ABSTRACT

SLIWOWSKA, SANDRA NICOLE. Factors Affecting the Assignment and Use of Pain Scores for Canines Having Cruciate or Hip Surgery in a Veterinary Teaching Hospital (Under the direction of Dr. Kimberly Ange-van Heugten).

Pain is both a sensory and emotional experience that greatly impacts the welfare of an animal. Despite growing awareness and advances in pain management for companion animals, pain is still considered undertreated in veterinary medicine. This undertreatment of pain is attributed to the inability of animals to verbalize pain, our lack of understanding of pain signals and / or lack of consistent quantitative measurements of pain for non-human species. To treat pain, it must be recognized and quantified efficiently and effectively. Pain scales have been developed in an attempt to better quantify pain in animals. However, the use of pain scales is very subjective as it involves the observation of one individual to rate and asses pain. When evaluating dogs, factors influencing subjectivity include physical features of the canine patient such as color of animal, breed, size, age and pre-conceived notions that the veterinarian might already have toward any aspect of the animal. To better quantify pain through the use of scales, biases need to be explored to determine the role they play in assignment of pain scores. To study the interaction between potential biases on the assignment of pain scores in a veterinary teaching hospital, retrospective analyses were performed on 499 canine patients who underwent cruciate or hip surgery. Surgeries performed from January 2013 through July 2018 were evaluated and included tibial-plateau-leveling osteotomy, tibial tubercle osteotomy, tibial tuberosity transposition, total hip replacement, modified maquet procedure and extracapsular stabilizations. Statistical analysis was performed to determine the relationship between the pain scores assigned and canine characteristics including color, breed, age, size, and the type of surgery performed. Additional parameters collected included name of dog, owner city, mileage traveled, duration of

surgery and others but were not used for analysis in this project. Results from this project found that the mean pain score (on a standardized 0-4 scale) given both prior and after these surgical procedures did not exceed a score of 1. The mean pain score assigned before surgery was 0.93 and the mean pain score 6 hours after surgery was 0.84. Of the three most common breeds treated, the American Staffordshire terrier (0.74, 0.75, 0.73 & 0.65) had consistently lower pain scores when compared to the Labrador retriever (0.93, 0.96, 0.93, & 0.92) and German shepherd dog (1.03, 0.92, 0.94 & 1.09) both pre-operation and 6, 12, and 18 hours post-operation respectively. Labrador retrievers had much higher pain scores at 6, 12, and 18 hours post-operation (0.96, 0.93 & 0.92, respectively) compared to all other breeds. Senior dogs were scored significantly higher in pain both pre-op and 18 hours post-op (1.10 & 0.90, respectively) compared to adults (0.89 & 0.75, respectively). At 6, 12 and 18 hours post op, large dogs (0.88, 0.88 & 0.87, respectively) had significantly higher pain scores than small (0.70, 0.74 & 0.70, respectively) and medium (0.82, 0.78 & 0.73, respectively) dogs. Sex and color of dog was shown to have no effect on both pre and post-op pain score assignment. Findings from this project can provide a basis of pain score means for these specific surgeries at this hospital and also the trend in pain scores assignment depending on definite factors. Due to the low overall pain scores, this work may indicate the need for increased training in pain score use. Additionally, further research into possible breed pain score biases via veterinary professional is warranted.

Factors Affecting the Assignment and Use of Pain Scores for Canines Having Cruciate or Hip Surgery in a Veterinary Teaching Hospital

by
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DEDICATION

I would like to dedicate this thesis to my family. Pieshu, which means dog in Polish, is my 23-year-old stuffed Dalmatian. He has been with me ever since my dad bought me him from Costco when I was a little girl. Pieshu is my reminder every night and every morning to never give up on my dreams. He is also my symbol of constant love from my family.

My parents have shaped me into the person I am today. They took a leap of faith to travel away from their home in Poland and start a new life in America. They have instilled all their hardworking characteristics onto me. My parents have always supported me in everything I do. They have never given up on my dreams even when I did. They push me to do my best and remind me of what I am capable of. I thank them for always being a phone call away and being such a great example of hard workers.

I would also like to dedicate this thesis to my sister Julia. I have always wanted to be a good role model and example for her. She was always there for me to make me laugh and make sure I was still the same person regardless of life changes. Without her, I would not know how Princess is doing everyday as she always sends me snapchats of her. For all of these things, I thank her.

Lastly, my biggest dedication goes to my Chihuahua, Princess. I always knew what my dreams were, but Princess really inspired me to never give up on my dreams. She was diagnosed with intervertebral disc disease (IVD) almost 3 years ago. The fear of losing her and the fact that there is no real practical treatment for such a disease really pushed me to make her life better and all dogs who suffer with IVD as well. Being away from her was incredibly tough especially in times where I felt at my lowest. However, even when we are 600 miles away, she is always a constant reminder to me to work even harder and that soon we will be back together.

BIOGRAPHY

Sandra Nicole Sliwowska was born in Rockaway Beach, New York. She grew up and lived in Rockaway her entire life. Sandra loved two things most in her life; dogs and school. Sandra had always succeeded in school and always wanted to perform better than she did previously. She focused much of her time in high school to maintaining her grades above a 95 in each subject. Being that her parents were both born and raised in Poland and spoke fluent Polish, Sandra was also enrolled in Polish school until she was a freshman in high school. Other than being an excellent student, Sandra loved to play sports, basketball in particular. Graduating from Scholars Academy High School on the honor roll she decided to take a leap of faith and leave the amazing state of New York and emerge in the North Carolina culture at NC State University in 2013.

New York City is not known for its agriculture, but it is known for its people. With people come companion animals. Sandra was exposed to dogs and cats from a young age. She always wanted to bring home a new dog every day. When she worked at her local animal hospital and stray or sick animals were looking for a home, she would bring them home only for her mother to say there isn't enough room for another dog. Her first year at NC State was difficult as she had never been to the South and adjusting to the changes in culture and people were very challenging. After her first semester at NC State, Sandra received a position in the animal science department being an office assistant. Although this wasn't the animal experience she was used to, it allowed her to build communication skills and relationships with people within the department. She was involved in a research project her Junior year collecting physiological parameters on beef cattle in two different locations in North Carolina. This exposed her to a new field of animals and got her excited about animal research. After not getting accepted into veterinary school her first round of applying Sandra contacted schools to determine what could make her a better applicant. The consensus was to continue her education. That she did as she was accepted into NC State's Animal Science Master's program. It was during her graduate career that helped Sandra fall in love with people, too. She got her first taste of being a teaching assistant for Dr. Trivedi's undergraduate anatomy and physiology lab. This allowed her to learn how to communicate with others, communicate concepts to students, and work as a team. She then went on to teach for Dr. Trivedi again the following semester and for Dr. Ange-van Heugten in ANS 400 and 105. She will be attending the Royal Veterinary College this Fall to start her lifelong dream of becoming a veterinarian.

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CHAPTER 1: Literature Review

Introduction

Animals play important roles as companions, research subjects, and sources of food. As such, veterinarians have an obligation to protect them from pain and suffering. Pain is a complex multidimensional experience with both sensory and psychological components. The sensory component is how the pain feels, which includes the type, source, and intensity of pain. The psychological and emotional component address how pain makes the animal feel. Pain has been described as any type of actual or potential tissue damage that causes both an unpleasant physical experience and an altered state of mind, generally triggering emotions such as discomfort, sadness and anger (Williams and Craig, 2016). The ability to measure pain in an accurate and dependable manner is essential to meet the growing demand for evidence based veterinary medicine research and to recognize, treat, and manage pain more effectively in animals (Robertson, 2002). Not only is treating pain important from an animal welfare standpoint, but it also reduces morbidity and mortality (Williams and Craig, 2016). Pain management is central to veterinary practice by alleviating pain, improving the health outcomes of patients and enhancing the quality of life of the animal (American Animal Hospital Association, 2011).

The recognition of pain in canines is a very subjective and difficult process. There are situations in which it is obvious to one person that an animal is in pain, such as chronic pain conditions like arthritis, but to another person it might not be so obvious. Color bias research was presented by Lum et al. (2013) evaluating the adoptability, desirability and chances of being euthanized for black colored dogs and cats. Results indicated that black dogs and black cats were found to be the least friendly and the least adoptable while the white cat and yellow dogs were considered the friendliest and most adoptable (Lum et al., 2013).Veterinarians, too, may have biases about certain animals or characteristics of an animal such as breed, color of dog, size of dog, or age of dog. When recognizing pain in dogs, education level of the veterinarian, age of the veterinarian and influence of others such as technicians and students can all play into the decision-making process.

