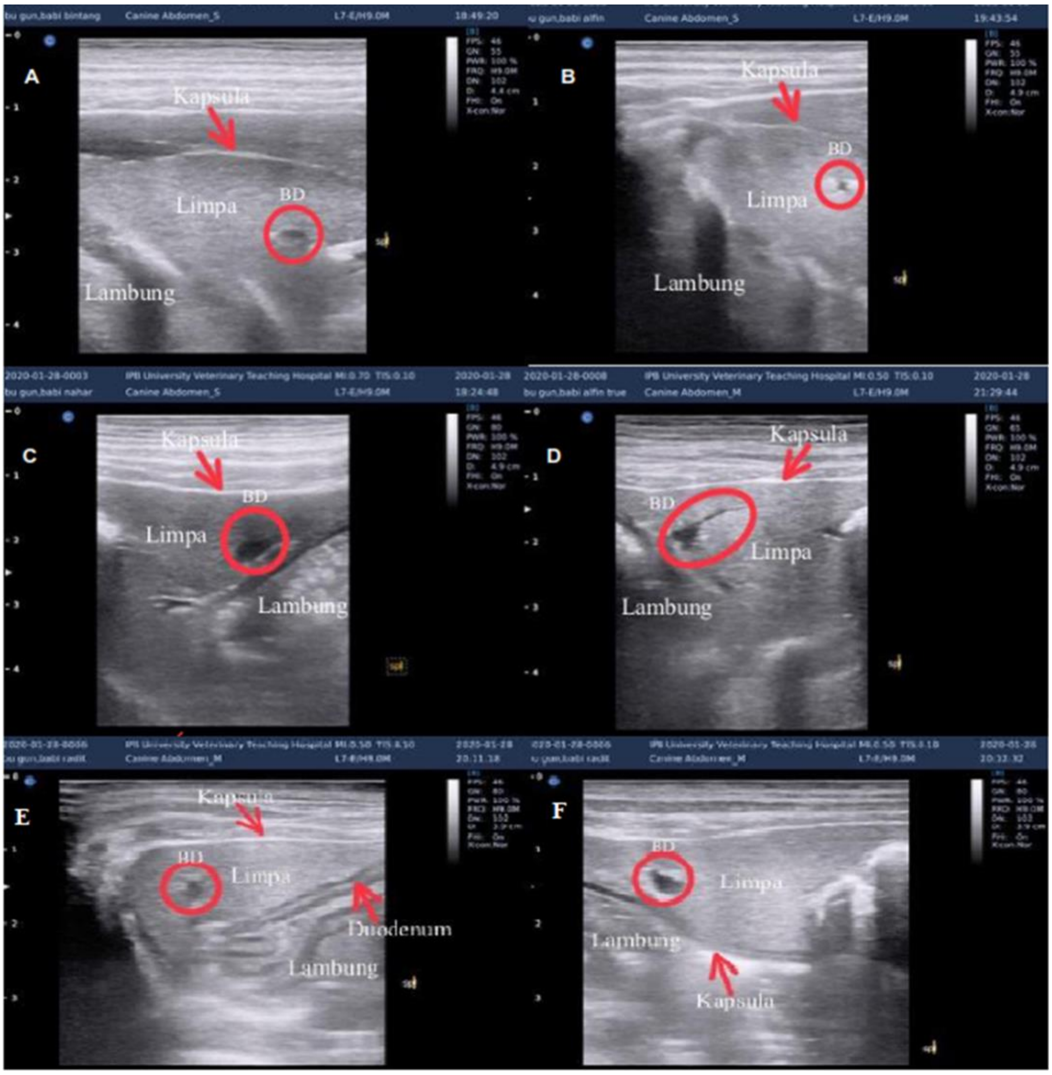

Figure 1. The sonogram of piglet spleen (*Sus scrofa domestica*). Parts of the spleen with a sagittal cut of A= Piglet 1, B= Piglet 2, C= Piglet 3, D= Piglet 4, E= Piglet 5, F= Piglet 6. The spleen was homogeneously hypoechoic and at the capsule there was a hyperechoic layer surrounding the spleen. BD= Blood vessels splenic vein

clearly. The lining of the stomach wall showed repeated hyperechoic and hypoechoic lines up to 4 layers, and the gastric lumen was also hyperechoic. Figure 2A, 2E, and 2F do not show the layers of the stomach wall clearly. This can be caused by improper frequency and gain settings.

