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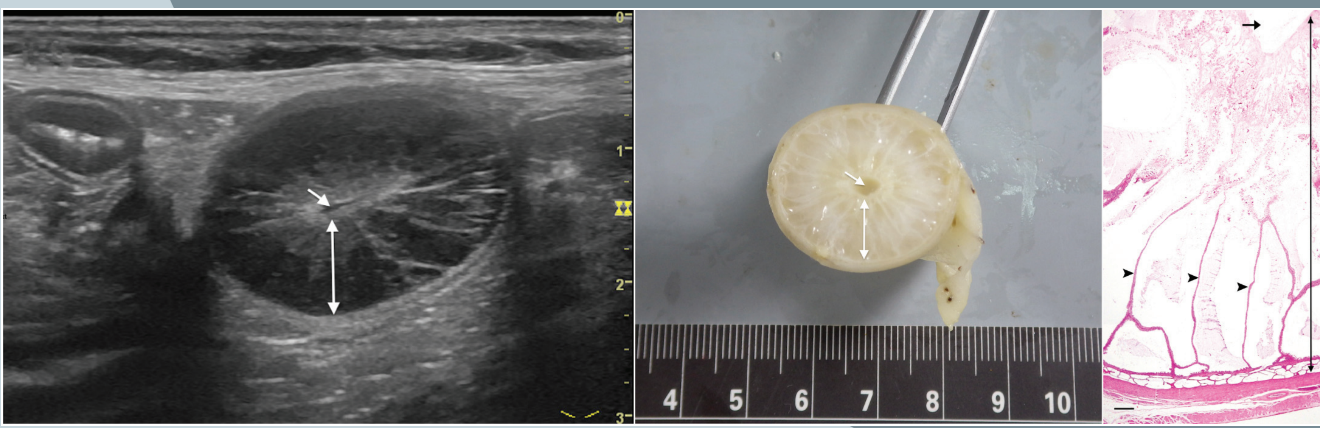

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ORIGINAL INVESTIGATION

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Abdominal ultrasound image quality is comparable among veterinary sonographers with varying levels of expertise for healthy canine and feline patients

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Abstract

Abdominal ultrasonography is increasingly used as a standard diagnostic test in veterinary practices, however, there is little published information regarding the effects of operator experience on image quality. In this prospective observer agreement study, image quality was assessed for abdominal ultrasound examinations performed by nine sonographers (three general practitioners, three credentialed veterinary technicians, and three board-certified specialists). Each sonographer independently performed abdominal ultrasound examinations on the same group of 4 sedated clinically healthy animals (3 dogs, 1 cat) using the same model machine and standardized presets. Twenty-five organs and anatomical landmarks per exam (26 for male dog) were evaluated. Still images and cine loops were recorded for each one of the organs. The final scoring of image quality for each examination was performed by two board-certified veterinary radiologists in a randomized and blinded fashion. Semiquantitative scoring system was used for each reading: 0 - not seen, 1- seen but poor quality/partial seen, 2 - average/good quality, and 3 - excellent quality. The average score for each animal and sonographer was tallied and sonographer groups and individual sonographers were compared. Scores were assessed for normality and data were ranked transformed prior to statistical analysis. No significant differences were found regarding the completeness and quality scores of sonographers of different experience levels and disciplines when measuring specific standard components of a full abdominal scan. There were no statistical differences between individual sonographers or groups of sonographers. Although not statistically significant, the general practitioner's group showed the greatest variability of their individual scores.

KEYWORDS

Sonographer experience, standard ultrasound protocols, quality control, ISDEP® protocol

1 | INTRODUCTION

Veterinary ultrasound was once considered a diagnostic modality restricted to use only in academic institutions and referral centers. Since its introduction in veterinary practice, veterinary ultrasound has, over the years, advanced in a number of ways that now allow for its daily use in general practice. Advances in research and technology, education, and competitive pricing have made ultrasound easier, better, and more readily available to all general practitioners. The average pet owner now has expectations that their family veterinarian will have ultrasound diagnostic technology at their disposal should their animal ever require it.[1] One of the challenges involved in implementing ultrasound examinations in general practice is the question of validating the quality of ultrasound examinations that are performed. Ultrasonography is a user-dependent imaging modality and competence is needed to ensure diagnostic accuracy which requires a combination of anatomical and clinical knowledge, technical skills, and the ability to interpret ultrasound images.[1] False-positive results will elicit unnecessary client anxiety and further unnecessary testing. Similarly, false-negative results potentially can lead to important diagnoses being missed.

