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Visualizing the reproductive tract of the female pig using real-time ultrasonography

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Summary

The availability of inexpensive, lightweight, portable ultrasound machines will greatly facilitate the use of reproductive imaging in the female pig and may prove useful in making management decisions based on an accurate diagnosis of the reproductive status of the sow or gilt at any point in time. Real-time ultrasonography (RTU) using 3.5 and 5.0 MHz transducers transabdominally or 5.0 and 7.5 MHz transducers transrectally can allow the practitioner to determine the pregnancy and estrous status of breeding females in commercial herds. In our experience, less structural detail was visually revealed with transabdominal RTU when assessing the ovary or uterus during the estrous cycle or early pregnancy. In contrast, transrectal ultrasound allowed faster and more detailed means of assessing fine reproductive structures of varying echogenicity (follicles, corpora hemorrhagica [CH], and corpora lutea [CL]) and the conceptus components of early pregnancy (day 16–20). In this article, transrectal and transabdominal procedures are described in detail, and image specificity, quality, and ease of imaging of the female reproductive tract is considered. Reference sonograms are provided.

Keywords: swine, real-time ultrasound, ovaries, uterus, pregnancy

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Pregnancy has traditionally been confirmed based on the absence of signs of estrus at 18–24 days after mating. As Doppler (motion mode) and A-mode (amplitude-depth mode) ultrasonography equipment became increasingly available and affordable ($400–$1200), these technologies were rapidly adopted in the swine industry to improve the accuracy of indirect pregnancy diagnosis in breeding females.[1,2] These ultrasonic modes, however, have intrinsic sensitivity constraints, which have generally limited their use to diagnosing pregnancy >35 days after mating. In contrast, real-time B-mode (brightness) ultrasound (RTU) is more accurate and sensitive for diagnosing pregnancy before 35 days postmating in swine compared to other methods (Martinez E, et al. *Proc. 11th IPVS*, 1990:476).

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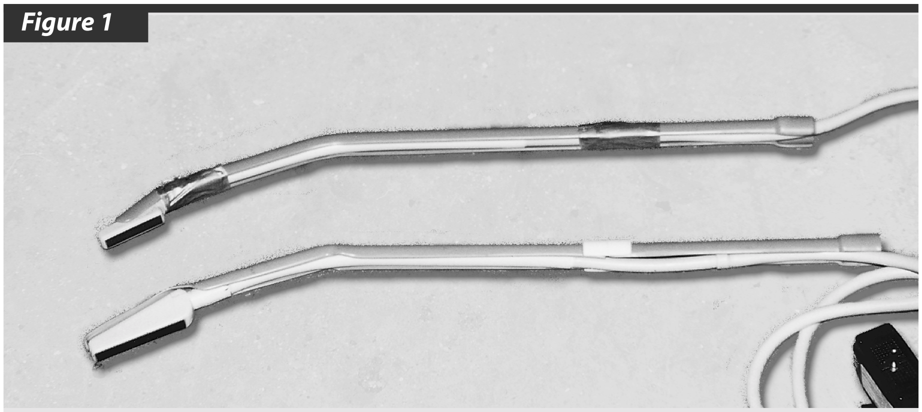
Using RTU, a transducer (probe) can be inserted in the rectum or placed externally on the abdomen. The transducer converts electric energy to sound waves through vibrating crystals and the resulting waves echo or reflect off the tissues they contact. Some transducers are large and are only suitable for handheld external use while others are small and thin and permit internal transrectal imaging with an adapter. Transducers are designed for different electronic arrangements (sector, convex, and linear) and frequency ranges (3.5–7.5 MHz). Sector and convex-array transducers produce images on screen that resemble a pie slice while linear-array transducers produce images in the form of rectangles. The size of the crystals in the transducer determines the frequency of the sound waves (MHz) and the depth of penetration and resolution (ability to clearly distinguish an object). The 3.5 MHz sound waves penetrate deeply and produce focused images over a large distance in the animal but result in overall low resolving power. The higher MHz transducers (5.0–7.5) produce sound waves that do not penetrate as deeply into the animal and produce focused images much closer to the location of the probe, but have considerably higher resolving power at these shorter distances.

Once the transducer receives the reflected ultrasound (echo), the reflected energy is converted into electrical energy and eventually into light as it is displayed on the screen as a series of dots in gray scale (ranging from black to white). The brightness of the dots is related to the density of the tissue which echoes the sound waves: the least dense objects — such as fluids — are shown as black, and more dense objects — such as bone — are shown as white. The RTU image of dots is displayed and erased 20–40 times (frames) per second to provide "real-time" imaging. Therefore, the major advantage of RTU over other modes of ultrasonography is that a real-time two-dimensional image is displayed on a monitor, allowing specific identification of the developing conceptus, embryonic vesicles, or fluid-filled uterus from direct visualization at 22 days gestation (Botero O, et al. *Proc. 8th IPVS*, 1984:306).[3,4]

With the recent development of less expensive and more portable RTU units, greater numbers of swine producers and veterinarians are using this technology to directly confirm early pregnancy in the field.

Real-time ultrasonic imaging has recently allowed ovarian structures to be visualized in swine by both transcutaneous and transrectal routes using 5.0–7.5 MHz transducers. This technology is important, because the ability to visualize the ovaries can help a practitioner determine whether a sow or gilt is cycling. For example, if the ovaries revealed cyclic activity (follicles with corpora hemorrhagica [CH] or corpora lutea [CL]), the approximate stage of the estrous cycle could be estimated, and management decisions for culling[5] or administration of gonadotropins to induce estrus[6–8] could be made. Real-time ultrasonography has also recently been used to identify ovulatory-sized follicles and their ovulation.[9] By detecting large follicles with RTU, it may be possible to determine the optimal number of doses and times for insemination.[10] Unfortunately, there is little published information regarding the potential or practicality for ultrasonically examining the ovary and determining time of ovulation under routine production conditions for improving reproductive performance.