The stomach wall consists of 4 layers, namely, subserosa or serosa with hyperechoic echogenicity, tunica muscularis with hypoechoic echogenicity, submucosa with hyperechoic echogenicity, and mucosa

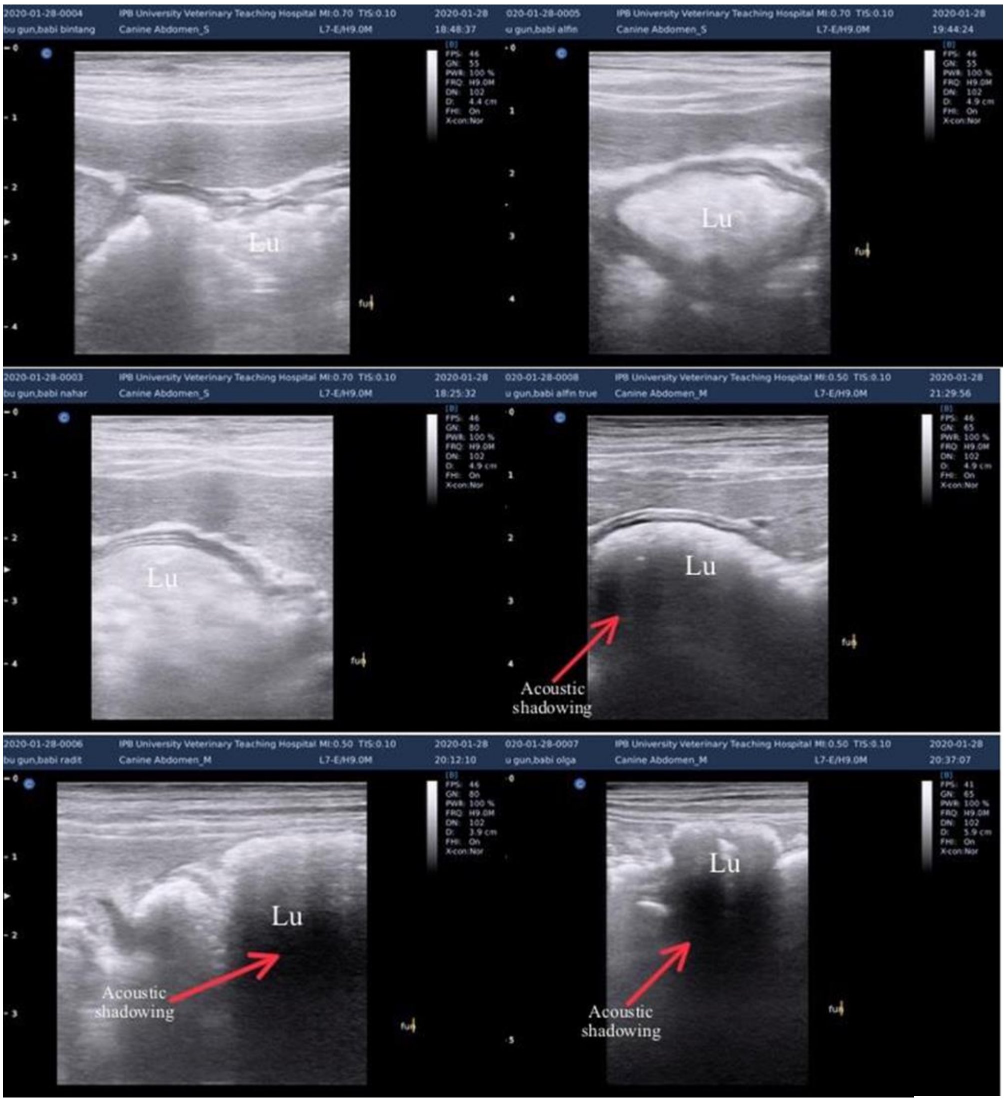

Figure 2. The sonogram of the stomach of piglets (*Sus scrofa domestica*). Fundus stomach with transverse cut, A= Piglet 1, B= Piglet 2, C= Piglet 3, D= Piglet 4, E= Piglet 5, F= Piglet 6. Gastric lumen A-C was hyperechoic and gastric lumen D-F was anechoic to hypoechoic. Artifact in the form of acoustic shadowing was formed in the gastric lumen due to gas that inhibits the ultrasound rate, Lu= gastric lumen

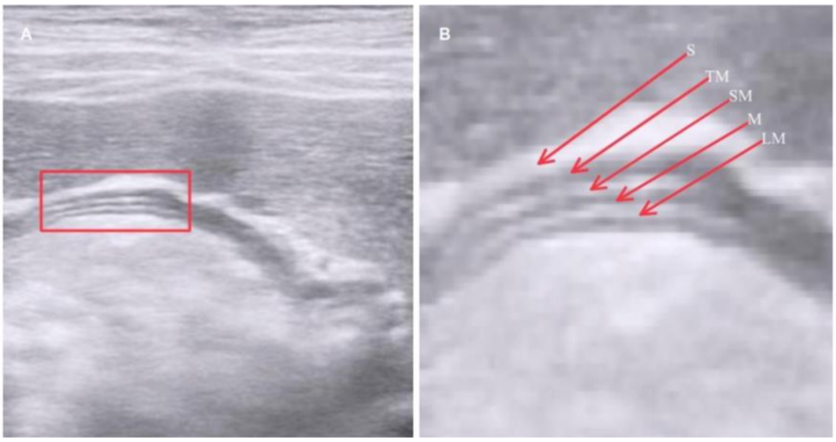

Figure 3. The sonogram of the stomach of piglets (*Sus scrofa domestica*). A= Fundal stomach with transverse section in piglet 3, B= Magnification of Figure A. The gastric sonogram showed 4 layers of the stomach wall; S= Subserous/serosa hyperechoic; TM= Hypoechoic tunica muscularis; SM= Hyperechoic submucosa; M= Mucosa, hypoechoic, LM= Mucous lumen hyperechoic

with hypoechoic echogenicity. Mucous lumen with echogenicity varies depending on the contents of the gastric lumen itself (Noviana *et al*., 2018). Gastric lumen filled with air/gas will produce hyperechoic echogenicity. If the gastric lumen is filled with fluid, it will result in anechoic to hypoechoic echogenicity. Lastly, if the gastric lumen contains food it will produce hyperechoic to hypoechoic echogenicity (Torroja *et al.*, 2015). Hyperechoic gastric lumen on the sonogram of the piglets showed that there was gas in the gastric.

Liver

The liver was examined for 3 lobes: the left liver lobe, central liver lobe, and right liver lobe (for gall bladder examination). The sonogram examination of the central liver lobe showed the presence of hepatic veins, portal veins, and diaphragms in the liver (Fig. 4.A-C). The portal vein wall is usually hyperechoic at various angles of the scan, whereas the hepatic vein wall is hyperechoic only when the echo waves and veins are perpendicular (Wachsberg *et al*., 1997). Liver echogenicity is likely to appear more hyperechoic than it should be. According to Noviana *et al.* (2018) the liver appears homogeneously hypoechoic with hyperechoic diaphragmatic echogenicity. This can be caused by using too high a frequency and using the wrong gain. The results of the sonogram examination of the central liver lobe did not show any changes in size and margins in the six piglets.

The sonogram examination of the left liver lobe showed a diaphragm in the lower part of the liver (Figure 5A). The echogenicity of the left liver lobe appeared to be more hyperechoic than it should be (hypoechoic homogeneous). The diaphragm was hyperechoic because it was composed of connective tissue with a highly reflective interface. The results of the sonogram examination of the left liver lobe did not show any changes in size and margins in the six piglets.