Acquiring and sustaining competencies of various ultrasound imaging modalities and procedures requires training and continual exposure to relevant clinical conditions. The range of imaging quality presented in the field of veterinary medicine with regards to the views to obtain, partial versus complete sonograms, the lack of definition as to what constitutes a complete sonogram, variable resolution, and machine quality are just a few issues that plague the field of veterinary clinical sonography and telemedicine. The ability to obtain a complete image set, as defined and utilized in this study, has a high variability sonographer to sonographer within certain levels of credentials and discipline as well as simply across the spectrum of whoever performs a sonogram in the veterinary field. Veterinary medicine consists of sonographers that span from board-certified radiologists, internists, and similar specializations, to general practitioner and recently, veterinary technicians that may or may not be credentialed. Unfortunately, there is currently no control over who performs an ultrasound in veterinary medicine. However, the talent to perform a full, high-quality sonogram also exists within all disciplines in the veterinary field just as suboptimal image sets may also be found in all disciplines. Moreover, many different methods of scanning have been and are currently being taught in the veterinary field without standardization or consensus with regards to required image sets and how many video clips, if any, are to be utilized together with still images. These are all problematic issues that plague the clinical sonography process in veterinary medicine. Human studies have shown that clinical ultrasound examinations with low-to-moderate complexity performed by general practitioners with sufficient prior training had a very high level of inter-rater agreement when compared to examinations conducted by radiologists.[2–4] In one study, general practitioners could perform acceptable ultrasound examinations of the abdomen after an intensive training period and there was good consistency between the examinations performed by the general practitioner and that of the radiologist.[4] A systemic meta-analysis human study showed that general practitioners could safely use point of care ultrasound in a wide range of clinical settings to aid diagnosis and better the care of their patients.[5] In the human field there has been a shift into the possibilities of utilizing ultrasound examinations in general practice, especially with the huge advances in ultrasound technology that have been made. One study concluded that general practitioners need a structured education with certification and a system to keep skills at a sufficient level over time and proposed more specific studies into the quality of ultrasound examinations performed by general practitioners.[6]

The aim of our study was to compare the quality of abdominal ultrasound protocols performed by different veterinary sonographers, grouped based on their experience levels and specialty. We hypothesized that image quality would not differ among these sonographers for healthy canine and feline patients.

2 | MATERIALS AND METHODS

The study was a prospective, observer agreement design. Ethical approval for the study was provided by the owners of the animals and the hospital director. A total of four animals (3 dogs, 1 cat), scanned under deep sedation were used, with all sonographers aware of the objective of the study. Sample size was empirically determined. Prior to sedation, each animal was fully examined by a veterinarian with sedation and analgesia expertise and deemed to be clinically healthy. Criteria used for determining clinical healthy status were the following: age, vaccination status, known medical history, core body temperature, resting heart rate, resting respiratory rate, body condition score (WSAVA.org, 2013), fear assessment score (FAS scale, Kenneth Martin and Debbie Martin, 2017), and cardiac ultrasound (Elite 8 table top mobile, Mindray, Mahwah, New Jersey, USA; transducer for the cat and small dog was the P10-4s phased array, transducer for the 2 larger dogs was the SP5-1s phased array).

The dogs were premedicated with trazadone (5-15 mg/kg) and gabapentin (10-20 mg/kg), followed by intramuscular dexdomitor/torbugesic (Dexdomitor 0.5 mg/ml, Orion Corporation, Espoo Finland, distributed by Zoetis, dosage .01 mg/kg; Torbugesic 10 mg/ml, manufactured and distributed by Zoetis Corporation, Spain, dosage 0.2 mg/kg). The cat was premedicated with gabapentin 100 mg followed by an intramuscular combination of dexdomitor 0.2cc/10lbs, /ketamine 0.2cc/10lbs, torbugesic 0.2cc/10 lbs (Ketathesia, 100 mg/ml, Henry Schein Animal Health, Dublin OH). All dosages were adjusted based on the results of the physical exam and consideration of medical history. All animals were continuously monitored by a credentialed technician and a veterinarian. The animals were designated P1 – cat, P2 – small dog (5 kg), P3 – medium-sized dog (9.3 kg), and P4 – large-sized dog (30 kg). Ultrasound examinations were independently performed by nine observers: three general veterinary practitioners, three credentialed veterinary technicians (D.M. plus one RVT and one CVT), and three veterinary specialists (one American Board of Veterinary Practitioners [ABVP Diplomate] in canine and feline

