Investigating the diagnostic value and cost-efficiencies of imaging tests in small animal emergency veterinary medicine.

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Candidate for the degree

Bachelor of Sciences

Submitted in partial fulfillment of the requirements for

Departmental Distinction in Biology

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Introduction

Imaging tests, such as radiographs and ultrasounds, are a significant tool in veterinary medicine used primarily for diagnostic purposes. At Berks Animal Emergency Center (BAERC), a few hundred patients are admitted each year for diagnostic testing. Many canine and feline patients show similar symptoms such as lethargy, diarrhea, vomiting, and/or urinary complications which may require an emergency laparotomy, commonly known as exploratory surgery. Given the similarity of the clinical presentation during emergency visits, it is imperative that further diagnostics are performed to clearly distinguish between certain medical diagnoses and create an appropriate treatment plan. However, the result of a certain imaging test for a patient may be inconclusive and require additional testing. Due to financial limitations, some pet owners may not be able to afford running several diagnostics and would prefer to minimize the number of diagnostic tests. The goals of this research are to utilize the patient records from BAERC to identify the common medical emergencies requiring laparotomies and complete statistical analyses to test the hypothesis. I hypothesize that similar to abdominal radiographs for the diagnosis of large, dense foreign body objects, that there are correlations between certain diagnoses and a positive imaging test. The overall purpose of this work is to evaluate if these relationships are present in order to determine the cost efficiency of each test.

In this research study, there will be two analytical sections, qualitative and quantitative, that will explore individually the diagnostic value and cost efficiencies of each imaging test. In the qualitative review, the common medical emergencies of canines and felines at BAERC and review of both radiographic and ultrasonographic techniques are discussed. In the latter section of this report, the findings from the qualitative analysis are investigated further by testing the hypothesis using statistical analysis. The hypothesis of this research is that significant relationships exist between a particular diagnostic imaging test and a confirmed medical emergency. The specific aim of this research is to determine if these strong correlations exist and if so, how can these findings be used to minimize overall expenses to pet owners while still receiving a confirmed medical diagnosis from the veterinarian. To begin, a detailed review of the common maladies in BAERC patients and a review of radiology and ultrasonography are addressed.

Common Maladies of BAERC Canine and Feline Patients

The American Veterinary Medicine Association (AVMA) states that certain symptoms can be indicative of an emergency and require immediate veterinary care. Patient symptoms such as vomiting and/or diarrhea, inability to urinate or defecate, poisonous or foreign body ingestion, lameness or inability to move, abnormal lumps on body, and refusal to drink can be suggestive of a veterinary emergency [1]. These particular symptoms may be highly associated with a particular diagnosis but due to the similarities between patient clinical representation, other tools such as imaging and blood work can be useful to confirm a diagnosis.

Some common small animal emergencies that may require an emergency laparotomy include foreign body objects, masses or tumors, pyometra which is a severe uterine infection, dystocia which is difficulty giving birth, urinary obstruction, and lacerations. A foreign body object is any material, item, or matter that is not naturally found within the body that typically is accidentally ingested. Common objects include rocks, coins, socks, and large hairballs. This phenomenon is considered a medical emergency because possible gastrointestinal or airway obstruction that can cause significant distress and potentially be life-threatening if the object causes significant damage to an animal's organs. Masses or tumors are any lumps or abnormal growth of tissue that could protrude out from the surface of the integument or internally on specific organs. Certain masses or tumors can be characterized as cancerous or a fatty mass, therefore, a biopsy may be performed to determine the nature of any possible disease based on the composition of the growth. Organ abnormality in this study includes the thickening of organ walls, internal bleeding, and pyometra. Dystocia is difficulty giving birth so this diagnosis is limited to female patients. Urinary obstructions include urinary bladder stones or crystals that can cause a blockage through the urethra limiting or preventing urine output. This situation is a dire emergency that will require immediate surgery. Lastly, lacerations are classified as deep wounds or cuts that protrude further than the outer surface of the skin. Ultimately, by discussing some of the major common veterinary emergencies and the critical symptoms associated with clinical representation, the discussion of advanced imaging tests and their effectiveness for diagnosis can be appreciated.