The gallbladder was examined by scanning the liver to the right of the linea alba. The echogenicity of the gallbladder was anechoic with thin walls. The size of the gallbladder varies greatly depending on the time the animal last fed and the imaging technique (Penninck and d'Anjou 2015). The results of the sonogram examination showed that the gallbladder in the six piglets were anechoic. The sonogram of piglet 1 showed a flattened gallbladder due to the longitudinal imaging technique (Figure 5B). A gallbladder that looks flat can also be

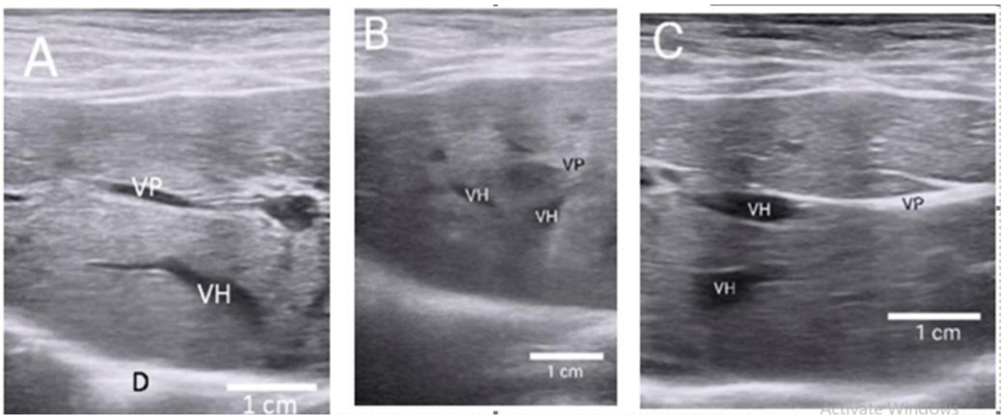

Figure 4. The sonogram of the liver (central liver lobe). A= Piglet 1, B= Piglet 3, C= Piglet 4, VP= Portal vein, VH= Hepatic vein, D= Diaphragm