One of the most well-known human biases about dogs is their discrimination regarding different dog breeds. Breed bias is most noticed with "pit-type" dog breeds (Lockwood and Rindy, 1997). American bulldogs, American Staffordshire terriers, bull terriers, English bulldogs, Staffordshire bull terriers, pit bull terriers (and American pit bull terriers) and their mixes are grouped together as "bully" or "pit type" dog breeds (Lockwood and Rindy, 1997). However, most people have difficulty distinguishing among these breeds and breed types (Lockwood and Rindy, 1997). American Staffordshire terrier is one of the most common names reported by owners for "pit-type" dogs as it is the primary one recognized by the American Kennel Club (AKC, American Staffordshire terrier, 2017). Research conducted at animal shelters identified that American pit bull terriers were the most prevalent breed available for adoption in shelters (Gunter et al., 2018). Negative perceptions and stereotypes of pit bull type dogs and their associations as being an aggressive breed have led to them being deemed less adoptable (Lockwood and Rindy, 1997). Inconsistencies in identification of the breeds by owners and animal professionals have also contributed to the high shelter population of pit type dogs. Research presented at a shelter medicine conference identified that 50% of dogs labeled as a pit bull actually lacked the DNA of the pit bull breed (Olson et al., 2011).

The objectives of this literature review are 1) review the current knowledge on pain, pain management and pain scoring in domestic animals, 2) discuss the trends and relationships of human medicine to veterinary medicine, 3) outline the current stereotypes and biases present in the field of veterinary medicine, most specifically in canines and how they impact pain management, 4) discuss the physical factors affecting pain judgements made by veterinarians in canine patients and 6) discuss canine pain scoring systems and how they are utilized in canine pain identification.

Canine Pain – Definition and Importance

Pain has been recognized as having various harmful effects on the body of all living creatures. (Williams and Craig, 2016). The definition of pain has been updated to a distressing experience associated with actual or potential tissue damage with sensory, emotional, cognitive and social components (Williams and Craig, 2016). Pain is complex and multi-dimensional as it has two main components: sensory and emotional. Pain is not just the physical pain that is felt (sensory) but also how it makes one feel emotionally (Robertson, 2002). Pain, however, is not always bad, as it is the body's way of letting one know that something is not right. As a result of pain, behaviors are changed in order to avoid further pain and not make the situation worse.

Prevention and management of pain is fundamental to the fields of human and veterinary medicine. Identifying and treating pain are important in order to decide on what the next step of care will be for all patients. Pain can cause an increase in stress responses to injuries, metabolic changes such as increases in body temperature and increases in heart rate. Consequently, the timeline for recovery may increase (Williams and Craig, 2016). Improper identification and management of pain can result in peripheral and central sensitization, which is a condition in which the nervous system is in a constant state of high reactivity, resulting in exaggerated painful conditions (Nikolajsen et al., 2006). Central sensitization underlies the relationship between the intensity of noxious stimulus and the perception of pain (Baron et al., 2013). This can result in a patient having more pain with less stimulation, causing painful situations to be even more painful but also causing general touch to be painful as well (Baron et al., 2013). Pain can either be classified as acute pain or chronic pain (Payne, 2000). Acute pain is pain that lasts for a short period of time, usually has a well-defined time course and is normally caused by a specific injury (Payne, 2000). Chronic pain lasts much longer, at least 12 weeks, but sometimes can last for a lifetime and is often caused by an underlying condition. (Baron et al., 2013) Ultimately, pain of any level causes changes in the everyday activities and life of individuals. There are many causes of physical pain such as, but not limited to, trauma, surgery, chronic illness, or inflammatory conditions (Baron et al., 2013).

Pain recognition and management is also important in veterinary medicine. In 2001 the American Veterinary Medical Association (AVMA) hosted an Animal Welfare forum in which 100 veterinarians attended with a goal of better understanding pain management in companion animals. Then in 2007, the American Animal Hospital Association (AAHA) and the American Association of Feline Practitioners (AAFP) worked together to create the AAHA/AAFP Pain Management Guidelines for Dogs and Cats. The purpose of the guide was to provide information to pet owners on how to correctly identify painful situations and conditions, and what the next steps are after identification (Hellyer et al., 2007). The creation of this guide shows the forward progress toward recognizing pain and improving animal welfare. The AVMA has also recognized the importance of animal welfare and pain management by including anesthesia, pain awareness, and patient welfare in their nine competencies expected of all graduating veterinary students (Hellyer et al., 2007). The expectation of all graduating veterinarians to be able to manage pain in animals shows the importance of the recognition of pain as a serious health concern.

There is a significant difference between determining pain in humans and in non-human animals. This difference is the ability of most humans to verbally communicate their pain with words while non-human animals cannot physically speak words. Animals do, however, communicate through their behavior. By necessity, veterinarians rely on parameters such as behavior, clinical observations, details from the owners, and developed means of pain assessment such as pain scales to determine the severity of pain felt in an animal (Reid et al. 2013).

Controlling pain is one of the most important aspects of patient management in the field of medicine (Gaynor, 2008). Pain judgments are the basis for pain management and can vary between different individuals. Pain judgments are decisions made by a veterinary professional, such as a veterinarian or veterinary technician, based on the perceived pain status of an animal. Incorrect identification of pain in a patient can lead to serious problems: inadequate pain control is associated with depressed immune function, increased recovery time, and significant stress to the patient (Gaynor, 2008; Hoffman et al., 2016). Patients with a previous history of illness are thought to be prone to higher levels of pain, making it important to treat such patients with the proper analgesics and to maximize their chances of recovery (Gaynor, 2008).

There have been a number of increased efforts in both human and veterinary medicine to place more emphasis on pain management. In a 2006 report by the US Department of Health and Human Services, it was reported that pain, both chronic and acute, affects more Americans than does diabetes, heart disease and cancer combined (National Center for Health Statistics, 2006). There has especially been an emphasis on more medical training in pain management for human medicine. In 2011, the Institute of Medicine published a report to change the way pain is viewed and treated through a cultural transformation of medical students (Institute of Medicine, 2011).

Recommendations included standardizing pain management content in the curriculum of medical and nursing schools, providing more opportunities to learn about pain such as seminars and through interprofessional settings like work related events or conferences (IASP, 2014). The International Association for the Study of Pain (IASP) has now implemented four core components of pain into medical school curriculum which include the multidimensional nature of pain, pain assessment and measurement, management of pain and pain in specific clinical conditions. (IASP, 2014). In 1999, the Association of American Medical Colleges listed eleven learning objectives that they wanted a “skilled physician” to obtain (Association of American Medical Colleges, 1998) One of those objectives was for the physician to have the knowledge about relieving pain and suffering from a patient (Association of American Medical Colleges, 1998). Although this is stated as a learning objective, medical schools are not always reliably providing physicians with the skills needed to complete such a goal (Turner and Weiner, 2002). For example, there is evidence that older adults with advanced cancers are commonly under-prescribed pain medication; a trend associated with a lack of training and knowledge of physicians on how to prescribe pain medication (Charap, 1978; Cleeland et al., 1994; Balducci et al., 2013).

One of the biggest factors affecting pain judgments are physical characteristics (Tait et al., 2009) In human medicine there is a known racial pain stereotype between white and black individuals (Hirsh et al., 2013). Although clinical guidelines in human health indicate that patient demographic characteristics, such as race, should not dictate decisions made about pain management, studies have shown that pain care does vary between white and black patients as well as between white and Hispanic patients (Hirsh et al., 2013). This indicates that people within these two demographics, Hispanic and black, are sometimes not being prescribed analgesics or medications properly based on their preexisting conditions. The stereotype being enforced is that the typical white person is more sensitive to pain compared to the typical African American or Hispanic person (Wandner et al., 2012). Hispanic and African American individuals were ranked the lowest on sensitivity to pain compared to white and Asian individuals by students on a college campus who completed the survey (Wandner et al., 2012).

The American Medical Association (AMA) Journal of Ethics indicates that racial bias in pain treatment is common in all aspects of the health care system, from both the prescribing physician side and the insurance decisions (Drwecki, 2015). It has been shown that emergency room patients already receive insufficient and inappropriate analgesia and African Americans and Hispanics are even less likely to receive the appropriate analgesics (Todd et al., 2000). African Americans have also been shown to receive lower quality pain treatment by being prescribed lower amounts of analgesics and decreased efforts to reduce mortality and morbidity compared to white individuals (Todd et al., 2000). This effect is documented even when the insurance is identical to patients of other races (Hostetler et al., 2002). The most recent findings of racial bias in human medicine have been in children. Johnson et al. (2017) showed that physicians have the same implicit bias toward African American children as they do to black adults. Meaning that children are exposed to the same racial bias and results that come from their health care providers as adults.