Review of Radiography

Radiography in veterinary medicine contributes significantly to the medical professionals' ability to accurately diagnose patients or recommend further diagnostic imaging to consider other differential diagnoses. The discovery of radiography was founded in 1895 by Wilhelm Roentgen and utilizes a cathode-ray tube and high voltage as an electricity source. The combination of these two allows for high energy gamma photons to produce images because of the release of electrons from the cathode to the metallic anode [2]. As a result, electromagnetic radiation can then be absorbed by an organism's bones with the stored calcium acting as the metallic anode [2]. Although X-ray radiography can be used for looking at overall bone structure and orthopedic health, there are many other ways that X-ray radiographs can be helpful especially in an emergency situation. Radiographs can also be an appropriate diagnostic for tissue or organ complications by altering the settings on the X-ray generator to penetrate and illuminate organs. These particular settings are called the radiographic exposure factors which include milliamperage and time (mAs), kilovoltage (kV), and focus-film distance (FFD) [2]. The milliamperage controls the radiation amount in a given amount of time and ultimately influences radiographic density [2]. The kilovoltage in X-rays is the overall voltage applied to the generator and allows for the patient's tissues and organs to be absorbed by the X-ray light. Additionally, the FFD setting controls the overall distance thus affecting the intensity of radiation [2]. As a result, the radiographic exposure factors settings on an X-ray generator can influence the type of diagnostic image produced and ultimately impacts the information that can be concluded from that image. Some of the common diagnoses confirmed by X-ray radiology include the presence of foreign body objects, Gastric Dilatation-Volvulus, dystocia, and pyometra if the cervix is closed. Therefore, X-ray radiographs (RGs) can be significantly helpful in determining a cause of distress in an animal and can be performed to assess numerous aspects of the animal's overall body in one test.

At BAERC, common imaging tests that can be performed in-hospital include abdominal RGs, thoracic RGs, and special RGs. Special RGs at BAERC are radiographs that require a particular view in order to confirm a diagnosis. Such as a 1 View Puppy Check special RG, is specific for female patients that are pregnant and a single lateral x-ray image can be taken to

determine the number of puppies and their sizes. For additional expertise, some radiographs taken in-hospital may be sent to Board-Certified Radiologist specialists through the service of PetRays to further explain or confirm a radiology finding [3]. Each diagnostic test varies price between approximately $90 to $240 depending on the number of views and if the patient requires sedation. Each radiographic image can provide different results that may or may not directly correlate with the root cause of the emergency. However, regardless if the imaging test led to a confirmed diagnosis, the results may help the veterinarian to narrow down the remaining differentials. Overall, to further understand the diagnostic value of radiographs, it is important to also consider the costs and benefits of having the imaging test performed.

Cost-Benefit Analysis of Radiography

In veterinary medicine, radiographs are an important tool in respect to diagnostics especially in emergency medicine given that they can assess not only orthopedic health but also provide insight into any tissue or organ abnormalities. One benefit of having radiographs performed is the process is fairly quick and can be taken by veterinary technicians and assistants as well. As a result, the test results can be interpreted by the veterinarian soon after the images are taken which can provide the client with results in a timely fashion. Research also shows that X-ray radiation is painless to pet patients and only in some rare cases sedation is required [2]. Yet, one significant setback is the high cost associated with the procedure, ranging up to $240, which may deter some pet owners due to financial constraints. Furthermore, if results from the radiograph reveal there may be a need for surgery or biopsies, the financial limitations of the pet owner may be considered. Nonetheless, radiography is an important diagnostic tool for veterinarians to diagnose patients and despite its cost, the important information the image can provide about the animal's health is what lies at the forefront.

At BAERC, computed radiography is performed and a variety of different RGs are available which differ in the number of total views as well as animal positioning. The different positioning of the patient allows for different arrays of information from the RG to be shown. For example, most abdominal and thoracic x-rays can be 2-View where a ventral-dorsal (VD) position and a left lateral position of the patient is included. This encompasses the VD position

where the area of interest (abdominal or thoracic) is shown in a front view and a left or right lateral that is the side profile of the area of interest. For a 3-View RG, the same 2 angles are included with the additional side view which may be the left or right lateral. Additional views are critical for an accurate diagnosis because, with limited RG views, some important findings on the other lateral view may be overseen [4].