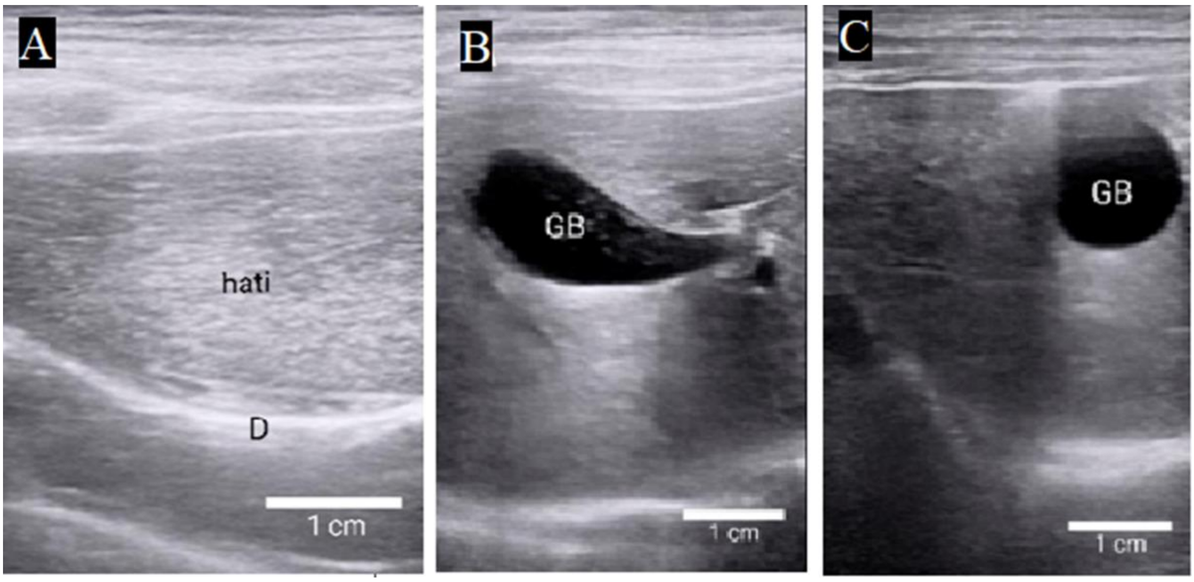

Figure 5. The sonogram of piglet liver (left liver lobe) piglet 1 (A), sagittal section of piglet gallbladder 1 (B), transverse section of piglet gallbladder 6 (C). GB= Gall bladder, D= Diaphragm

caused by the animal having just been fed. A round gallbladder is taken with a transverse section technique (Figure 5C) and indicates that the animal has not consumed feed according to Penninck and d'Anjou (2015). The normal wall thickness of the gallbladder in animals is < 1 mm, but in this study measurement of the thickness of the gallbladder wall was not carried out

Kidney

In kidney imaging, measurements of the depth of the kidneys and the length of each kidney were taken. The average depth of the left kidney in ultrasound retrieval was 4.20 cm with an average kidney length of 4.08±0.26 cm. The average depth of the right kidney was 5.32 cm with an average kidney length of 4.73±0.50 cm (Table 1). According to Lazo *et al.* study (2012), the average kidney length in 5.5-month-old piglets was 12.73 cm. Kidney size can be influenced by factors like age, gender, sterilization status, and body weight (Griffin, 2020). There was no significant difference between the right and left kidneys, but kidney observations using samples from different sexes showed that male animals had larger kidneys than female animals (Stocco *et al.*, 2016). Renal echogenicity was more likely to appear hyperechoic than it should be, according to Noviana *et al.* (2018), the capsule on the sonogram was hyperechoic, the cortex was hypoechoic, and the medulla tended to be anechoic.

Based on Huynh and Berry (2017), normal kidneys in animals have a symmetrical size and shape, this is in accordance with the results of examinations where there appeared to be not much difference between the lengths of the right and left kidneys (Table 1). The kidneys in piglet 3 showed quite a difference in lengths between the right and left kidney, with the left kidney measuring 3.86 cm and the right kidney 5.62 cm.

The length of the larger kidney can be caused by acute renal impairment. Acute renal impairment can be defined as a rapid and sudden or severe decrease in the renal filtration function. This condition is usually characterized by an increase in serum creatinine concentration or azotemia (increased blood urea nitrogen (BUN) concentration). However, immediately after a kidney injury occurs the level of BUN concentration returns to normal, thus the sign for kidney damage is typically indicated by a decrease in urine production (Legatti *et al.*, 2018).

The kidney sonogram results in piglets showed that the boundary between the cortex and the medulla was not clearly visible. For comparison, the normal renal cortex in dogs can be slightly hyperechoic and in cats the normal renal cortex becomes hyperechoic to the hepatic parenchyma. The renal medulla is homogeneous but has a coarser echotexture than the renal cortex (Huynh and Berry, 2017). This is what causes the capsule, cortex, medulla, and renal pelvis on imaging results in cats and dogs to be seen more clearly than sonogram results in piglet kidneys. In addition, the results of kidney sonograms in the piglets also showed an uneven surface in piglets 3 which can be seen in Figure 6.

Bladder

In the bladder scan, the bladder wall thickness was measured (Table 1). Based on the results in Table 1, it can be seen that the average bladder thickness was 1.3

Table 1. The sonogram examination of the kidneys and bladder

Piglets	Body weight (kg)	Left kidney	Right kidney	VU wall thickness (mm)
		Length (cm)	Length (cm)	
1	7.1	3.84	4.61	1
2	6.5	-	4.40	1.6
3	6.4	3.86	5.62	1.4
4	5.1	4.45	5.00	1.7
5	4.9	4.06	4.29	1.1
6	4.4	4.21	4.43	1
Average	5.73	4.08	4.73	1.3
Standard deviation	0.44	0.26	0.50	0.31