TABLE 1 List of standard required views used in the study

Bladder – sagittal and transverse
Pelvic urethra
Prostate in males
Medial iliac lymph nodes longitudinal plane
Left kidney
Left adrenal
Spleen
Splenic hilus
Pancreatic left limb
Stomach
Liver
Gallbladder
Portal vein
Common bile duct
Diaphragm
Pancreatic right limb
Right kidney
Right adrenal
Duodenum
Jejunum
Ileum
Colon
Cecum
Small intestine – serosa, muscularis, submucosa, and mucosa
Mesenteric lymph nodes

practice (E.L.), one American College of Veterinary Radiology [AVCR] Diplomate (A.R.), and one German Boarded Specialist in Radiology and Diagnostic Imaging). Each sonographer was anonymized with a designation of S1-S9. Each sonographer used the same model machine (Elite 8 table top mobile, Mindray, Mahwah, New Jersey, USA) and the same standardized presets for the particular animal and was only permitted to adjust the gain, frequency, and depth. Transducers available were C11-3s micro-convex and L14-6Ns high-frequency linear probes with sonographers free to choose their transducers. A checklist of standard required views was used (Table 1), which allowed for the evaluation of 25 different target images (26 in the male dog). Additional details regarding sonographer expertise are provided in Table 2.

Each sonographer rotated to each animal and had a 20-minute maximum time period to complete the full abdominal scan. All 9 sonographers performed the sonogram in the same room in rotation, and completed all the required scanning in a single session. No sonographer viewed the scanning session of another sonographer. A semi-quantitative scoring system used by the blinded evaluators for each reading was: 0 - not seen, 1- seen but poor quality/partial seen, 2 - average/good quality, and 3 - excellent quality. A total score for each examiner was tallied with a maximum of 78 points (25 (female)/26 (male) x 3, with 25/26 being the required standard views and 3 being an excellent quality image). The scoring system was semi-quantitative as a qualitative ultrasound scoring system would have been impossible as each abdomen is different in size, fat content, connective tissue, thickness of skin, as well as machine, transducer, and presets all adding attenuating confounders.

The blinded reviewers were to consider if the whole structure was imaged and readily recognized in its entirety and if detail recognition was present in order to assess parenchymal integrity. Depth, gain, and other settings were considered in overall image quality as well as proper sagittal and short-axis alignment. One of the objectives of the study was to assess the participant's ability to combine proper settings in order to obtain professionally acceptable images of each organ.

It was the sonographer's choice as to whether to present a still image of the view, or a 3-s video clip that contained the view. Based on their scanning history and method of instruction, four sonographers presented primarily video clips with stills of sagittal views of kidneys and adrenals whereas five sonographers presented mixed videos and still images.

Although the use of depth and gain was neither scored nor specifically noted on the scoring sheet prepared by the reviewers, both were considered in the overall image quality. Image quality was based on the ability to stop a loop to evaluate the organ in a still status, as well as ensuring that the video loops were not pixelated and of continuous diagnostic quality throughout the loop encompassing the entire organ.

The key outcome factors for each sonographer were detail recognition and detail recognition adjustments specific to the organ or area of interest; accurate anatomic alignment in long and short axis; ability to scan an organ/structure and its anatomic environment in its entirety. Appropriate scanning speed and appropriate recording and transfer of still images and loops were also considered outcome factors of the study.

All images were anonymized and viewed in DICOM format on a system with the following parameters - 21" 2 MP monitor, up to 1200 cd/qm, and a greyscale range of 8–10 out of a maximum of 14. All protocols were a mixture of cine loops and static images with the sonographer's choice as to whether to present a still image of the view, or a 3-s video clip that contained the view. Two board-certified veterinary radiologists (N.O. and _ECVDI) judged the image sets to be complete and of appropriate diagnostic quality.

The nine sonographers represented five different formats/programs of historical ultrasound training with experience levels ranging from 30 years to less than 18 months of veterinary sonography experience (Table 2). This study was strictly limited to image acquisition with a standard spectrum of patients regarding size and body type found regularly in veterinary medicine and did not address interpretation of pathology.