Some of the common RGs of the patients included in this study include abdominal and thoracic radiographs but also specialized radiographs typically that are 1-View X-rays due to the veterinarian suspecting a particular medical differential or interested in focusing on a particular area of the abdomen. The abdominal RGs focus on the abdominal organs and thoracic RGs focuses on the thoracic cavity, the area within the rib cage. These types of X-rays can be helpful in identifying foreign body objects, organ abnormalities within thoracic or abdominal organs, and orthopedic health. Additionally, specialized radiographs in this study include a 1-View Puppy Check in pregnant patients, 1-View Gastric Dilation-Volvulus in canine patients, and 1-View Urolith Check in patients with urinary difficulties due to bladder stones present. These types of RGs will be utilized when the veterinarian is highly suspicious of a particular medical diagnosis and from the results of the test, a diagnosis may be confirmed.

In 2016, BAERC changed from conducting 2-View or 3-View RGs to always performing a 3-View RGs as a full abdominal study because this has greater sensitivity for detecting gastrointestinal foreign body or obstruction compared to a 2-View RGs. The cost of each type of radiographs varies depending on the number of views typically but as a result of BAERC switching to 3-View Study for all abdominal and thoracic radiographs, the fixed cost without sedation is $233.50. For 1-View RGs the price is roughly $116.50. Additionally, the price for a PetRays consultation would be $90.25. As a result, it is cost-effective for BAERC to charge a fixed price for abdominal or thoracic studies that way the hospital is maximizing the accuracy of diagnosis. As an emergency hospital, many patients with various health histories and different regular veterinarians come in for their emergency and in some cases, it may be difficult to confirm a diagnosis with absolute certainty. Therefore, 3-View RG study maximizes diagnostic value meanwhile if a particular diagnosis is suspected, a special RG will be more cost efficient.

Review of Ultrasonography

Another important advanced imaging test type is ultrasonography. Ultrasonography is the creation of images by ultrasonic sound waves in a particular frequency that reflects back from the site of interest on the patient [5]. These particular images must be used with a transmission gel, a clear gel that is composed of propylene glycol, glycerine, Phenoxyethanol, and water, in order to successfully transmit the sound waves from the transducer probe back to the machine. This process allows an image to be created and displayed in real time. The transmission gel serves as a conductive medium and allows for the sound waves needed for the ultrasound image to easily travel into the transducer probe instead of the air. The transducer probe is able to transmit signals depending on the velocity of the sound waves as it travels through various tissues and organs which eventually leads to the formation of an echo [5]. Some echoes can then be received by the transducer probe and the computer can then allow for the transition of echoes into electrical impulses and ultimately creates an image of the patient's body structures.

There are many types of ultrasounds and the most common one that is performed is the B-mode ultrasound that is a 2-dimensional anatomic image [5]. B-mode ultrasounds specifically analyze the abdominal organs or fetuses in a pregnant patient. Additionally, different tissues or organs can be assessed and captured in real time to allow for veterinarians to assess for foreign body objects, masses or tumors, and potentially any organ abnormalities. At BAERC there two types of ultrasonography that can be performed by a veterinarian, a F.A.S.T. ultrasound and a full Ultrasound. The difference between the two diagnostics tests is that F.A.S.T. ultrasounds are quick readings to assess if there is any fluid or internal bleeding within the body where full ultrasounds are a complete assessment of the abdominal area. Ultimately, ultrasounds can also work in conjunction with radiographs to help confirm a medical diagnosis which represents how both imaging tests are valuable diagnostic tools for small animal emergency patients. Further insight into the diagnostic value of ultrasounds can be assessed through the analysis of its costs and benefits.