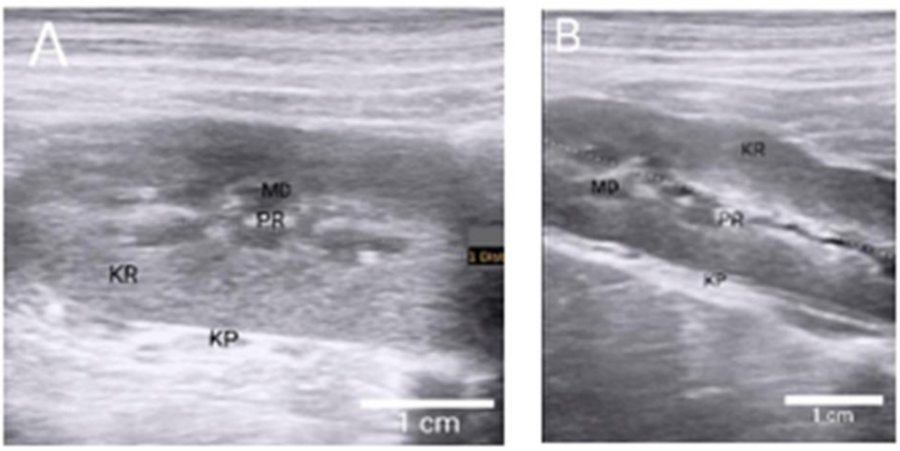

Figure 6. Sonogram sagittal section of piglet kidney 3. A= Left kidney, B= Right kidney, KP= Capsule, KR= Cortex, PR= Renal pelvis, MD= Medulla

mm. Based on research conducted by Geisse *et al.* (1997), on a dog sample, the size of a normal bladder wall thickness with minimally distended bladder was 2.3 mm, mildly distended was 1.6 mm, and moderately distended was 1.4 mm. The size of the bladder wall thickness of piglets obtained from this study was smaller than the thickness of the bladder in dogs. The difference in bladder wall thickness between pigs and dogs can be influenced by animal body weight and the size of the distension of the bladder during ultrasound examination (Geisse *et al.,* 1997). The echogenicity of the bladder was anechoic with walls that tended to be unevenly hyperechoic. Based on the literature, the lumen structure will typically look anechoic and the wall structure will be hyperechoic (Noviana *et al.,* 2018).

Based on the bladder examinations on piglets 3 and 6, there were deposits in the form of shed cells (Figure 7) which tended not to cause acoustic shadowing with a degree of hypo-hyperechoic. The upper bladder wall appeared to be thickened with a hypoechoic degree in pigs 5 and 6 with a bumpy and uneven surface. Sonograms in pigs 3 and 5 showed the presence of hyperechoic mass deposits located at the bottom of the bladder, which was suspected to be mineral deposits. Calculi are stones formed from mineral deposits in the bladder. Calculi can cause blockage and even injury to the urinary tract. The clinical manifestations of urolithiasis are non-specific and vary greatly depending on the size, number, and location of the calculi. Urolithiasis is generally followed by hematuria, dysuria, and stranguria (Mihardi *et al.,* 2019).

The sonogram results on the three piglets showed a thickening of the bladder wall with a bumpy surface. The bladder wall was accompanied by irregular hypoechoic thickening which is usually caused by cystitis. Cystitis is an inflammation of the bladder which is an inflammatory reaction of the urothelium cells that line the urinary bladder. Cystitis can be caused by microorganisms that are in the urinary bladder (Majdawati and Amna, 2012). Sonogram of piglet 4 also showed cell debris in the lumen of the bladder (7F). Cell debris appeared as floating sand grains or clouds between urine when the transducer was moved. Cell debris found in the lumen can occur due to contraction of the bladder so that the urolith is mixed with urine (Simatupang *et al.,* 2019).