Statistical analyses were performed by a biostatistical epidemiologist. Scores were assessed for normality by calculating descriptive statistics, plotting histograms, and performing the Anderson-Darling test in commercial software (MINITAB Statistical Software, Minitab Inc, State College, Pennsylvania, USA). Scores were described using box plots in the ggplot2 package within R. Data were ranked transformed prior to statistical analysis. Linear mixed-effects models were used to

TABLE 2 Scanning history, cases per week, and educational background for each sonographer that took part in the study

Sonographer expertise and training	On-site Ultrasound Caseload Per Week	Training/Experience	Years doing Ultrasound
DABVP	2002-2017, 80 per week2018–2020, 40 per week	Traditional and SDEPTM protocol, mobile	23 years
DACVR	15-20 per week	Traditional	28 years
Diplomate German Board of Radiology	50 per week	Traditional 4 years of training (University of Giessen)	13 years
General practitioner 1	3 per week	Traditional course, Self-taught, then SDEP™ protocol	20+ years
General practitioner 2	15-20 per week	8-10 Traditional courses/wetlabs, RACE approved mentorship with RDMS; Full time mobile Experience 6 months	15 years
General practitioner 3	3 per week	Traditional and SDEP™ protocol as of 2018	5 years
Technician 1, RVT	15-20 per week	SDEP™ protocol only, mobile practice	6 years
Technician 2, CVT	18-22 per week	SDEP™ protocol only, mobile practice	2 years
Technician 3, RVT	15-20 per week	SDEP™ protocol only, mobile practice	18 months

compare scores between sonographers including random effect terms for radiologist and animal to account for the dependency among collected data. Sonographer group was included in the model as a fixed effect term and random effects were modeled using a variance components correlation structure. Post-hoc pairwise comparisons between sonographer groups were adjusted using Bonferroni correction. Statistical modeling was performed in commercial software (IBM SPSS Statistics Version 27, International Business Machines Corp., Armonk, NY, USA) with significance set at the 5% level.

3 | RESULTS

The average score for each animal and sonographer was tallied. The median and interquartile ranges (IQR) of radiology scores for the general practitioners, technicians, and specialists were 54.5 (43.3, 71.3), 58.5 (47.5, 72.8), and 61.0 (55.0, 74.8), respectively. The individual sonographers and the sonographer groups were compared (Figures 1 and 2). There were no statistical differences between the individual sonographers or sonographer groups across all four animals scanned. In addition, there was no statistical difference between individual animals and sonographer's scores. Although not statistically significant, the general practitioner's group showed the greatest individual variability.

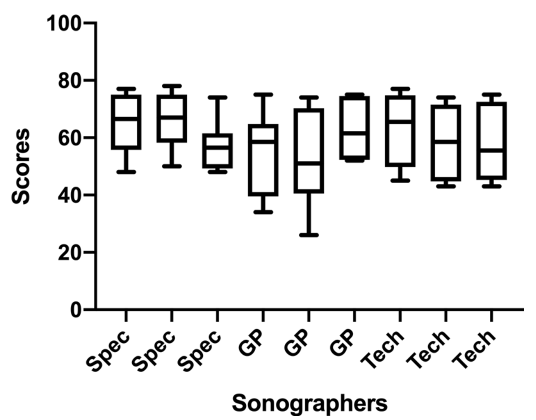

FIGURE 1 The average score generated for individual sonographers showing no statistical significance between the various sonographers. Spec, specialist; GP, general practitioner; Tech, veterinary technician

4 | DISCUSSION

Based on a literature review of PubMed, CABI, Scopus, and Web of Science spanning the years 1963 to present using the words "veterinary, companion animal, abdominal ultrasound, systemic review, comparison, general practitioner, specialist, goal-orientated", no comparable studies were found in the English veterinary literature. This double-blinded study was therefore a first of its kind, aimed at examining the skills of nine clinical sonographers that were trained in different disciplines with an experience spectrum from 18 months to 30 years of veterinary sonography, and all placed into the exact same sonography environment with regards to animal, machine, and presets. Standard required views were the same for each sonographer but the ability to obtain those views was subjective by the individual participant whether utilizing standard published traditional views, structured protocol from continuing education over the previous 10–15 years, or through the recently presented Sonographic Diagnostic Efficiency Protocol (SDEP®) abdominal protocol.[7] In other words, sonographers in the veterinary field obtain their image sets through different modalities depending on their education, experience, and specialty whether that education derived from university-based programs, continuing education seminars, or privately taught protocols. This study reflected that spectrum as participants spanned geographically from Europe and North America.