Figure 1



7.5 MHz (top) and 5.0 MHz (bottom) linear-array transducers attached to PVC, fixed-angle, transrectal stabilizing rods.

In this article, we discuss the use of RTU to visualize and assess the reproductive tract of breeding females, based on our experience with over 200 sows and gilts. We discuss the image quality and detail you can expect from the 3.5, 5.0, and 7.5 MHz transducers, used transabdominally or transrectally, and provide reference sonograms to help you characterize and interpret the reproductive status of the breeding female.

All external transabdominal imaging discussed in this article was performed by the authors using an Aloka 500V ultrasound (Aloka Co., Tokyo, Japan) with 3.5 MHz convex-array and 5.0 MHz linear-array transducers. Internal transrectal imaging was performed using the same equipment with 5.0 and 7.5 MHz linear transducers fitted to fixed-angle PVC adapters (Figure 1). All reference images included in this article were printed to a video graphic printer at a resolution of 10 dots per mm.

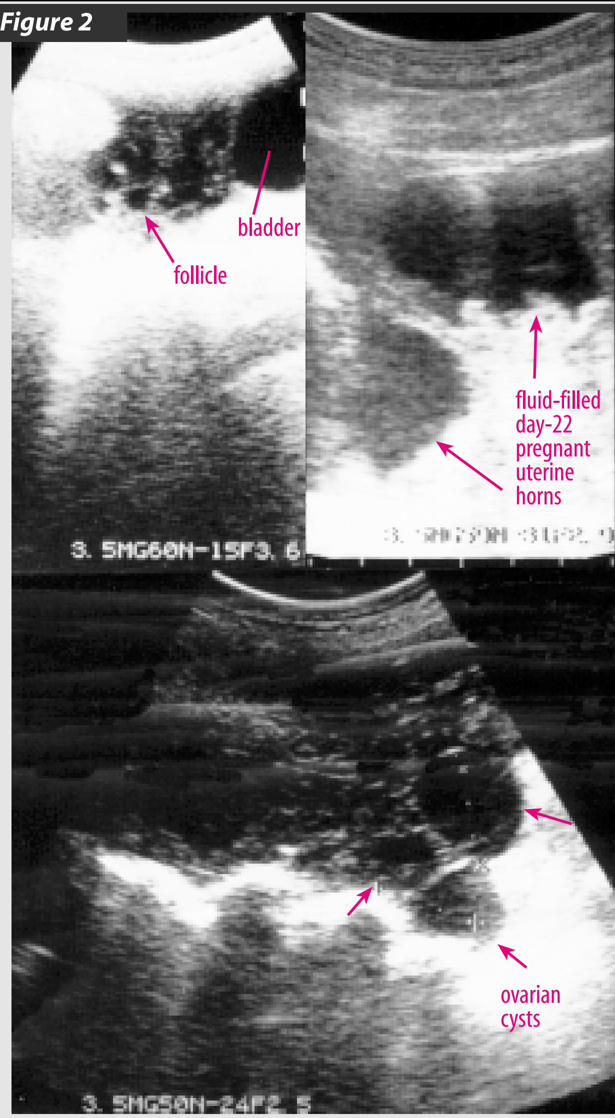
Comparison of external versus internal imaging

You can perform external ovarian imaging using the convex 3.5 and the linear 5.0 MHz transducers because these produce images that penetrate deeply enough to visualize the reproductive tract. In our experience this method proved difficult for the operator when the animal moved; i.e., when she was eating, excited by a boar, or nervous from abdominal transducer placement. In such situations, the image was more difficult to obtain, and it often took considerable time to establish an interpretable image. The ease of imaging when the animal was lying down depended largely on the animal's position, but in general was not possible.

Gross structures, such as large follicles (≥ 6.5 mm), ovarian cysts (≥ 12 mm), and the day-22 pregnant uterus can all be determined with external imaging using either the 3.5 or the 5.0 MHz transducers (Figure 2). However, in our experience, external transabdominal imaging with these transducers provided neither the resolution nor the sensitivity needed to accurately and consistently assess ovarian structures (e.g., follicles, CH, and CL) and uterine contents.