Prostate

The prostate sonograms of piglets can be seen in Figure 8C and Figure 8D. Prostate echogenicity appeared to be hypoechoic in well-defined hyperechoic piglets. Figure 8A, Figure 8B and Figure 8E, Figure 8F show an artifact in the form of acoustic shadowing with homogeneous or "clean" echogenicity near the prostate due to gas in the colon, thus inhibiting the ultrasound rate. Figure 8A and Figure 8F shows the length and width of the prostate in each individual piglet. The average prostate length of the 6 piglets was 2.68 cm (SD= 0.45) and the average prostate width of the 6 piglets was 1.69 cm (SD= 0.35). The prostate in piglets (*Sus scrofa domestica*) aged 1 month and 1 day can grow even bigger if the piglets are not castrated. Figure 8A and Figure 8F shows the varying shape of the prostate in piglets, Figure 8A and Figure 8D shows the prostate with an oval shape, Figure 8B and Figure 8C show the prostate with a round shape, and Figure 8E and Figure 8F shows the prostate shaped like an aloe vera plant without thorns. The shape of the prostate in the results obtained varied, but all prostates remained curved following the urethral wall of each individual. The prostate in pigs is attached to the urethral wall which forms a cylindrical groove on the broad anterior surface (Hinman, 2012).

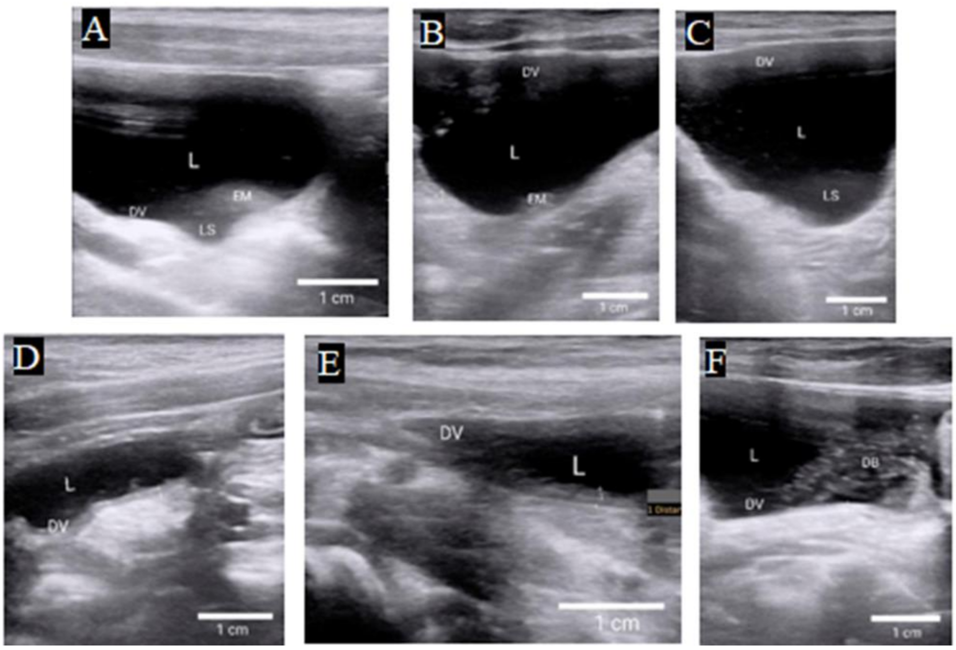

Figure 7. Sonogram sagittal section of piglets bladder, A= Piglet 3, B= Piglet 5, C= Piglet 6, D= Piglet 1, E= Piglet 2, F= Piglet 4; L= Lumen, DV= Bladder wall, EM= Mineral deposits, LS= Cell debris