Evidence is also present that gender affects decisions made by clinicians. In a study evaluating the effects of socioeconomical factors on the administration of analgesia, it was found that women were less likely to receive analgesics for extremity injuries such as a suspected fracture, dislocation, or laceration to the upper or lower extremity when compared to men (Michael et al., 2007). Such results show that females have a risk factor of not receiving acute pain treatment in the prehospital hospital setting (emergency medical care), meaning sex affects the way a person is medically treated.

Animal Species, Canine Color and Canine Breed Biases by Humans

Just as there have been trends seen in bias in human medicine, there are similar trends in veterinary medicine. The main type of bias seen is cognitive or implicit bias, which is the concept that human nature can cloud one's judgement and decision making (Dacey, 2017). Decisions made by humans rely heavily on past experiences, knowledge, skills, stereotypes, upbringing and society. When decisions are made with clouded minds, this ultimately can affect the health and safety of the patient being treated. The biggest factor influencing decisions being made by veterinary health professionals is their perception of situations and perceptions of an individual animal (Sevillano and Fiske, 2016). Perception plays a role in categorizing specific animal groups (companion animals, predators, prey and pest) into competence categories, which describes how able an animal is able to do a task successfully, and warmth categories that describe if someone feels warmly about that specific animal (Sevillano and Fiske, 2016). Predators, such as wolves, were ranked low warmth and high competence while prey animals, such as cows, were ranked high warmth and low competence (Sevillano and Fiske, 2016). Companion animals were ranked both high warmth and high competence. This research showed that animals are perceived differently just by species appearances and roles in society (Sevillano and Fiske, 2016). The second part of Sevillano and Fiske's (2016) work showed the emotions associated with these four animal groups. Each group was associated with a different emotion perceived by the human as well as different behaviors (Sevillano and Fiske, 2016). This showed that animals and humans were matched with each other based on perception, such as companion animals being put on the same level as humans while prey animals were not. Reasons for this may be perhaps that humans lack social responsibility toward animals that we eat for example. This also may be due to underlying effects like anthropomorphism in our companion animals compared to other animal groups (Sevillano and Fiske, 2016). Anthropomorphism is a result of more of a focus on animal welfare. For example, lobby groups trying to have pet "owners" legally be changed to "pet guardians" shows just how attached humans are to their animals and how simply changing words has such powerful effects as a result (Butterfield et al., 2012) Same effects are seen when trying to assign human like qualities to dogs to try to improve how they are treated and looked at (Butterfield et al., 2012).

Bias is not only seen in the treatment of different animal species but also within a companion animal species, such as dogs, in animal shelters. When potential adopters are looking at adoptable dogs at an animal shelter, there are a lot of factors that play into whether or not the dog is deemed adoptable. Trainability of a dog was a factor explored in one study to determine if training a dog at the shelter would make them more adoptable than their appearance (Protopopova and Wynne, 2016). In this study, it was hypothesized that the demeanor of shelter dogs affects their adoption rates. They had one group of dogs that were trained to do basic commands, such as sit and stay, while a second group did not go through training. It was found that training had no effect on the rate of adoption in shelter dogs but rather it all depended on the morphology of the dog, i.e. color, shape and breed type; potential adopters preferred small, young, long coat and lighter colored dogs (Protopopova and Wynne, 2016).

Further evidence that dogs are also judged on phenotypic characteristics has been shown in a study of "big black dog syndrome" as defined Sinski et al., (2016). This syndrome is termed as such because big dogs, black dogs, and big black dogs all have lower rates of adoption which impacts their rate of being euthanized (Leonard, 2001). Sinski et al.'s (2016) research focused on whether having a black coat would affect the likelihood of adoption versus euthanasia. Results indicated that black-colored dogs were 23.8% less likely to be adopted than any other colored dog (Sinski et al., 2016). However, results also show that the black dog syndrome theory is not entirely correct but rather breed, size and purebred status were better indicators of whether a dog would get adopted (Sinski et al., 2016). Meaning that adopters were likely to adopt a dog based on the breed and size of dog and not as much on what color they are. When it comes to a specific breed, there are sometimes specific colors the breeds can be found in, so in some cases picking a breed comes with picking a color. For example, the most popular dog in the United States, the Labrador retriever, comes in 3 colors: yellow, chocolate (brown), and black. Historically, black was the most common color in Labrador retrievers (AKC. Labrador retriever Dog Breed Information, 2017; AKC. Most Popular Dog Breeds of 2018, 2019). Euthanasia rate and black dog adoptability were explored in a study focused on an open intake shelter, an animal shelter that takes in all dogs regardless of any physical or behavioral characteristics, versus a selective intake shelter, which can pick and choose dogs based on coat color, size, space availability and temperament (Svoboda and Hoffman, 2015). After analysis of the data, it was identified that color of dog was not the best indicator of length of stay in either shelter, but rather age and breed were much better indicators on the outcome of the dogs stay in the shelter (Svoboda and Hoffman, 2015).

Thus, available research indicates that breed is the best indicator of the potential bias present in adoption rates of dogs (Sinski et al., 2016; Svoboda and Hoffman, 2015). The most recognizable breed type bias is against the Pitbull. "Pitbull" and "bully breed" are not actual dog breeds as many believe, but generic terms assigned to all dogs within breeds such as the

American and English bulldog, Staffordshire bull terriers, American and British Staffordshire terriers, American Pit Bull terriers and any dog that has any mix of these breeds (Lockwood and Rindy, 1997). Pitbull's are the most prevalent dog breed available for adoption in public shelters, but are often discriminated against by adopters, apartment complex management, and by the public when walking around (Gunter, et al., 2016; Protopopova et al., 2012). Animal shelters may be contributing to breed bias by accidentally or purposely mislabeling dogs as one breed type versus another such as labeling Labrador retriever mixes as American Staffordshires and vice versa (Voith et al., 2009). A study was conducted that used DNA kits, the MARS Wisdom Panel™ (Lincoln, NE), to correctly identify the dog breed listed on their adoption profiles (Voith et al., 2009). From the results of the study, only 4 out of 20 dogs were correctly identified for their main breed by the shelter staff. However, the accuracy of the test must also be taken into account as not all breeds will be correctly identified by the DNA panel. If one shelter could misidentify so many breeds, it likely means a lot of dogs are getting mislabeled. Research using the MARS Wisdom Panel™ showed inconsistent identification of pit bull type dogs, and therefore, showed the disconnect between shelter staff who were identifying the animals and the DNA results (Olson et al., 2015). Much of this bias is not intentional but is just based on the staff's previous knowledge and judgment of dogs and dog breeds (Olson et al., 2015). This, however, is the baseline of how many biases get formulated. Previous research has indicated that pit bull type dogs were 81.4% less likely to be adopted compared with Labrador retrievers (Sinski et al., 2016). It was identified through a different study that bully type breeds had a longer length of stay at shelters, an average of 27 days, than most younger dogs or other dog breeds, which had an average stay of 10 days (Svoboda and Hoffman, 2015). Breed bias was also evaluated at two selective intake shelters in a rural part of New York (Brown et al., 2013). Analysis of the data showed that coat color did not influence the stay of a dog in a shelter but rather breed (Brown et al., 2013). Dogs identified as a "bully" breed had the second longest length of stay in the shelters at an average of 49 days, right behind the "guard dog" breeds, which had an average length of stay of 60 days and include breeds such as the Doberman Pinscher and Akita (AKC. Best Guard Dogs). The "giant" group had the shortest length of stay at 20.8 days on average and would include dog breeds such as Saint Bernard's and mastiffs (Brown et al., 2013). By realizing that such biases are present and making animal professionals aware of them, the welfare of shelter dogs and dogs in veterinary hospitals can be enhanced.