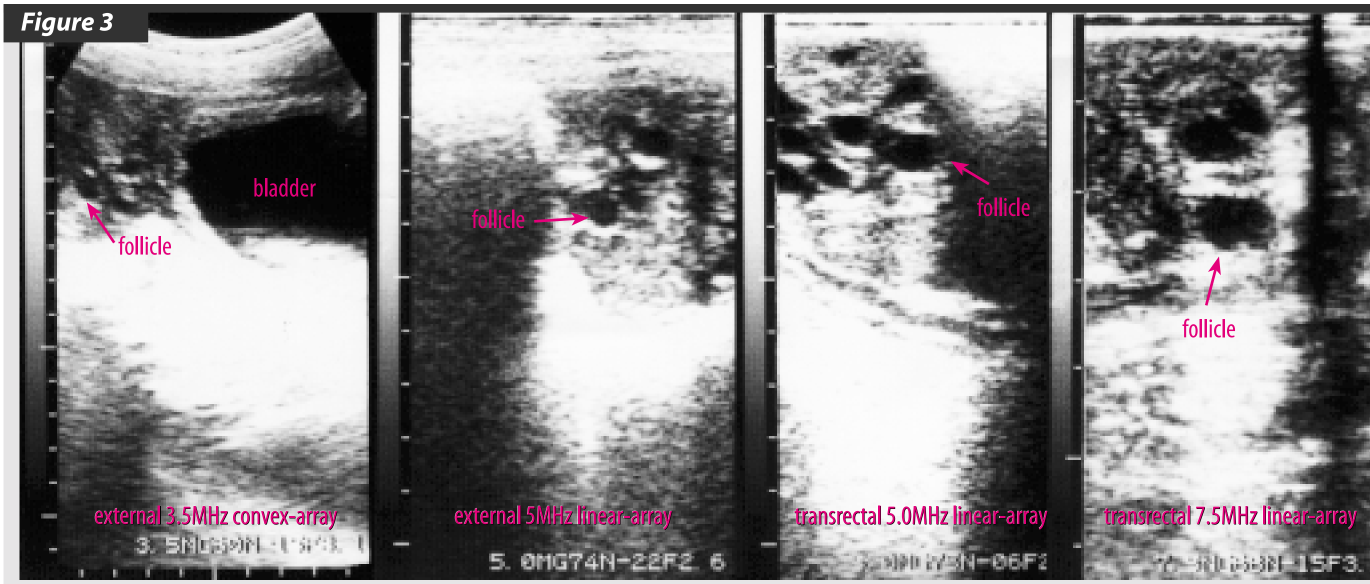
In contrast, transrectal imaging, in our experience, is a faster and

Figure 2



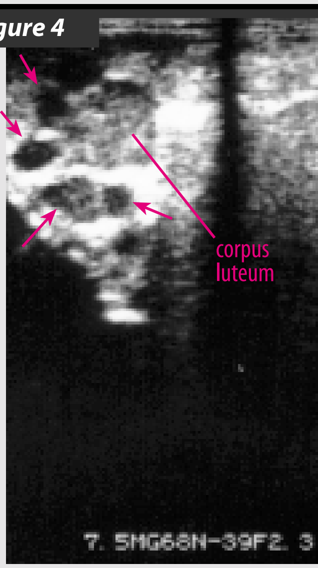
upper left: estrus ovary with multiple large follicles and bladder visualized with 3.5 MHz convex-array transabdominal transducer; **upper right**: fluid-filled day-22 pregnant uterine horns; **below**: three large (≥12–50 mm) ovarian cysts

Figure 3



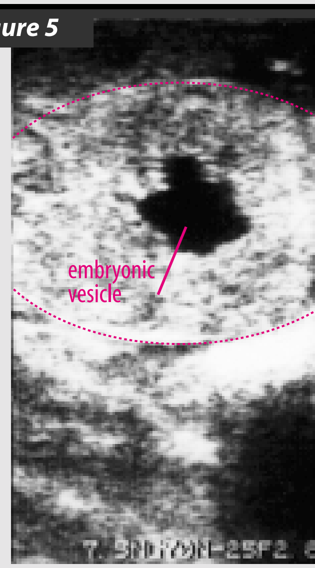
Ovary from the same sow during estrus. The ovary is located cranial to the urinary bladder and contains 7-mm follicles as visualized using (left-to-right) external 3.5 MHz convex, external 5 MHz linear-array, transrectal 5.0 MHz linear-array, and transrectal 7.5 MHz linear-array transducers.

Figure 4



Cross-section of sow ovary on day 18 of the estrous cycle showing a corpus luteum and medium sized follicles (arrows) visualized using a transrectal 7.5 MHz linear-array transducer.

Figure 5



Cross-section of a day-16 fluid-filled embryonic vesicle surrounded by isoechoic pregnant uterus visualized using a transrectal 7.5 MHz linear-array transducer. Dotted line defines the outer serosa of the uterus.

more reliable method to recognize and resolve all ovarian structures compared to external imaging (Figure 3). Transrectal ovarian imaging also allows one to make an easy, indirect pregnancy diagnosis on day 16–19 postmating by imaging for the presence of CL (Figure 4) and the fluid-filled uterine horns at 16 days of gestation (Figure 5). The ability to image transrectally will be only minimally affected when the animal moves or lies down, due to pelvic and rectal retention of the probe. Also, for females that are housed in crates, transrectal ultrasound will not inhibit or disrupt daily feeding or routines for detecting estrus that occur at the front of the crate while transrectal ultrasound is simultaneously being performed at the back of the crate. Adjacent females can also be bred by artificial insemination (AI) while ultrasound is being performed on the next crated sow.

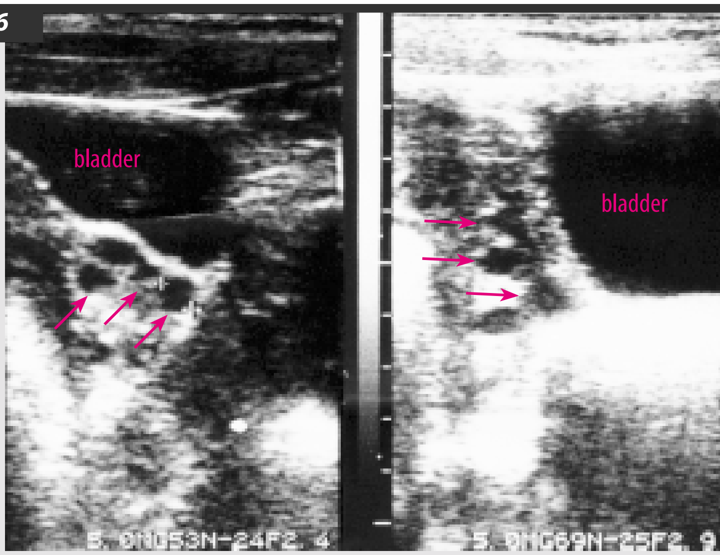
Transabdominal RTU

For performing transabdominal ultrasound of the reproductive tract, the female should be housed in a crate that will restrict forward and lateral movement but that allows easy access to the animal's side. Females can also be snared or held in place with panels to restrict motion; however, the success and ease of this may depend upon the animal's disposition. External observation requires coupling gel (obstetrical lubricant or mineral oil) to effectively transmit and receive ultrasound waves through the skin. The coupling gel is placed on the transducer surface and the transducer is firmly applied to the animal's abdomen. The placement is crucial and should be in front of the hind leg and lateral to the nipple line. The probe should be aimed toward the spine and can be angled slightly forward and back to initially visualize the bladder.