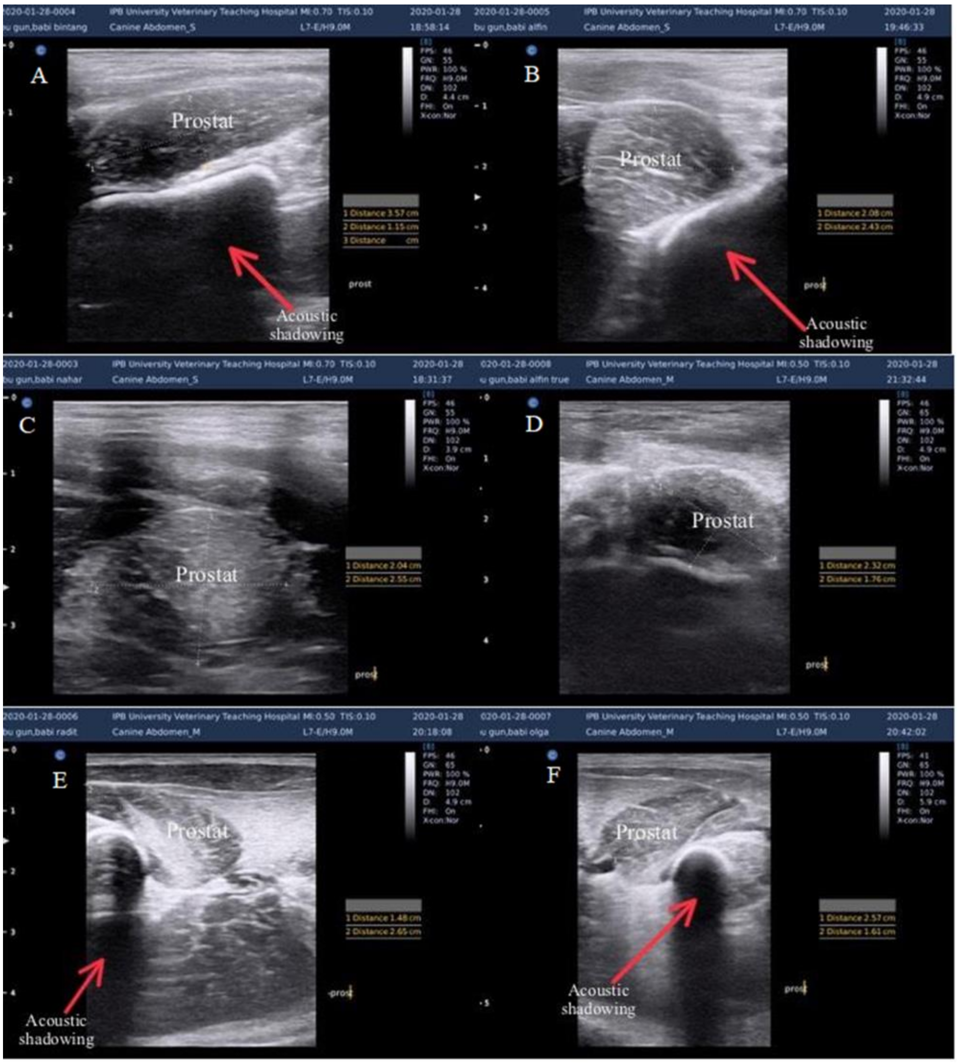

Figure 8. The prostate sonogram of the piglets (*Sus scofa domestica*). Prostate with transverse section. A= Piglet 1, B= Piglet 2, C= Piglet 3, D= Piglet 4, E= Piglet 5, F= Piglet 6. Prostate was hypoechoic with clear hyperechoic boundaries. Artifact in the form of acoustic shadowing was formed near the prostate due to gas in the colon, thus inhibiting the ultrasound rate

CONCLUSION

Ultrasound imaging can be used to determine organ position, organ structure, echogenicity, and organ size of the spleen, stomach, liver, kidneys, bladder, and prostate in piglets. The results of the spleen ultrasonography were that the head shape varied in each individual. The results of stomach ultrasonography showed the gastric lining clearly in all of the piglets, and that there were similarities in the position, shape, structure, echogenicity, and size of the stomachs. The results of liver ultrasonography showed that the echogenicity of the livers of the piglets tended to be hyperechoic, the kidneys to be hyperechoic, and the bladder to be hypoechoic due to the use of improper gain use.

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