Biases and Factors Affecting Analgesic Prescription and Pain Scoring

In 1993, postoperative patients at a NC State University veterinary hospital were evaluated retrospectively by Hansen and Hardie, to determine how the presence of pain was evaluated and how analgesics were prescribed (Hansen and Hardie, 1993). This was accomplished through determining the frequency of analgesic prescription and use in postoperative pain in dogs. The operative procedures included in this analysis were thoracotomy, limb amputation, limb salvage, bone tumors, humeral fractures, cervical vertebral instability and cervical vertebral malformation. A total of 243 dogs undergoing one of the aforementioned surgeries were included in analysis (Hansen and Hardie, 1993). It was found that 40% of the dogs were under the influence of an analgesic at any time post operatively and most analgesic orders, if written, were to be given as needed. This indicates the reluctance of surgeons to prescribe analgesics during this time period (1983- 1989) where there was less information available as to if animals felt pain at all or how to treat them (Hansen and Hardie, 1993). One parameter not measured in this study was pain scores (Hansen and Hardie, 1993) as these were not available. It was also noted that the interaction between dog breed and color were not analyzed but were acknowledged as potential factors affecting analgesic prescription.

Other factors can play into whether a veterinarian prescribes analgesics or not to an animal. For example, it was identified that females and most recently graduated veterinarians were more likely to administer analgesics compared to males (Hunt et al., 2015). This doesn't come as much surprise as females are dominating the veterinary field currently over males, with 69,908 out of 113,394 total veterinarians in the US in 2018 being females (American Veterinary Medical Association (AVMA) Market Research Statistics, 2018). The AVMA put out a data report in 2014 about the statistics of veterinary students and veterinarians which reported that in 1970 the percent of men enrolled in US Veterinary Colleges was 89% and in 2014 was 20.4%, which is a huge drop. In 1970, the percentage of women enrolled was 11% and in 2014 was 79.6% (AVMA. Market Research Statistics, 2018; Association of American Veterinary Medical Colleges. Annual Data Report, 2014). When it concerns assigning pain scores to dogs and cats following surgery, female veterinarians were more likely to assign higher pain score than the males (Williams et al., 2011). Female veterinarians ranked postoperative (PO) pain more severe than their male counterparts (Beswick et al., 2016). More recently graduated veterinarians are less experienced than veterinarians who have been in the field, contributing to the discrepancies between analgesic prescription between the two groups (Hunt et al., 2015).

Graduation year of veterinary students has been shown to impact the use of analgesics and perception about pain in animals (Weber et al., 2012). A recent study asked veterinarians to rank how painful specific procedures were using a 0-10 scale (0 = no pain and 10 = worst pain imaginable). Specifically, for cranial cruciate surgery, recent graduates (<10 years) assigned a median pain score of 6 at 48 hours post-surgery while older graduates (over 20 years) assigned a pain score of 3 (Weber et al., 2012). This is consistent with both Hunt et al. (2015) and Hugonnard et al. (2004) findings in which the majority of recent veterinary school graduates felt comfortable with their education on pain and analgesics prescription. These differences attributed by graduation year may be a result of more recent medical advances and providing current faculty with a better understanding of pain physiology and analgesia, which is then taught to the student population (Weber et al., 2012). A study was conducted to explore the relationship between pain scoring in students still in veterinary school and veterinarians who were enrolled in residency training, PhD programs or were diplomates of the American College of Veterinary Anesthesia and Analgesics (Doodnaught et al., 2017). It was identified that graduated veterinarians and current veterinary students were pain scoring the same dog differently although they were provided with the same instruments; current students were more likely to prescribe rescue analgesics for a dog compared with the veterinarians (Doodnaught et al., 2017).

Anthropomorphism is the interpretation of what is not human in terms of human characteristics. (Merriam-Webster Dictionary). Anthropomorphizing our pets has led humans to have notions that pets are on the same level as people when it comes to pain and emotional feelings (Sevillano and Fiske, 2016). Such factors contribute to the human-animal relationship and the way animals are treated. Interestingly, it was found that dog owners were more likely to anthropomorphize their pet compared to cat owners as dogs were found to resemble infantile characteristics more as a result of domestication (Szasz, 1968; Bahlig-Pieren and Turner, 1999). People's attitudes to companion animals such as dogs, are usually preexisting and result from how the dog behaves toward the human, which then leads to projective anthropomorphizing by the owner. In addition to anthropomorphism, empathy is an emotion that is an important influencing factor in the human-dog relationship (Ellingsen et al., 2010). Empathy is a response that is generated from recognition of another's emotions or behavior and is similar to what the other person is feeling. Both anthropomorphism and empathy play a role in animal welfare as it contributes to the identification of pain or a painful situation by both the owner and the veterinarian. Research was conducted to determine the relationship between three factors, empathy, attitudes and perceived animal pain, and how it relates to owners rating pain (Ellingsen et al., 2010). A Pain Assessment instrument was utilized in which participants were exposed to 17 photos of dogs in painful situations and asked to rank their pain on a Visual Analogue Scale. It was found that empathy was the best predictor of how people rated pain in dogs as empathy elicited the fastest affective response when viewing an animal in pain. It was also found that gender of dog owner was one of the most stable factors influencing empathy, attitudes or pain rating. The pain assessment scales testing for both empathy and attitudes indicated that the levels of both were highly involved with pain assessment. However, when the correlation between both factors were conducted, it showed that there may be other factors playing a role when assessing for pain such as education level, background with animals, and biases (Ellingsen et al., 2010). A drawback in the study was that an entire population group of people who did not own dogs were not included in the survey, which could have resulted in different effects on empathy toward pain.

Trends in Analgesic Prescription and Administration in Veterinary Medicine

Analgesic prescriptions were not always a common practice in veterinary medicine (Rosenblum et al., 2008). From 1996-1997, in the UK, veterinarians were very unlikely to administer analgesics to any animals after routine surgeries, such as castration (Hunt et al., 2015). A questionnaire was given to determine the attitudes and prescription of perioperative analgesics of veterinarians in the spring of 2013 (Hunt et al., 2015). Results showed that 98% of respondents were giving non-steroidal anti-inflammatory drugs (NSAIDS) to cats and dogs following routine surgeries such as castration and lump removal (Hunt et al., 2015) Thus, results indicate that more veterinarians in the UK are administering analgesics compared to previous years.

Oligoanalgesia is defined as the failure to provide analgesia to patients experiencing pain (Simon et al., 2017). Reasons for not administering pain medicine in human practice are due to the lack of vocalization, procedures that are not deemed “painful”, improper time allocation to the patient and patients who do not require immediate attention (Simon et al., 2017). However, it was recently demonstrated that the main factors for the lack of pain medicine administration were age, race, gender and ethnicity of the patient (Simon et al., 2017). The prevalence of pain in postoperative dogs was evaluated at the University of Georgia veterinary teaching hospital (Morman and Hofmeister, 2013). Veterinary students evaluated pain in dogs after surgery through the use of three different pain scoring systems and identified that only 22% of dogs were considered to be painful (Morman and Hofmeister, 2013). This number is low and indicates that pain reported is likely much lower than the pain actually experienced by the dog. Hence, postoperative pain may not be identified correctly, which could be leading to a multitude of consequences to the animal. Similar trends were seen at The Ohio State University Veterinary Teaching Hospital with outpatients, where only 57 out of 231 dogs with pain were treated with analgesics (Muir et al., 2004). Such low numbers of animals potentially misidentified and treated (or not treated) with analgesics gives insight that something else must be playing a role into which animals will receive analgesics and which will not. These studies were conducted at veterinary teaching hospitals, so it could be student error as they are actively learning how to properly identify pain. It could also be that pain and painful situations are not being taught properly, resulting in such low numbers.

The perioperative period is defined as the period that the animal is going through their surgical procedure, which includes administration, anesthesia, surgery and recovery. There are many different drugs and medications that animals can receive during this period. A review article by Gurney states that all surgical procedures include a noxious stimulus, that is painful in an awake animal (Gurney, 2012). Based on that, all animals undergoing surgical procedures should be provided with multi-modal analgesia. Multi-modal analgesia combines at least two different analgesics that utilize two different pathways to maximize the overall analgesic effect at lower doses (Gurney, 2012). The concept of multimodal analgesia is that pain can be better managed by giving several different drugs at the same time to target different parts of the nociceptive system, which is the nervous system's response center to any physical, chemical or thermal stimulus (MacFarlane, 2018). The use of perioperative opioid's during routine surgery was explored in a recent study. Results showed that 90.5% of all respondents of a survey prescribed perioperative opioids to dogs undergoing routine surgery (Hunt et al., 2015). This same study showed that a higher proportion (78.4%) of female veterinary surgeons prescribed postoperative NSAIDS for routine surgeries over male veterinary surgeons.