Assessing the reproductive tract transabdominally

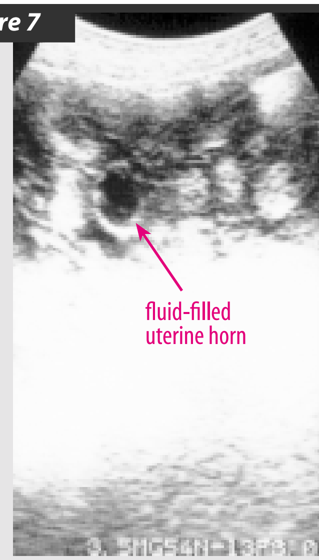
Once the bladder has been visualized, scan anterior toward the bladder to visualize the ovaries and the uterus (Figure 6). The orientation of the bladder and ovaries from the transabdominal image are often inverted compared to transrectal image because

Figure 6



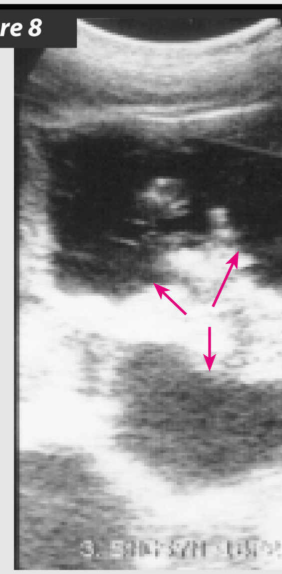
External imaging of ovaries from different sows at estrus using a 5 MHz linear tranducer applied to lower abdomen. Note the appearance of large follicles (arrows) and bladder. Note that the relative orientation of bladder and ovaries may change depending upon the direction and position of transducer.

Figure 7



External transabdominal image of a day-21 pregnant sow uterus using a 3.5 MHz convex-array transducer. Note the appearance of the fluid-filled uterine horn.

Figure 8



External transabdominal image of a day-25 pregnant sow uterus. Note the appearance of the fluid-filled uterine horn (arrows).

ultrasound visualization is occurring through a transducer located ventrally on the abdomen and pointed upward toward the spine. Therefore, the picture is usually inverted and on the screen the ovaries are located below the bladder (but anatomically above). Pregnancy can also be detected early on but the images are more difficult to interpret (Figure 7); however, as gestation progresses visualizing pregnancy status becomes much easier (Figure 8).

Preparing for the transrectal ultrasound examination

Crate

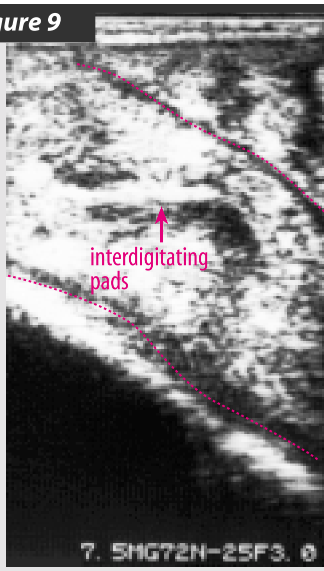
When performing RTU, sensitivity, accuracy, ease, and practicality must all be kept in mind. We have found that performing RTU in the housing crate, which allows some forward and lateral animal movement, does not stress the animal and allows adequate space for the technician to perform the transrectal technique. We have found that low-back crates, and/or crates with step-through rear gates, may both aid in facilitating technician entry and exit from the crate. Ultrasound can be performed quickly on sows that are housed in crates connected in rows. If crates are not available or none are found to be suitable, a single crate may be permanently stationed and all animals moved to this crate for observation. If crates are not available, some method to minimize forward or lateral movement of the animals must be employed, such as snaring and holding them in place with a gate or panel.

Transducer

The transducer fits snugly into a customized PVC adapter, which is fixed in place and secured with tape. The adapter is semirigid but has some flexibility. The technician should put on gloves and lubricate the probe with obstetrical lubricant or mineral oil. A finger should be gently inserted into the anus and then the adapter with the probe quickly but gently inserted with a rotating motion into the rectum. While inserting the rod, maintain firm pressure downward to pass the transducer below any fecal material in the rectum. Sometimes, removing fecal material in large sows will greatly improve imaging, although this is often not necessary in sows and can be very difficult in gilts due to the small size of the rectum. Continue to gently insert the lubricated probe and maintain control of the transducer by firmly holding on to the adapter outside of the animal. Gently advance the transducer in the animal while observing the screen for the reference points such as the cervix and bladder. Large dark areas that prevent visualization or black streaks are probably fecal material on the transducer surface. These will need to be cleaned off or the probe repositioned to eliminate it from the surface.