Cost-Benefit Analysis of Ultrasonography

Similar to radiographs, there are many benefits to having an ultrasound performed on a companion animal that relates to the confirmation of a certain medical diagnosis. Ultrasounds are not invasive and can be completely painless to the patient. Unlike radiographs, ultrasounds do not subject patients to any type of radiation exposure and can also assess the patients' soft tissues in more detail. Veterinarians may also use ultrasonography for additional medical procedures such as needle biopsies or sterile urine collection directly from the bladder using a needle (guided cystocentesis), to directly observe collection [5]. One setback is the diagnostic test must be performed by an authorized veterinary professional and could also be associated with high cost depending on the type of ultrasound and if sedation is required. The cost of F.A.S.T. ultrasounds at BAERC is $90.25 and for full ultrasounds, the cost is $370.00. As a result, many comparisons can be made between the cost/benefit analysis between radiographs and ultrasounds as diagnostic tests in emergency veterinary medicine. Ultimately, this study focuses on discovering if certain medical emergency categories such as foreign body objects, masses or tumors, organ abnormality, dystocia, urinary obstruction, or lacerations, may be associated with a particular diagnostic imaging test. The practical significance of this study can be related back to the cost/benefit analysis for pet owners in order to provide historical and statistical evidence corresponding to the average cost of diagnostic imaging plans.

Qualitative Analysis - Conclusion

Diagnostic imaging is used frequently in veterinary medicine as an effective tool to confirm a particular diagnosis. Many different maladies of small animal patients will potentially require a certain advanced imaging test or a combination of tests to determine the cause of the emergency. While both radiographs and ultrasounds are commonly used diagnostic imaging tests, they differ in their specific specialization in terms of what the image portrays. These differences between imaging tests are important when veterinarians propose a diagnostic workup because the doctor wants to minimize the number of tests for a confirmed diagnosis just as the client does. Therefore, considering the differences in specialization between the tests, their overall costs, and their benefits to the patient, are crucial for investigating their prospective

diagnostic value and cost efficiency. The following section of this work further investigates the findings of the qualitative section by utilizing statistical analyses to directly test the hypothesis.

Quantitative Analysis - Methods

The methodology of the quantitative section of the research includes the collection of data from medical records from canine and feline patients at Berks Animal Emergency Center between 2015-2017. In particular, the patient's discharge instructions, the doctor's SOAPs which stands for Subjective, Objective, Assessment, and Plan (a method of patient file documentation), and the itemized invoice were used to determine the confirmed medical diagnosis and the diagnostic imaging tests performed prior to the patient's laparotomy.

This data was collected and organized into an excel sheet that can be used in R to provide further statistical relationships. The medical emergencies of this study were categorized into the following six diagnoses; Foreign Body Object, Mass/Tumor, Organ Abnormality, Dystocia, Urinary Obstruction, and Lacerations, for the descriptive statistics. For each patient file reviewed, the type of diagnostic test and total diagnostics cost was recorded. The diagnostic imaging tests performed at Berks Animal Emergency Center include abdominal and thoracic radiographs, follow-up radiographs post-surgery, Focused Assessment with Sonography in Trauma (F.A.S.T.) Ultrasound, a full ultrasound, and the option of contacting PetRays for a Board-Certified Radiologist consultation review of the acquired radiographs.

Descriptive statistics will be calculated using excel to present data including but not limited to the total number of canines and felines patients, the average cost of diagnostics, and number of patients who received each type of imaging test. Additionally, a log-linear analysis was performed using R software. The medical diagnoses included in this analysis was reduced to 4 total diagnoses (FBO, Dystocia, Organ Abnormality, and other). The log-linear analysis will be used to determine if there are significant relationships between a particular diagnostic imaging test and a confirmed medical emergency. From this, the total cost of the veterinary bill may decrease as a result of exploring the diagnostic value of different imaging tests according to the medical diagnosis.

Quantitative Analysis - Results

The categories of common medical emergencies, as well as types of diagnostic imaging tests available at BAERC, were used primarily used for descriptive statistics. A total of one hundred and twenty-six patient files were analyzed and found that a majority of emergency cases at BAERC are canine patients comprising of 92% of total patient files utilized. The number of analyzed feline patient files compared to canine patients was significantly lower due to the random selection of patient files from 2015-2017. Out of all the possible diagnostic imaging tests, the most common diagnostic imaging test performed was the F.A.S.T. ultrasound with approximately 35 canine patients who received this test. For feline patients, 10 out of 11 received a general abdominal radiograph performed prior to exploratory surgery. The overall average cost for feline patients with the total diagnostic imaging test workup plan was $290.69±183.64. For canine patients, the complete diagnostic workup cost was relatively higher resulting in the average of $315.15±169.09. The average cost from the entire study including both species was $313.03±169.78.