Opioids are the traditional drug used for perioperative analgesia and play a vital role in managing pain (MacFarlane, 2018). Opioids are one of the most effective drugs for managing acute pain as well as managing some chronic pain cases (MacFarlane, 2018). Full μ-opioid agonists, which activate the opioid receptors in the brain resulting in full opioid effects, are the most effective analgesics of this class in most species. A range of full μ-agonists exist with differing pharmacokinetic properties and effects (MacFarlane, 2018). As long as the concentrations of the analgesics are kept constant the effect is expected to be the same. For example, fentanyl is not a more effective analgesic than methadone, but it is more potent, hence an increased concentration of methadone will have a stronger effect (MacFarlane, 2018). Veterinarians have to understand the chemistry and pathways behind these drugs to understand their modes of action to be prepared to address any adverse effects that might result from the drug or drug interactions (Epstein et al., 2015). For a patient that is undergoing major surgery, the AAHA recommends that the surgeon choose from a few strategies which include periodic readministration of opioids, constant rate infusions, or long-acting formulations such as a fentanyl patch (Epstein et al., 2015). There are two routes to applying analgesic dosing to a patient (MacFarlane, 2018). The first is through pain scoring which allows for a more personalized type of analgesics approach by only prescribing analgesics if pain is present depending on the individual patient (MacFarlane, 2018). The second is through the blanket approach which is when a specific type of analgesic is prescribed to be given every "x" amount of time (MacFarlane, 2018). The issue with the blanket approach is that it is not personalized to each individual patient but rather applied universally throughout as well as possible over prescription of analgesic (MacFarlane, 2018).

Non-steroidal anti-inflammatory drugs (NSAIDS) are another class of drug commonly used for perioperative analgesia. NSAIDS play an important role postoperatively and are given pre- or intraoperatively in order to maximize their effectiveness (MacFarlane, 2018). However, there are some well-known adverse effects associated with the use of NSAIDS, biggest being gastrointestinal toxicity (Epstein et al., 2015). The most common signs of toxicity in dogs include vomiting, diarrhea and a lack of appetite (Epstein et al., 2015). This is important to know for owners so that they can monitor their animal to see if they have developed signs of toxicity after their surgical procedure or if the side effects complicate recovery.

The History and Use of Animal Pain Scales

One of the main reasons that veterinarians do not administer analgesics to animals in pain is the difficulty to identify and assess what a painful situation actually is (AAHA, 2011). Since animals are nonverbal and cannot tell a human about the presence of pain in words, pain recognition and assessment are in the hands of veterinarians. It is now accepted that the most accurate method for evaluating pain in animals is not by physiological parameters but rather by behavior (AAHA, 2011). Therefore, it is vital to have valid and reliable indicators of pain, to allow for better treatment and management of all domestic and non-domestic animals. One of these indicators of pain is pain scoring, which is considered the "fourth vital sign" after temperature, pulse and respiration (AAHA, 2011).

Charles Darwin noted that non-humans were capable of expressing emotions, including pain, through facial expressions and body language (Langford et al., 2010). Pain assessment by analyzing the facial expressions of animals has been reported for different species of animals including both laboratory and farm animals (Langford et al., 2010). Langford et al. (2010) were some of the first who developed a system in which pain could be detected and ranked on a scale by interpreting facial expressions in laboratory mice. In development of the Mouse Grimace Scale, five facial features termed action units were identified; these included orbital tightening, nose bulge, cheek bulge, ears pulled apart, and whisker movement in any direction from the baseline (Langford et al., 2010). Three of these action units are identical to what is seen in humans and what was originally observed by Darwin. Similarly, the Rat Grimace Scale (RGS) was developed by Sotocinal et al. (2011) and both scales demonstrated high accuracy, reliability and validity. As a result of the Mouse Grimace Scale being developed, Grimace Scales were developed for other laboratory animals and domestic animals.

Animals that are used in a laboratory or on a farm need to be identified from one another. This is usually accomplished through ear tagging or tattooing. This can be a painful procedure for the animals, therefore a way to identify the animals in pain from not only ear tagging but any painful situation was developed. Following the development of the Mouse Grimace Scale, a Rabbit Grimace Scale (RbtGS) was developed by Keating et al. (2012) and the same facial recognition units that were used in rodents, were applied to rabbits. The RbtGS showed to have over 83.6% accuracy in identifying overall global pain in rabbits (Keating et al., 2012). The RbtGS can now be applied to rabbits used in laboratory testing when they are having their ears tagged or tattooed as well as determining how much pain they are experiencing when they are going through testing, for example testing new drugs. Having such scales can help in both identifying sources of pain and how to treat pain in laboratory animals, ultimately helping to improve animal welfare (Keating et al., 2012).

A Grimace Scale has also been developed for sheep, termed the Sheep Pain Facial Expression Scale (SPFES) (McLennan et al., 2016). Some of the more painful conditions seen in sheep are conditions such as foot rot, a condition which causes the foot to rot away, or mastitis, inflammation of the udder usually caused by a bacterial infection (Häger et al., 2017; McLennan et al., 2016). Both conditions are sometimes seen in large flocks on farm settings. Foot rot is considered to be a serious health problem in sheep flocks, with over 21% of producers in Virginia agreeing on the health risk to sheep (Whittier and Umberger, 2009). Controlling foot rot in all hooved domestic farm animals can save producers money and resources. Foot rot can cause populations of animals to decline and suffer, which can lead to loss of profit. When foot rot becomes a problem on the farm it takes great effort and labor from individuals to control and eliminate the problem. The SPFES also follows five action units very similar to that of the MGS, which include orbital tightening, cheek tightening, ear posture, lip and jaw profile, and nostril shape (McLennan et al., 2016). The SPFES has been deemed successful in assessing postoperative pain of sheep following an osteotomy (Häger et al., 2017). Sheep used in a research study were found to have higher SPFES scores compared to baseline control sheep and the SPFES was higher than the clinical scoring scale, which utilizes physiological parameters (Hager et al., 2017). This indicates the SPFES is a much more robust scoring method (Häger et al., 2017). It has been indicated that a sheep's ear position also determines their pain status (Guesgen et al., 2016). It was determined that ears pointed forward indicated a negative experience, which is an indicator of pain (Guesgen et al., 2016). This method of monitoring ear position also takes into account the behavior of the animal, is noninvasive and relatively simple to conduct. Development of this pain scoring system where pain can be assessed early will allow managers to treat animals faster and potentially diagnosis diseases earlier.

A Horse Grimace Scale (HGS) has also recently been developed as a result of horses undergoing routine castration so frequently without the true recognition of pain (Costa et al., 2014). Although not studied much in horses, it has been shown in other species that animals experience pain and discomfort following routine castration (Llamas et al., 2008). Researchers have noted that castration has been shown to cause pain for several days after the initial procedure (Love et al., 2009; Massen and Gerhards, 2009; Sanz et al., 2009). However, it is only reported that only 36.9% of horses received any type of analgesic after the procedure (Todd et al., 2000). The current attempts at creating horse pain scales have all involved behavioral actions rather than physiological measures such as temperature, pulse and respiration, as physiological measures alone are not good indicators for pain (Price et al., 2003). Gleerup and Lindegaard (2016) conducted a study to determine the behaviors in horses that are associated with induced acute pain. Pain was induced by using a noxious stimulus or application of topical capsaicin. Gleerup and Lindegaard, (2016) noted that both stimuli resulted in painful behaviors. This included an increase in distance between the ears as a result of the ears dropping down, tightening of the muscles around the eyes which results in an angled eye and eye stare, and dilated nostrils (Gleerup and Lindegaard, 2016). These features, especially the ear distance and rotation, are consistent with what was seen in the mouse grimace scale developed by Langford et al. (2010). One of the biggest threats to equine health is the occurrence of laminitis. Laminitis or founder occurs when the laminae of the hoof is inflamed causing extreme pain to the horse, which could result in inability of the horse to stand (Costa et al., 2016). The Horse Grimace Scale has been deemed successful in determining the pain levels caused by laminitis in horses according to recent findings (Costa et al., 2016). The reason for such success with the HGS is because this system is used to evaluate facial expressions rather than when the animal is moving. The previous system that was commonly used to assess laminitis pain in horses was the Obel grading system, which requires the horse to walk and trot, which could ultimately cause more pain (Costa et al., 2016). Findings from the development of horse pain scales have shown that facial expressions and behavior can be used as a successful tool to identify pain and painful situations. If pain cannot be detected in domestic animals, then animals will suffer more, ultimately compromising their health and ability to survive.