Locate the urinary bladder on the image to orient yourself. The bladder will rarely be

Figure 9

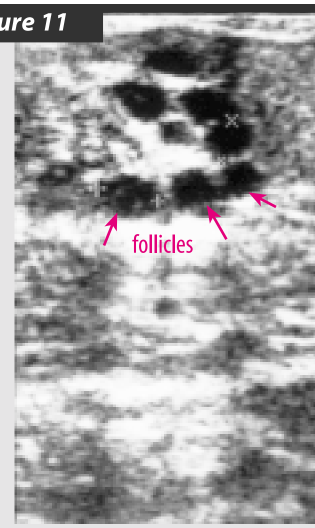


Cross-section of a sow cervix showing inter-digitating pads visualized using a transrectal 7.5 MHz linear-array transducer. Dotted line defines the outer serosa of the cervix.

Figure 10

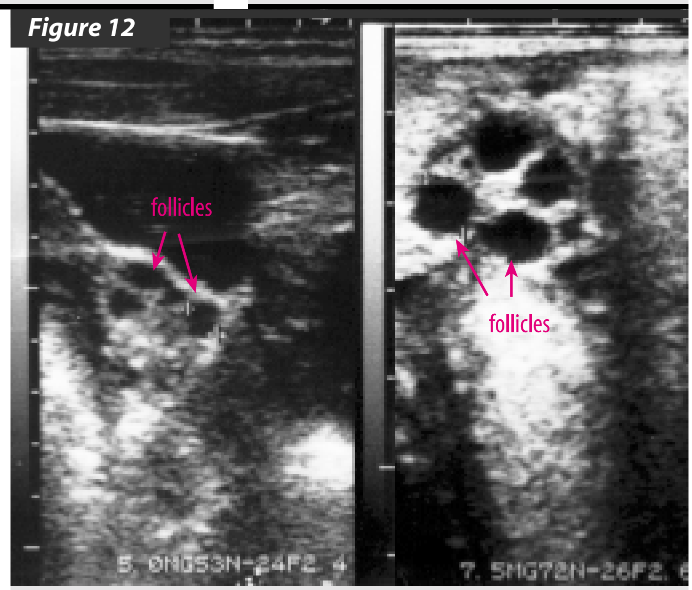
A sow ovary on the day of weaning showing the presence of only small- and medium-sized follicles (arrows).

Figure 11



Cross-section of a sow ovary 3 days after weaning. Several medium (3–6.5 mm) and large (≥6.5 mm) sized anechoic follicles (arrows) are visualized using a transrectal 7.5 MHz linear-array transducer.

Figure 12



Comparison of a sow ovary at estrus visualized using an a) external, transabdominal 5.0 MHz linear-array, or b) internal, transrectal 7.5 MHz linear-array transducers. Note the size and improved resolution of the large ovulatory follicles.

completely empty, and when full or even slightly filled with urine, should be easy to locate. The bladder is viewed as a large anechoic area (black) surrounded by thick hyperechoic layers of smooth muscle (white, Figure 6). Depending upon the stage of the cycle or whether the female is pregnant, the cervix is usually located just dorsal to the bladder (Figure 9) and the ovaries will usually be slightly anterior and just lateral to the bladder.

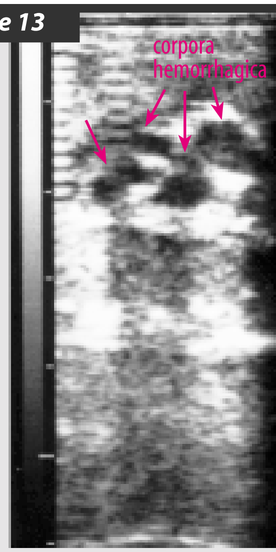
Assessing the reproductive tract transrectally

Examine the ovaries for the presence and diameter of follicles, CH, and CL. Follicles are black and have a smooth spherical outline and range in size from 3–10 mm in diameter. Prepubertal females exhibit only small- (<3 mm) and medium-sized (3–6.5 mm) follicles that are similar to the appearance of the ovary in the sow at weaning (Figure 10). If you can see only small to medium follicles in a gilt, without any other ovarian structures (e.g., CH or CL), she has not yet attained puberty.

Female swine fertility is often estimated solely on the absence or presence of signs of estrus. However, errors using this system are likely. There are many reports of estrus occurring without ovulation[11,12] and of ovulation occurring in the absence of estrus.[13–15] To assess the true estrous status of mature females using RTU, sequential sonograms should be obtained in mature gilts beginning 15 days after last estrus and continuing every 3–5 days until estrus is detected with large follicles. For weaned sows, begin ultrasound at weaning and then repeat every 2–3 days until estrus is detected using a mature boar. At weaning, sow ovaries have many small and medium-sized follicles, essentially similar to those of the prepubertal gilt (Figure 10). By day 3 postweaning, numerous medium-sized follicles can be observed, with a few follicles ≥6.5 mm in diameter (Figure 11). Once estrus is detected, image females once or twice daily for the presence of numerous large follicles (≥ 6.5 mm) and continue until these structures are no longer detectable (ovulation is complete). At the onset of estrus (day 0) in both gilts and sows, multiple large follicles, averaging 7.0 mm, should be easily visualized transrectally with the 7.5 MHz transducer. These large follicles can also be detected with external transducers (Figure 12) but with considerably less resolution. On the second day of estrus, follicular size increases only slightly to approximately 7.5 mm. In our experience, using twice-daily estrus detection and once-daily ultrasound, we observed that most females ovulate between 1.5 to 2 days after onset of estrus (day 0). Ovulation appeared to occur from only the largest follicles, with only a few medium-sized (5.0–6.0 mm) follicles remaining. After ovulation is completed, CH can be visualized for 8–48 hours as irregular shaped hypoechogenic structures (Figure 13) by conducting once-daily ultrasound. The disappearance of the previously documented large follicles during estrus and/or the appearance of the newly formed CH are the most reliable methods of confirming ovulation. Corpora lutea are first detectable approximately 6 days after onset of estrus and should be detectable, through day 16, as more uniform hyperechogenic structures approximately 10–12 mm in diameter (Figure 14).