In this study, the 11 feline patient files used encompassed only 3 different medical diagnoses including foreign body object abdominal obstruction, organ abnormality, and urinary obstruction. Whereas at least 3 individual canine patients were diagnosed with each of the 6 common medical emergencies. The most common confirmed diagnosis was foreign body object in both species with organ abnormality as the second most common. As a result, these two medical emergencies were explicitly chosen to be included in the log-linear analysis to conduct a comparison with a greater likelihood of significant results.

A log-linear analysis performed using R software was used to determine the relationship between the diagnostic test and medical diagnosis. To simplify the models, medical diagnoses were collapsed into the following four groups; foreign body object (FBO), organ abnormalities (OA), dystocia, and other. FBO abdominal obstruction was the most common confirmed medical outcome, therefore, it was utilized to compare all other medical outcomes. It is important to note that this model predicts an outcome based only on the diagnostic imaging tests and not the actual outcome of the tests performed. Therefore, the model is missing some of the data to make the model more complete. Positive values correspond to that specific value of a greater likelihood to

occur relative to FBO and negative values correspond to a decreased likelihood. To represent the different probabilities of the confirmed medical outcome in relation to the type of diagnostic imaging test performed, three patient cases selected at random will be discussed.

A canine patient who had a two-view abdominal radiograph performed with no other diagnostics would have different likelihoods of probability for a certain medical outcome according to the log-linear model. In this case relative to FBO, the patient is 3.93 times less likely to be diagnosed with dystocia, 18.10 times more likely to be diagnosed with OA, and 9.75 times less likely for others. Overall, the most likely outcome would be FBO and ultimately this patient was confirmed to have a corn cob in their small intestine. Ultimately, this demonstrates that the log-linear model can accurately discriminate between confirmed dystocia versus an FBO. Another canine patient only had a one-view specialized abdominal radiograph for a puppy check performed and the probability of dystocia was 21.0 times more likely, for OA was 2.30 times less likely, and for other was calculated to be 10.8 less likely relative to FBO. As a result, the calculated value is in agreement with the actual medical diagnosis of difficulty giving birth in a female canine patient. Lastly, a patient had a two-view abdominal radiograph and a F.A.S.T. ultrasound performed and the probability that the patient has dystocia is 1.49 times less likely, 20.2 times more likely for OA, and 7.89 times less likely for other, relative to FBO. Therefore it can be predicted that this patient, based on the calculated value, will be diagnosed with an organ abnormality which was supported by its actual outcome of a pyometra diagnosis.