Pain management is a huge area of concern in both dairy and beef cattle. As with all other species, inconsistent identification of pain has led to inconsistent analgesic prescription

(Flecknell, 2008). Using physiological parameters to identify pain has been inconsistent and inaccurate as many factors such as stress and environment can play a role in those values (Hansen, 1997). Therefore, relying on behavior to determine pain has been a better indicator to use and has been used in castration surgeries in cattle and other domestic species (Pritchett et al., 2003). Cattle are stoic animals, meaning they do not show obvious pain behaviors (Gleerup and Lindegaard, 2016). However, as seen with other stoic species such as horses and rodents, a Grimace scale has been successful in establishing pain. A cattle pain scale that relies on facial features has not yet been created, but rather a scale that relies on changes in behavior and overall body features has been developed (O'Callaghan et al., 2003). These include crouching, arched back, low head position, vocalization, teeth grinding and changes in social behavior (O'Callaghan et al., 2003). A Cow Pain Scale was developed based on previous behavioral findings found in horses and rodents which included lowered head position, lowering of the ears, altered facial expressions and back arching (Gleerup and Lindegaard., 2016). Development of the Cow Pain Scale has shown to be useful to animals under constant human interaction, such as a dairy farm, and to clinically identify pain.

Development of such pain scales for the use in farm settings is useful for both the animal and the producer. Animal welfare awareness has increased the importance of pain management in livestock. Work by Dr. Temple Grandin has shown that livestock animals experience emotions such as pain and highlights the increased importance of animal welfare (Grandin, 2013). Having pain scales designed for use in farm animals now allows farmers to identify animals that might be suffering from pain. Farmers being better in tune with their animals allows for the animals to be managed better and live a better life. If animals are healthier then farmers can produce more and higher quality products.

Types of Pain Scales in Canines

Pain scoring is a very subjective process resulting in variability between observers. Having relevant clinical experience is an effective way to become accustomed with painful situations and how animals react to pain differently. Although there is some variability, pain scales can be useful in identifying pain in canines. Having a pain scoring mechanism in use in clinical settings can be used as an indicator of analgesic need (Holton et al., 2001). A pain scale used in small animal practices is the Glasgow Composite Measure Pain Scale (CMPS). This behavior-based scale was developed by Holton et al. (2001) and is primarily used for canines in acute postoperative pain. It is a structured questionnaire completed by an observer following a standard protocol which includes assessment of all behaviors, interactions with the animal and clinical observations (Reid et al., 2007). The questionnaire consists of seven behavioral categories which include posture, activity, vocalization, attention to wound or painful area, demeanor, mobility and response to touch (Holton et al., 2001). Holton et al. (2001) provides each category listed with a definition so that each person using the scale has the same idea of what each category entails, allowing for less subjectivity. Within each of these categories are a group of words from which the observer can choose in each category which best describes the dog's behavior (Reid et al., 2007). The CMPS is unique in that it uses psychometric principles, which are well established in human medicine, for the measurement of complex and intangible constructs such as pain and quality of life (Reid et al., 2007). A short form of the Glasgow scale has been developed for use in a clinical setting where time is more limited. The short form allows the veterinarian to do a few things including look at the animal and select the words that best describe the animal, put a lead on the animal and describe how it rises and walks, describe the wound, and give an overall assessment of the animal (Reid et al., 2007). All of these are accomplished by selecting the word that best describes the animal in that specific section and assigning it a number. Once all the words are circled the overall pain scale is determined by the sum of all the sections with a maximum score for a CMPS of 24. Benefits of the CMPS are its descriptive words which allow for more details to be known about the pain symptoms. Due to such descriptors, the CMPS requires more time to complete, which ultimately limits its success in clinical practice (Reid et al., 2007).

Different approaches to pain scoring come from much simpler scales, which involve number scores as well as simpler and shorter descriptive words. These pain scales have developed as adaptations from human medicine. The simple descriptive scale (SDS) asks the scorer to choose a statement, ranging from "no pain" to "very severe pain", that most accurately describes the level of pain experienced by the individual being scored (Holton et al., 1998). Each statement corresponds with a number which can then be used to determine the level of pain in the animal from a scale of 0-4 with 0 meaning no pain and 4 being very severe pain. Figure 1 provides an example of these simpler scales (Fig 1). The SDS is very similar to what is seen in pediatrician's offices with smiley/ sad faces showing how a child feels, termed the Wong- Baker faces pain Scale (Colorado State University, 2006). The equivalent of the Wong-Baker Scale is the SDS developed by Colorado State University, which utilizes pictures of dogs for each level of pain from 0 to 4 (Garra et al., 2010). The visual analogue scale (VAS) is another scoring system, in which a 10cm line ranges from 0cm indicates no pain and 10cm indicates the worst pain possible (Holton et al., 1998). The scorer / observer will then put a mark along the line where they feel the patient's pain lies relative to the extremes (Holton et al., 1998). Figure 1 also outlines the use of the VAS. The Numerical Rating Scale (NRS) is a simple scale and similar to VAS but instead it utilizes the discrete numbers 0-10 with 0 being the least amount of pain and

10 being the worst possible pain (Holton et al., 1998). The difference between the VAS and NRS is that the NRS only allows for whole numbers to be used while with the VAS you can use numbers in between two whole numbers (Holton et al., 1998). The VAS allows for a more accurate score to be assigned by being able to use the entire scale. All the scales have different benefits and drawbacks to their use (Holton et al., 1998). One of the drawbacks is that the score must be given by the veterinary professional involved. Secondly, all of these scales can have bias in them as all the scores are subjective (Holton et al., 1998). The veterinarian's judgement comes into play when assigning these scores and is affected by bias factors described previously such as age of the veterinarian, gender of veterinarian, previous experience, and factors of the animal such as breed, color, age, etc.

Pain scoring systems serve the purpose of providing a means to identify painful behaviors and signs in dogs. There are a few main categories that capture most behaviors. The first category would be the attitude of the animal which would include identifying if the animal looks scared, its willingness to eat, interaction with people and ability to lay down (Reid et al., 2007). Next category is the animals body movement which includes identifying if the animal is shaking constantly even when temperature is constant, flinching when touched by a human and reluctant to be touched (Reid et al., 2007; McCurnin and Bassert, 2002). Identifying facial expressions is crucial and include furrowed brows, lips drawn back, dilated pupils, and ears flat against head (Orskov, 2010; Reid et al., 2007; McCurnin and Bassert, 2002). It is also important to note behaviors such as guarding or biting at incision sites and growling (Orskov, 2010; Reid et al., 2007; McCurnin and Bassert, 2002). Posture is important to recognize as well, such as identifying if the animals' back is hunched up or tense and where they are in the cage, hiding in the corner, etc. Lastly you want to identify vocalizations and breathing which include identifying if the breathing is harsh and fast or short and shallow as well as is the animal crying, whining or whimpering at all (Orskov, 2010; Reid et al., 2007; McCurnin and Bassert, 2002).

In clinical settings, pain scoring usually begins with a visual assessment (McCurnin and Bassert, 2002). This will begin with the assessor observing the patient from a distance without touching or handling them to observe and assess the normal behavior of the animal. This is when measurements such as breathing rates, breathing patterns, posture, facial expressions, body position, and overall body assessment are observed prior to the observer having physical contact with the patient (Orskov, 2010; McCurnin and Bassert, 2002). Interacting with the patient immediately can cause the patient to tense up and completely change its behavior, which will not allow for an optimal evaluation. Once a visual assessment is done the observer can conduct a physical examination (Orskov, 2010). Physical exams are tricky as the observer wants to determine physiological parameters without causing the animal more pain. This is accomplished through gentle handling of the animal and performing more stressful procedures towards the end of the procedure; however, sometimes observers have to manipulate the painful body parts to elicit a response from the animal (Orskov, 2010).

Quantitative Sensory Testing (QST) has become a widely accepted and valuable method for assessing pain sensation in humans, with some application in dogs (Shy et al., 2003; Hunt et al., 2019). QST determines the sensation and pain thresholds for cold and warm temperatures and pressure thresholds by stimulating the skin (Shy et al., 2003). QST is non-invasive and relatively unique technique that utilizes technology along with instruments to serve as a diagnostic tool in determining pain thresholds, as well as identifying sensitization resulting from degenerative joint diseases and chronic pain (Shy et al., 2003). Thermal (heat) QST is conducted by attaching a small thermal probe, capable of increasing the heat to a desired temperature and cooling as needed, onto the animal's skin. Tests conducted by thermal (heat) QST can either increase the temperature to a specific temperature and keep it there until the animal withdraws its leg (somatosensory response) or you can keep increasing and decreasing the temperature until the animal withdraws its leg (Freire et al., 2016). The whole process of heating is timed, and each trial will conclude once the animal makes a behavioral response. This indicates the heat tolerance threshold of that animal (Freire et al., 2016). Mechanical QST is accomplished by using an instrument that applies pressure to an area with consecutively increasing stimulus each time to determine the average mechanical pain threshold of the affected and unaffected skin areas (Freire et al., 2016). Breed differences have been noted when conducting thermal testing on three working/sporting breeds, the Greyhound, Harrier hound and New Zealand huntaway (Bowden et al., 2018). It was found that the New Zealand huntaway was the least sensitive to the thermal testing. This information provides some basis on specific breeds and their sensitivities to specific stimuli and potentially pain (Bowden et al., 2018).