Determining the time of ovulation will allow more precision in timing AI to maximize farrowing rate and litter size. Most swine are bred at certain times based on the onset of estrus and the frequency of estrus detection. However, recent data in pigs provides evidence that the time of ovulation varies after onset of estrus,[9, 10] and is influenced by season and wean-to-estrus interval.[16–18] Another common breeding procedure in the field is to inseminate females in a timed manner as long as they are found to be in standing estrus. Female pigs, however, have been observed to express estrus signs even after ovulation has occurred,[19] and breeding after ovulation has been reported to be detrimental to fertility.[20] Based on these reports, improving reproductive performance may be possible by using transrectal RTU to aid in determining the time of ovulation.

Figure 13

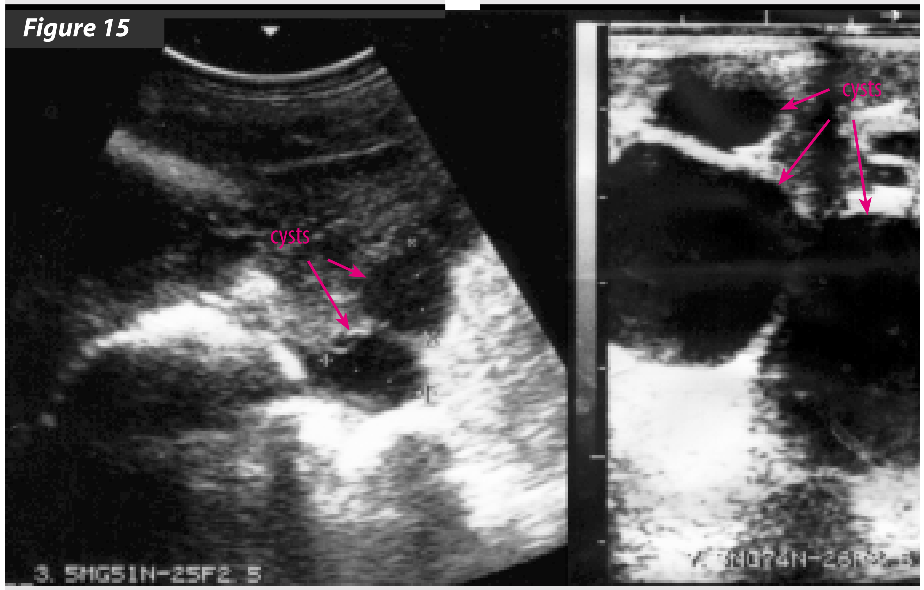


A sow ovary showing the presence of hypoechoic corpora hemorrhagica less than 24 hours after ovulation, using a transrectal 7.5 MHz linear-array transducer. Note the irregular shape.

Figure 14

A sow ovary showing multiple corpora lutea (arrows).

Figure 15



Ovarian cysts (≥20 mm) — **left**: viewed by transabdominal 3.5 MHz convex transducer; **right**: viewed by transrectal 7.5 MHz linear-array transducer.

Abnormalities

Ovarian cysts are large (≥12–50 mm) unovulated or luteinized follicles that can quickly be identified transabdominally in sows using the 3.5 or 5.0 MHz probes or transrectally with the 5.0 or 7.5 MHz transducers (Figure 15). Cystic ovaries are a common abnormality of swine and have been reported to account for 5%–14% of all reproductive failure.[21–23] Cysts generally appear as large, smooth, circular, anechoic structures. Ovarian cysts have previously been visualized and characterized transrectally using a 5.0 MHz linear transducer.[24] In our experience, we found that sows that returned to estrus at irregular intervals after breeding had ovarian cysts at the time of ultrasound scanning—an observation that is consistent with reports in the literature.[25] A faster diagnosis of cystic ovaries by RTU will allow the animal to be removed in a more timely fashion from the breeding herd, since females with multiple ovarian cysts are frequently reported to be infertile or sterile.[23]

Pyometra is another pathologic condition that can be diagnosed using RTU. Sonograms from sows with pyometra usually show heterogeneous echogenic material within an enlarged uterine lumen, surrounded by thin-walled uterine tissue (Figure 16). Traditionally, these sows are diagnosed as pregnant using Doppler or A-mode ultrasonography. With the use of RTU, however, sows with pyometra can be quickly differentiated from the pregnant sows based upon characteristic echogenic structures of each condition. Thus, these infertile sows can be rapidly identified and culled from the breeding herd.

Figure 16

A uterine sonograph showing transverse sections of a pyometra. Note the heterogeneous echogenic material within an enlarged uterine lumen. The hyperechoic bifurcating structure in the center of the sonograph is a cross-section of the uterine wall.