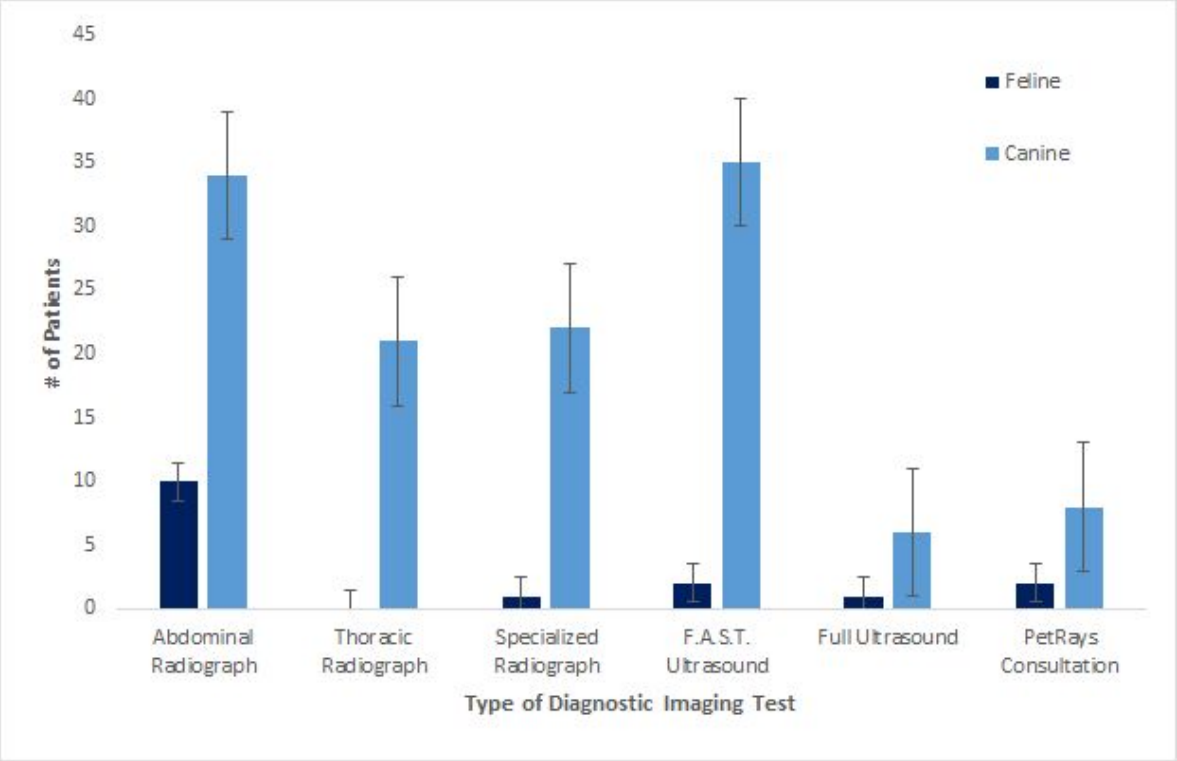

Figure 1. The total number of feline and canine patients at Berks Animal Emergency & Referral Center between 2015-2017 who received one of the following diagnostic imaging tests. Abdominal and thoracic radiographs which may be 2 or 3 Views, specialized radiographs that x-ray a particular area for a suspected differential such as suspected Gastric Dilatation-Volvulus, a F.A.S.T ultrasound, a full ultrasound, and a PetRays Board Certified Radiologist consultation. The standard error was calculated using the standard deviation in excel.