Personal Experience with Quantitative Sensory Testing

QST trials were being conducted at the NC State Veterinary Teaching Hospital during the time of data collection for the following research report. Due to the topic of this research and committee member connections, the opportunity to participate and observe trials under the leadership of Dr. Samuel Chiu was available. Dogs included in this QST trial had previously undergone orthopedic surgery. The testing began with a randomized list of pain threshold tests that were to be conducted on the animal as described below. Each animal had a randomized list of tests generated for them.

There were three main types of pain threshold tests performed:

A.) The first test was applying a heat probe onto the affected limb and connecting up to the computer system which was connected to the NTE-2A Thermal Probe and Controller (Physitemp Instruments) modem. This modem is a non-invasive device used to evaluate neurological fiber function, through a series of heat tests. One of the tests was to ramp the heat up to a desired temperature and keep the temperature constant at that point and determine how long it took the dog to withdraw or have a reaction to the heat. There are 3-4 rounds of this test conducted and then the average of all runs is taken. The second heat test was to ramp up the heat to a desired temperature, hold it for a second then go back down and ramp up again. Again, the researcher looked for a reaction or withdrawal from the dog to determine the latency to response.

B.) The second test involves applying pressure to the affected area or limb, which was not painful at all to the animal, but rather just an applied pressure for less than a second of time. The device used was a Bioseb Algometer for Big Mammals which applies pressure to the given area. Once the device was applied there was a recording on the device of the amount of pressure applied. A total of 3-4 rounds were performed and the average taken.

C.) The third test was also a pressure test however it began by applying a constant pressure of 23.6 on the ProdPro device. The ProdPro device conducts mechanical threshold testing for a 2-minute time period. After 2 minutes had passed the device was removed, and the same pressure tests as before were applied to see if there are any different values. The purpose of such a test is that applied pressure for a period of time could cause hypersensitivity to an applied stimuli.

The purpose of conducting QST trials is to more completely understand the way the sensory nervous system processes pain and to better understand how it works in our animals. QST allows the opportunity to find what threshold and tolerances certain dogs might have and how it changes among individuals. QST is a tool that can also be utilized to determine pain threshold differences between different breeds of dog.

The personal experience of watching pain threshold being determined was instrumental in the ability to better understand the retrospective data collected for this project. This experience also allowed numerous helpful observations of the differences among individual dogs for all the particular tests and thresholds.

At the NC State Veterinary Teaching Hospital, a modified Numerical Rating Scale is utilized for pain scoring of dogs. Pain scores are given from a 0 to 4 scale with each number corresponding to a set of descriptive words. A 0 translates to no pain at all, a 1 to mild pain, a 2 to moderate pain, a 3 to very severe pain and a 4 to unbearable pain. Half scores were also utilized. The use of the NC State scale allows for elevated awareness of pain and a way to quantify pain.

From this literature review it is noted that more information is needed on pain score assignment in general and patterns of pain scores based with specific surgeries. It is also noted that more information is needed on potential biases present in the veterinary field. Therefore, the following research was conducted to explore pain scoring in cruciate and hip surgeries and determine if any potential parameters affect pain scoring.

Chapter 2: Analyses of Factors Affecting Pain Score Assignments at NC State Veterinary Teaching Hospital from January 2013 to July 2018

Introduction

The proper recognition of pain in canines is a very subjective and difficult process (Williams and Craig, 2016). There is a plethora of factors that can play into the decision-making process of a veterinarian who is observing a potentially painful patient. Veterinary professionals may have biases (known or unknown) for or against certain animals or their characteristics. Breed type, color, size, age, sex, and body condition score (BCS) of canines can all potentially affect one's decisions about particular animals (Gunter et al., 2018; Lum et al., 2013). Additionally, the age, sex and / or education level of the veterinary professionals can factor into decision-making processes (Weber et al., 2012).

Color bias has been noted via people reporting that black dogs and cats were the least friendly and adoptable while white cats and yellow dogs were the friendliest and most adoptable (Lum et al., 2013). Breed biases are most notable against the "pit type" dog breeds as many believe they are more aggressive (Gunter, et al., 2016; Protopopova et al., 2012). This is unfortunate as these are the most common canines in most animal shelters (Lockwood and Rindy, 1997). Bias due to sex of the veterinary professional has been shown by female veterinarians administering more analgesics and assigning higher pain scores following surgery (Hunt et al., 2015; Williams et al., 2011). The type of surgical procedure performed also plays a role in not only the amount of analgesics administered but also the pain score assigned. Orthopedic surgery had the highest chance of analgesics being administered and the second highest pain scores assigned (Hugonnard et al., 2004)

Deciding if inclusion of a pain scoring system is accurate in relieving animal pain is necessary in veterinary hospitals to better treat and quantify pain in all animals. Although recent research has shown there are biases in human and veterinary medicine, many areas remain understudied (Gunter, et al., 2016; Hunt et al., 2015; Lockwood and Rindy, 1997).

To better understand canine pain scores and associated descriptive parameters of bias (breed, size, color, sex, BCS, and life stage), determining parameters that strongly influence pain scores is needed, therefore specific objectives of this study were to determine:

1.) if pain scoring is a process frequently utilized in the veterinary teaching hospital and if it is being utilized, how the numbering scale is being utilized;
2.) if dog breed type affects pain score assigned by veterinary professionals both pre and post operation;
3.) if dog color affects pain score assigned by veterinary professionals both pre and post operation;
4.) if dog size and life stage affect pain score assigned by veterinary professionals both pre and post operation;
5.) if type of surgery affects pain score assigned by veterinary professionals both pre and post operation;
6.) the most common breeds, ages, and sizes that have hip or cruciate surgery at the NC State teaching hospital.

Materials and Methods

Description of Data Set

Records of dogs admitted at NC State University Veterinary Teaching Hospital, Raleigh, NC for surgery between January 2013 and July 2018 were selected by searching the University Veterinary Information Software (UVIS) system for animals that had one of the following orthopedic cruciate or hip surgeries: extracapsular stabilization (EXST), femoral head osteotomy (FHO), medial patellar luxation (MPL), modified maquet procedure (MMP), tibial-plateau-leveling osteotomy (TPLO), tibial tubercle osteotomy (TTO), tibial tuberosity transposition (TTT), tibial wedge, total hip replacement (THR). A total of 499 dogs undergoing one of the mentioned surgeries were identified and used for data analysis.

Age and Breed Categories

The age and breed of each dog patient was recorded as reported by the owner. Dogs included in this study were purebred animals. If an owner indicated a mixed breed dog (a combination of several breeds, a mutt, or any two breeds together such as Labrador retriever / boxer) they were not included. However, two specific designer mix breeds were allowed: the Goldendoodle and the Labradoodle. These were included since these breed mixes are very popular and often confused as a true breed by the general public. Since the breed of dog was provided by the owner, these data may have some unintentional error. Additionally, the top three most common dog breeds within the data set were used for analyses to compare among each other and to all other breeds.

The dog age for each canine in the study was recorded and was also provided by the owner. Individuals were grouped into three age categories: puppies (15 months of age and under), adults (ages which varied by breed specific classifications), and senior (ages also varied by breed). The cutoff for a puppy used was 15 months of age. Most large breed dogs will be fully grown at around 15 months of age while small breed dogs will be full grown at around 9 months of age (Kraus et al., 2013). The cutoff for adult and senior dog was determined by the Petrics, Inc.'s (Wilmington, NC) online nutrition application.

Size Categories

Each dog was grouped into one of five size categories: extra small, small, medium, large or extra-large (American Kennel Club (AKC) Dog Breeds). The size categories were determined by AKC listings for breed size; in the case of non AKC registered breeds, the breed-specific website was used to determine size. AKC has a range of weight for each specific breed which then classifies into a size category. The weight ranges are: under 10 pounds for extra small, 11-25 pounds for small, 26-55 pounds for medium, 56-70 for large and over 71 pounds for extra-large. Breeds were cross-checked with the weight the owner reported for the dog to ensure that the size category of the breed was accurate.