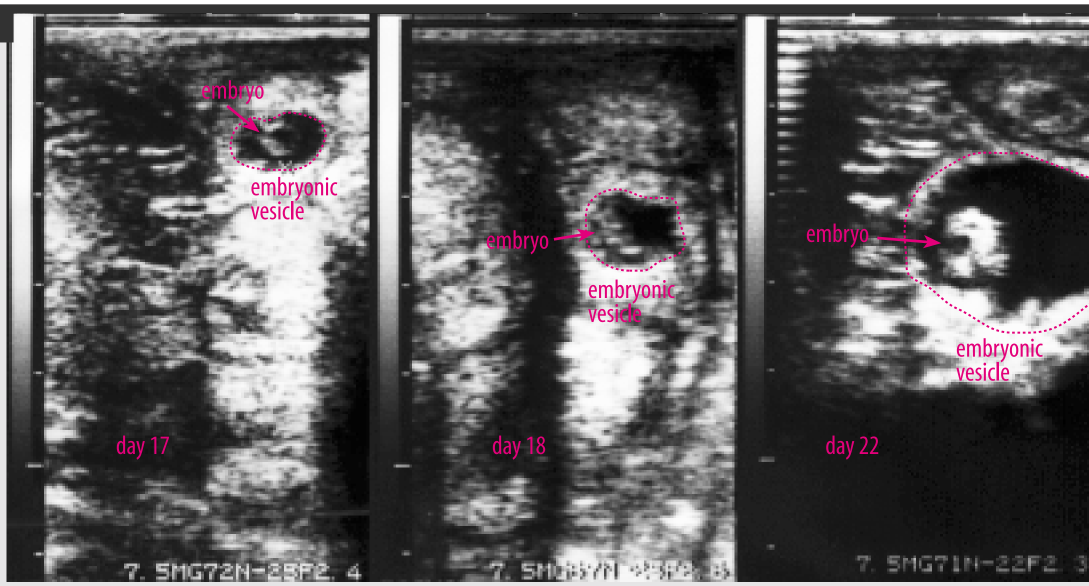
Using transrectal imaging to confirm early pregnancy

Confirming pregnancy on day 16–18 after breeding by transrectal ultrasound either by visualizing the embryonic vesicle (day 16), embryo (day 17), or ovarian CL (day 18) provides producers and practitioners with a simple, noninvasive technique to diagnose pregnancy more quickly and reliably than any other method reported to date (Martinez E, et al. *Proc. 11th IPVS*, 1990:476. Botero O, et al. *Proc. 8th IPVS*, 1984:306).[1–4] An earlier pregnancy diagnosis allows a producer to rapidly identify and rebreed the nonpregnant female and to reduce sow nonproductive days.

The 7.5 MHz transrectal transducer will be required to confirm early pregnancy (days 16–21) status in gilts and sows. The 5.0 MHz transducer can also be used transrectally or transabdominally, but may not provide the necessary degree of resolution to accurately confirm pregnancy status at this early stage. Orient yourself by locating the urinary bladder. Then, look for the uterus. The sonographic appearance of the swine conceptus should be distinct, with its echoic mass surrounded by the dark anechoic fluid of the vesicle, which is in turn surrounded by a uniform hyperechoic uterus. It should be easy to visualize the conceptuses in the uterine horn of pregnant sows on days 18–22 of pregnancy (Figure 17). By day 24, the form of the conceptus is easily distinguished (Figure 18) and by day 30 has clear shape (Figure 19). At this time, you can visualize the highly echogenic embryo in the anechoic fluid-filled embryonic vesicle. Pregnancy can also be distinguished at 16 days by comparing the anechoic fluid-filled uterus (Figure 20, left) to the day-16 nonpregnant uterus (Figure 20, right), which lacks any detectable anechoic areas in the uterine lumen. By day 18 after breeding, large hypoechogenic CL should be identifiable in gravid females (Figure 21, left), whereas in nonpregnant females, only large follicles should be present on the ovary, indicating approaching estrus (Figure 21, right). Identifying nonpregnant females 18 days after breeding could help producers anticipate the expression of estrus in these females within the next few days.

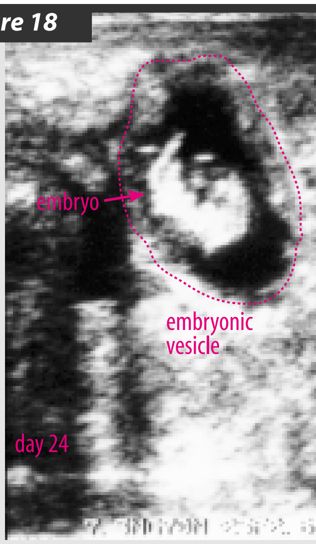
Until some level of proficiency is achieved, it is advisable to corroborate the accuracy of the RTU early pregnancy diagnosis with estrus detection between 18–24 days after mating and later by either RTU

Figure 17



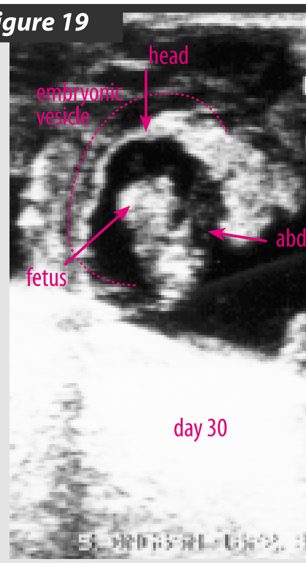
Swine embryos visualized as a hyperechoic mass within the anechoic embryonic vesicle on (left-to-right) days 17, 18, and 22 of gestation using a transrectal 7.5 MHz linear-array transducer.

Figure 18



Swine embryo within the embryonic vesicle on day 24 of gestation. (visualized with a transrectal 7.5 MHz linear-array transducer).