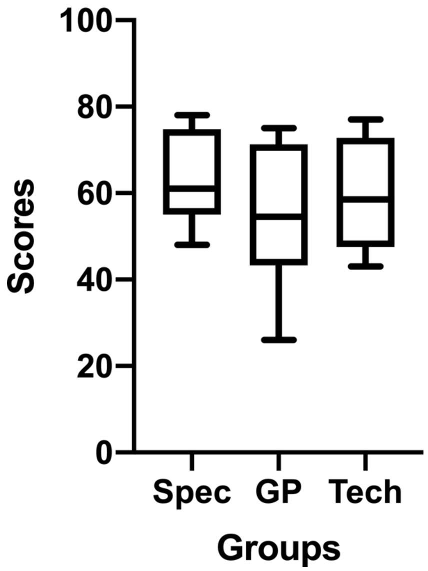

FIGURE 2 The average score generated for the sonographer groups showing no statistical significance between the three groups of sonographers. Spec, specialist; GP, general practitioner; Tech, veterinary technician

The amplification of access of the veterinary patient to the complete sonogram by means of general practitioners and veterinary technicians, properly trained in a complete repeatable sonogram format was evidenced in this study. The sonographers in this study represented five different formats/programs of historical ultrasound training with experience levels ranging from 30 years to less than 18 months of veterinary sonography experience. Despite this vast variation in training and experience, there was no significant change in image quality acquisition as evaluated by independent blinded radiologists. This study showed that proper image acquisition can be rapidly learned by veterinary technicians as well as general practitioners and boarded specialists to allow for remote interpretation and telemedicine operations at a comparable level, hence limiting the need for boarded specialists to be on site for image acquisition. However, in the opinion of the authors of this manuscript, on-site need for advanced interventional and specialized ultrasound-based procedures will always be necessary.

This study agreed with what has been reported in human studies that clinical ultrasound examinations with low-to-moderate complexity performed by general practitioners with sufficient prior training had a very high level of inter-rater agreement.[2–4] After training using the SDEP® protocol,[7] veterinary sonographers are able and competent to perform acceptable ultrasound examinations of the abdomen, which is in agreement with what has been reported in the human literature.[4]

Limitations of this study include the lack of structural pathology in any of the patients and did not consider the experience-based necessity for recognition of visceral pathology and how to approach it sonographically. Further double-blinded studies need to be performed with various common pathological presentations such as splenic and hepatic masses, common bile duct pathology, lymphadenomegaly, gastrointestinal mural lesions and obstructive patterns, invasive adrenal masses, and thrombosis as well as many other presentations that a sonographer may encounter on a daily basis. The variety of visceral pathological presentations present various sonographic challenges regarding approach, image quality, and resolution as well as the potential for omission of lesions in the image set. Although this study's sample size of 9 sonographers was relatively small, the study designers agreed that the participants represented a solid cross section of clinical sonography abilities in current veterinary environments producing diagnostic sonograms for in-house evaluation or for telemedicine submission. Moreover, historically there is no point of reference to refer to regarding a standard abdominal sonographic protocol. Therefore, variability between educational approach to the sonogram may be even more vast than represented by the 9 participants in this study.

5 | CONCLUSION

Findings from this study indicated that diagnostic quality assessments of abdominal ultrasound examinations in three healthy dogs and one cat were comparable among nine sonographers with varying levels of expertise. This small double-blinded study demonstrates the solid potential for multidisciplinary backgrounds to provide solid diagnostic image sets for interpretation. This is a key point in a rapidly expanding world of remote imaging and interpretation, and the consequent need for qualified veterinary ultrasonographers.

LIST OF AUTHOR CONTRIBUTIONS

Category 1

(a) Conception and Design: Lindquist, Lobetti, McFadden, Ondreka-Eley, Roth.
(b) Acquisition of Data: Lindquist, Lobetti, McFadden, Ondreka-Eley, Roth.
(c) Analysis and Interpretation of Data: Ondreka-Eley, Lobetti.

Category 2

(a) Drafting the Article: Lindquist, Lobetti, McFadden, Ondreka-Eley, Roth
(b) Revising Article for Intellectual Content: Lindquist, Lobetti, McFadden, Ondreka-Eley, Roth

Category 3

(a) Final Approval of the Completed Article: Lindquist, Lobetti, McFadden, Ondreka-Eley, Roth

CONFLICT OF INTEREST DISCLOSURE

The authors have no conflict of interests to report.

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