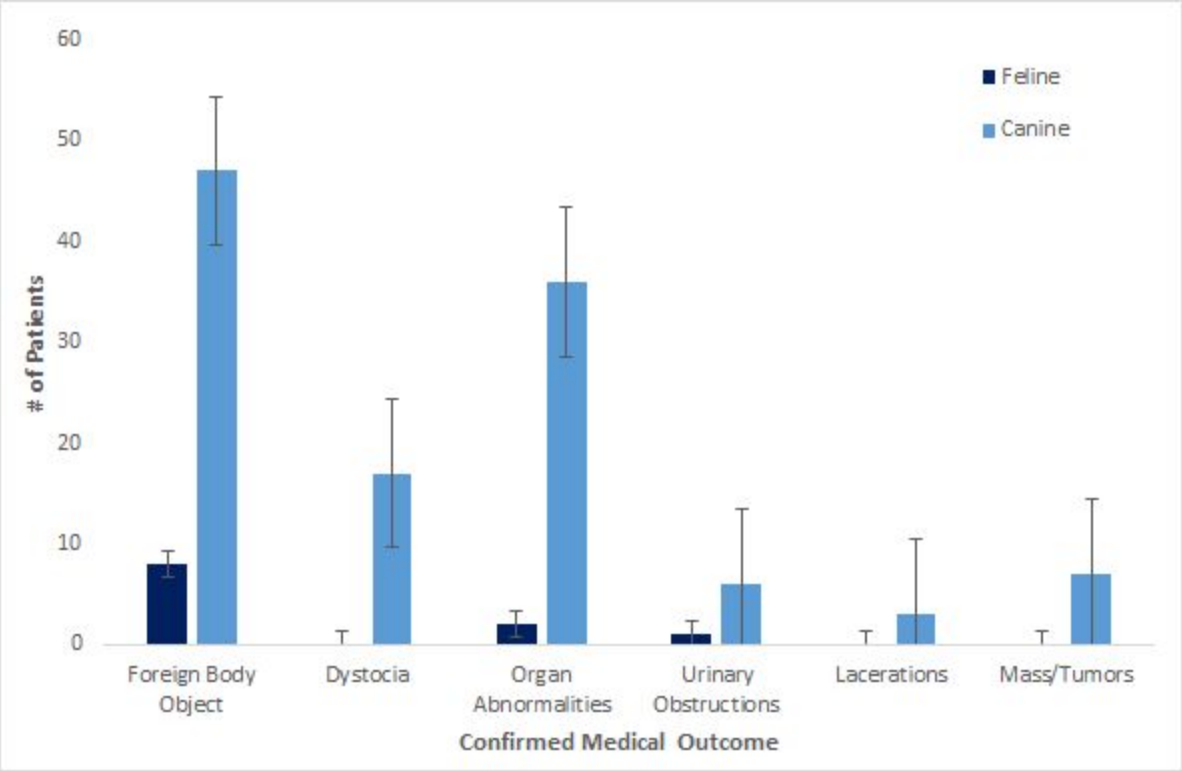

Figure 2. The differences in the total number of the following common medical emergencies between feline and canine patients at Berks Animal Emergency & Referral Center between 2015-2017. There are many different individual medical emergency outcomes such as Gastric Dilation-Volvulus, pyometra, and different masses or types of tumors but were ultimately categorized to better organize and differentiate the patient's medical emergency type. The standard error was calculated using the standard deviation in excel.

Table 1. The coefficients for the log-linear model examining diagnosis as a function of diagnostic imaging tests. From these values, equations were derived for the calculations of the ratio of probabilities. The following abbreviations represent the following: PEL-Pelvic region, PUP-puppy check, and URO-urolith (bladder stones) check. The analytical formula was created using R software by Dr. Stephen Mech.

Coefficient	Dystocia	Organ Abnormality	Other
Intercept	-1.67465	18.55684	-9.25458
General abdominal x-ray	-1.2717	-0.22605	-0.24812
Special abdominal x-ray PEL	1.755905	0.381197	-2.49318
Special abdominal x-ray PUP	22.72137	-16.2595	-1.5736
Special abdominal x-ray URO	1.333693	-37.653	10.43161
General thoracic x-ray	-6.72287	0.31435	0.859171
F.A.S.T. ultrasound	2.439393	2.063641	1.856218

Quantitative Analysis - Discussion

Ultimately, the log-linear model equations provide a calculation of the ratio of the probability of a certain medical outcome relative to FBO using the coefficients of the diagnostic test used. The two most common diagnostic imaging tests in this study are F.A.S.T. ultrasounds and abdominal RGs and the model ultimately predicts that these are the best at discriminating between the different medical outcomes potentially possible. The most common diagnosis from this study was FBO obstruction, therefore, this outcome was used in comparison to other medical maladies such as dystocia, organ abnormalities, and ‘other' which encompasses all the other diagnoses as described in Figure 2.

FBO abdominal obstructions are a common medical emergency in small animals due to ingestion of a foreign material that may cause a blockage or cause severe internal damage to the

digestive tract following consumption. Considering many pet owners may not see this particular action occur, the clinical symptoms of the pet such as vomiting, not eating or drinking are concerning and of unknown origin. Therefore, performing diagnostic imaging is necessary for potentially determining the primary cause of discomfort in the pet. There is sufficient evidence in veterinary medicine research that radiography is definitely appropriate as the first diagnostic imaging test performed and can often provide the evidence needed to confirm the medical outcome of an FBO obstruction [2]. In the absence of radiographs as a diagnostic tool, other imaging tests such as Computed Tomography scans, Magnetic Resonance Imaging, and ultrasonography can be used to confirm an FBO diagnosis. The study conducted by Ober and his team found that ultrasounds were the most proficient following CT scans for detecting FBOs [7]. Given that this particular study is confined to the patients and diagnostic tools of BAERC, the conclusions regarding CT scans may not be supported but the implications of ultrasonography can be considered. In the log-linear model used in this study, patients who only have an abdominal x-ray performed to have the greatest likelihood of an FBO diagnosis. Yet, some patients may also receive an ultrasound if there is still a suspicion of FBO yet the findings of the x-ray are inconclusive. As a result, the implications of the study by Ober et al. and this research study may not place the same diagnostic test as the most efficient for FBO, but it can be concluded from the log-linear analysis that there is a strong relationship between FBO and abdominal RGs. The log-linear analysis was then also used to determine if significant relationships exist between dystocia and a particular diagnostic imaging test.