Figure 19



Swine fetus visualized as a hyperechoic mass within the embryonic vesicle on day 30 of gestation using a transrectal 7.5 MHz linear-array transducer

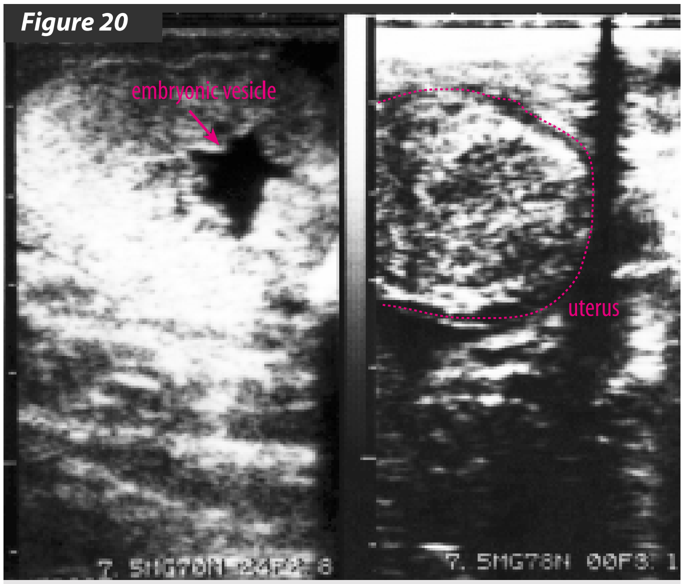
with either 3.5 or 5.0 MHz transabdominal probes or with A-mode or Doppler ultrasound between 35–40 days after mating.

Other considerations

You should perform an on-farm analysis of labor and cost to determine the practicality of actually performing routine, transrectal RTU to determine ovarian status. However, RTU of females once or twice daily, prior to the last insemination of the day, could allow producers to breed nonovulated females and can prevent inseminating a bred female that has already ovulated. Transrectal RTU can be completed in less than 3 minutes, with an average time of 1.5 minutes per female. Further research will be needed to determine whether breeding based on occurrence of ovulation yields economic returns to producers by reducing the number of open days, reducing the numbers of unnecessary services, and improving farrowing rates and litter sizes, over the costs of the equipment and labor associated with ultrasound.

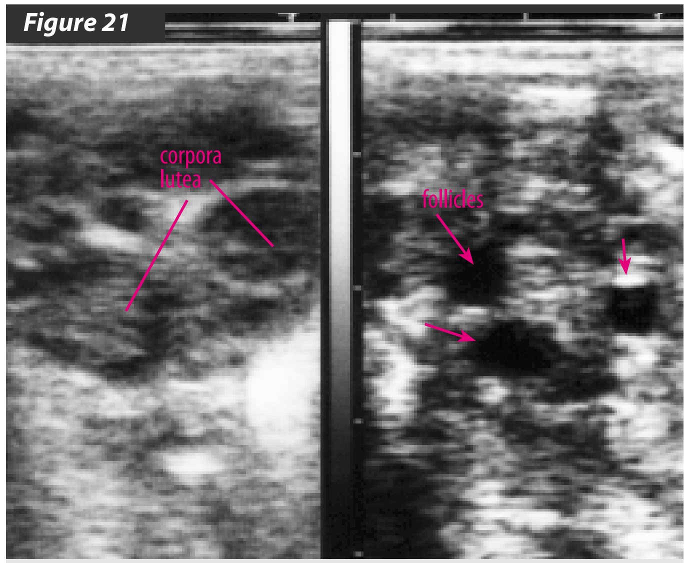
With the diversity of swine genetics and variety in management and housing systems used in production operations today, it is only logical to expect differences in reproductive performance among herds. Established industry techniques, such as mating 12 and 24 hours after onset of estrus, may not provide optimum performance across all seasons, genetics, and management practices. Practitioners and producers may be able to use RTU to characterize the critical components of their own herds to implement management strategies to improve the reproductive efficiency of their operation. Because the most critical component of reproductive performance of the female appears to depend upon breeding time after onset of estrus,[26] it may

Figure 20



left: A day-16 pregnancy is identified by detecting the anechoic fluid of the developing embryonic vesicle in the uterus. **right**: a day-16 nonpregnant uterus (dotted line defines the outer serosa). Images were generated using a transrectal 7.5 MHz linear-array transducer.

Figure 21



left: Swine pregnancy can be determined indirectly by detecting corpora lutea (CL) on day 18 after estrus and insemination. **right**: A nonpregnant female is detected as open on day 18 by presence of large (>6.5 mm) and medium sized (3–6.5 mm) follicles in the absence of any corpora lutea. Both images were generated using a transrectal 7.5 MHz linear-array transducer.

be worthwhile to characterize the time of ovulation for particular breeds and lines of swine under different management systems and seasons of the year. Optimizing individual breeding times has the potential to yield significant returns to producers through improvements in farrowing rate and litter size. The transrectal ultrasound procedure could identify the status of the female at any given time and could allow producers and practitioners to implement informed management decisions to improve herd reproductive performance.

The sonographic images included in this report should help you choose between the transabdominal or transrectal imaging method, in combination with transducer type, in order to obtain images that you can readily interpret to accurately diagnose the reproductive status of the female pig. Since more portable, less expensive RTU machines are not expected to provide the same degree of image detail as the Aloka 500V we used to generate these images, the images included in this report can serve as a general reference for the ease and time required for imaging, and for determining the applicability of these portable RTU units for reproductive tract imaging.

Implications

- Earlier pregnancy diagnosis is possible with transrectal imaging using the 5.0 and 7.5 MHz transducers for visualizing the conceptus and embryonic vesicle at day 16–17.
- Determining ovarian status to facilitate management decisions can be quickly and accurately accomplished on any female pig using transrectal RTU with the 7.5 MHz transducer.
- Ovarian cysts can be readily identified using transabdominal and transrectal imaging due to their immense size, shape, and anechoic nature. Rapid diagnosis of these ovarian abnormalities will allow the producer to more precisely identify and cull these infertile animals.
- The structural specificity and image detail resulting from comparisons between transabdominal and transrectal procedures, in conjunction with transducer sensitivity, should aid in ultrasound training for practitioners, students, and producers.

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