Dystocia is an urgent medical emergency and due to the variation of its cause between each patient, diagnostic imaging tests are significantly valued. By electing an RG to be performed, additional information about the total number in the litter and their position within the mother's body can be revealed. Whereas, with the US, the assessment of fetal health can be revealed through the evaluation of heart rate, positioning, and motion of fetuses [8,9]. Therefore, both radiographs and ultrasounds can be helpful in determining a pregnant patient's current state of health in the event of dystocia but in different aspects. In a review written by Gendler et al., to successfully manage canine dystocia both medically and surgically, it is important to include both RG and US in the diagnostic workup. Both of these tests are needed because ultrasounds

provide an assessment of overall viability of the litter and RGs can provide insight on the probability of successful labor by revealing total litter size, all fetal positions, and possible obstructions in the birth canal [8,9]. This dystocia management protocol was also evident in the data of BAERC patients where almost every single canine dystocia patient received both a special abdominal x-ray and F.A.S.T. ultrasound. Overall, it is imperative that diagnostic imaging tests are performed on a pregnant patient suspected to have dystocia because both tests provide important information about the current health condition of the dam and fetuses. Ultimately, from this research, it can be concluded that for dystocia patients, there is a high diagnostic value when both RG and US are performed thus providing the veterinarian with a full health examination of the dam and her current state of pregnancy.

The specific goals of this research study were to utilize patient files to collect data and to use both qualitative and quantitative analyses to investigate diagnostic imaging in veterinary medicine. The specific aim was to test the hypothesis if a certain diagnostic imaging test was performed, a particular medical outcome was strongly correlated. These relationships would then be valuable to both the veterinarian and client for maximizing diagnostic value and cost efficiency during an emergency visit. As a result, the common medical emergencies such as foreign body object obstruction and dystocia were shown to be strongly associated with abdominal RGs and/or F.A.S.T. ultrasounds as each imaging test provides new or supporting evidence for diagnosis. Therefore, a particular test may be useful for confirming a medical diagnosis but a combination of tests may be equally beneficial in terms of diagnosis as well as creating a potential treatment plan. This statistical model overall provides insight to students and pet owners about the overall likelihood of certain medical diagnoses in relation to the imaging test performed by a veterinarian. The benefit of performing diagnostic imaging tests relevant to the symptoms the patient presents and not just every possible diagnostic available is to minimize the financial component to owners that are needed to accurately confirm a medical diagnosis. Ultimately, the significance of diagnostic imaging and its implications in relation to the diagnostic value and cost efficiencies of imaging tests relative to the owner and veterinarian were investigated and reported.

Ultimately, some changes I would incorporate into this research study would be to collect information from more than 3 years of data to have a greater sample size. I would have recorded more details during data collection about each case such as the type of foreign body object and the reported biopsy results. Furthermore, I think it would have been beneficial to note the breed of each animal to potentially compare the total diagnostic testing cost based on the overall size of the animal or breed disposition. Included with these changes, one future direction would be to compare this data with other emergency hospitals within Pennsylvania or to other states emergency veterinary hospitals. In addition, potentially adding in the comparison of diagnostic value and cost-efficiencies to other diagnostic imaging test types that are available at other veterinary hospitals such as CT scanning and Magnetic Resonance Imaging tests. Fundamentally, diagnostic imaging is a significant tool in veterinary medicine for accurate diagnosis and this work focused on providing the foundation of radiography and ultrasonography in order to understand the relationship between certain imaging tests and medical diagnoses.

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