Body Condition Score (BCS)

Prior to surgery, dogs were given a body condition score based on their weight and physical appearance by a veterinary professional. BCS are ranked on a 1.0 -9.0 scale, with 1.0 being severely emaciated and 9.0 being severely obese (Nestle Purina, 2019). The individual dog BCS numbers were used to calculate BCS for sex, age, life stage and size groups within this study.

Dog Coat Color

Dogs that came into the NC State University Veterinary Teaching Hospital were described by their primary coat color, followed by the secondary color and any extra color/markings. All of the color options were categorized into 3 different hue groupings: light, dark, and other. These were determined by the primary color indicated on the file then grouped into what hue they fell into. For example, if a dog was listed as black and brown in color they would get categorized into the dark category. Light was categorized as any combination of gray, white, cream or yellow. Other was categorized as any combination such as tri color, multi-color or anything that could not be classified discretely as light or dark.

Pain Scoring

Pain scoring was accomplished through a modified version of a Numerical Rating Scale (NRS) by assigning a pain score from 0 to 4, with 0 being no pain at all and 4 being extreme pain (Holton et al., 1998). Pain scores were assigned by veterinary professionals before surgery (pain score pre-op) on a 0 to 4 scale. These pain scores indicated how much pain the professional felt the dog was in prior to surgery. After the surgical procedure was completed, pain scores were recorded every 6 hours or until the patient had been discharged. Scores were assigned by either a veterinary student, veterinarian, or veterinary technician. Data for all pain scores up to 48 hours after surgery were extracted. Records following surgery, including veterinary student daily comments and checkups, were included for any subjective description of pain and to explore pain scores that were given to patients that had comments associated with them.

Analgesics

All analgesics given during surgery were recorded as well as each medication given up to 24 hours after the procedure. Medications given after surgery were recorded individually based on the time that medications were given and indicated as medication 1, medication 2 and medication 3. The classifications do not signify any significant order but rather they indicate which medication was given first based on the time documented on each patient file. The duration of the surgical procedure as well as duration of anesthesia was also recorded.

Other Parameters

A number of other canine and surgical variables were recorded. These include canine sex, owner name, city (with mileage traveled to NC State University Veterinary Teaching Hospital), diet, dietary supplements, any noted non-surgically related health problems, date of surgery, discharge medications, discharge medication dosages, anesthesiologist, anesthesiologist pain score for each canine patient, anesthesia duration, pre-operative medications, surgery comments, route of administration of analgesic (intra venously or intra muscular), epidural, if a medication was given PRN (given as needed) or not, where the animal recovered, the rescue plan, and all pain scores from pre operation to every 6 hours post-surgery up to 48 hours.

Statistics

Statistical analysis was performed using SAS 14.1 (Cary, North Carolina) to determine:

1. Is pain score affected by dog's color? If yes, does pain score differ between dark and light-colored dogs?
2. Is pain score affected by the size of dog? / Breed of dog? / Life stage of dog?
3. Does body condition score differ between breeds, size, life stages or color of dog?
4. Is pain score affected by the sex of dog? / Type of surgery?

Effect of independent factors was determined by the use of ANOVA, least squares (LS) means and Tukey-Kramer adjustment where appropriate. Significance was declared at $P < 0.05$ and tendencies at $P < 0.10$.

Canine breed, age, size, color, type of surgery, BCS and pain scores 6, 12 and 18 hours post operation were compared to determine patterns of bias in pain scoring.

Results

The most frequent orthopedic surgery during the January 2013 through July 2018 time period was tibial plateauing leveling osteotomy, TPLO, (n=131). This was followed by total hip replacement, THR (n=85), extracapsular stabilization, EXST (n=79) and tibial tubercle osteotomy, TTO (n=73). Table 1 summarizes all surgeries and the total number of individual patients in each surgery category.

The most frequent breed brought in during the study time period was the Labrador retriever (Labs) (n=102) with the American Staffordshire terrier (AST) being the second most frequent (n=36) followed by the German shepherd dog (GSD) (n=33). Appendix A lists all the dog breeds that were included and the total number of that breed that had surgery during the study time period.

Table 2 summarizes the top dog breeds seen for each specific type of surgery, except for medial patellar luxation (MPL) and tibial wedge (TW) as these procedures were less common did not have many canine breeds represented. Large dog breeds were the most common breeds noted for every type of surgery except for EXST surgery which had the toy Poodle, Bichon frise, Beagle and the American Cocker spaniel as top breeds along with the Labrador retriever.

Life stage of dogs that came in for these orthopedic surgeries are in Table 3. The most common life stage undergoing orthopedic surgery during this study was adult dogs (n=268) followed by puppies (n=137) and then senior dogs (n=94).

Sizes of dogs that came in for these orthopedic surgeries are in Table 4. The most frequent size of dog was large dogs (n=250) followed by medium dogs (n=126), small dogs (n=49), extra-large dogs (n=30) and lastly extra small (n=27). There were 17 dogs that were not able to be classified into a size category as the breed type provided by the owner (hound or terrier) was too vague to determine size.

Body condition score summary statistics (n=485) are in Table 5. The mean BCS of a canine on the 1.0 – 9.0 scale during this study was 5.8 ± 0.05 with a maximum of 9.0 and a minimum of 2.0. Of the 485 dogs with a BCS, 123 (25.4 %) were considered obese (7.0 score or higher).

The colors of study dogs are in Table 6 (n=496). Dark colored dogs were most numerous (n=223) followed by light colored dogs (n=164). Any color category clearly not able to be identified as dark or light was classified as other (n=109). A list of all the colors described by the owners of their canine is in Appendix B, with the most frequent color being black (n=67) followed by black and tan (n=56). Three dogs did not have a color indicated on their file. (Appendix B)

Pain scores assigned before surgery are found in Table 7. There were (n=463) dogs that had a pain score assigned pre-operation (pre-op) with a mean pain score before surgery of 0.93 ± 0.033 with a maximum pain score assigned of 3.5 and minimum of 0. Pain scores assigned 6 hours post operation (post-op) are found in Table 7. There were (n= 392) dogs that had a pain score recorded after 6 hours post-op with a pain score mean of 0.84 ± 0.021, a maximum pain score of 2.0 and a minimum of 0. Canine pain scores assigned 12 hours post-op are in Table 7 (n=387). The pain score mean was 0.84 ± 0.022 with a maximum of 3 and a minimum of 0. Pain scores 18 hours post-op (n=367) had a mean of 0.80 ± 0.031 with a maximum pain score of 3

(Table 7). Pain scores 24 hours post-op (n=231) had a mean of 0.68 ± 0.031 with a maximum pain score of 2.0 (Table 7). Pain scores 30 hours post-op (n=74) had a mean of 0.42 ± 0.056 and a maximum pain score of 1.5 (Table 7).

The list of the first noted medications given to the canine patients following the orthopedic surgeries in this research report are in Table 8. The most frequent medication given after surgery was Hydromorphone (n=347) followed by Dexmedetomidine (n=62) and Carprofen (n=48). The second noted medications given to the canine patient's post-op are also shown Table 8. The most frequent second medication given post-op was Hydromorphone (n=193) followed by Dexmedetomidine (n=176) and Fentanyl Patch (n=25).

The most numerous 6 head surgeons conducting orthopedic hip and cruciate surgeries during the research time period are in Table 9. An "other" grouping is included and encompasses surgeons who had less than 10 total cruciate or hip surgeries during this research period. The surgeon with the greatest number of surgeries performed was surgeon 1 with 249 surgeries followed by surgeon 2 with 97 surgeries.

Pain score means assigned based on the surgery type were evaluated to see if any differences were present based on the type of surgery performed. The mean pre-op and post-op pain scores are shown in Table 10. The pain score pre-op for a FHO was higher than for EXST and for TTT (P= 0.030 and P=0.001). Extracapsular stabilization pain score pre-op also was higher than the pain score for TTT (P=0.047) The pain score pre op for MPL has a tendency to be higher than a TTT (P=0.060). The pain score 6 hours post-op for EXST was higher than that of TW (P=0.041). For pain scores 18 hours post-op, EXST had a tendency to be higher than TW (P=0.079), MMP was higher than TPLO (P=0.036), TW had a tendency to be higher than THR (P=0.091), TTO was higher than TPLO (P=0.015) and TW was higher than TPLO (P=0.031).

Pain Score Comparisons

Life Stage

The relationship of pain score pre-op, 6 hours post-op, 12 hours post-op and 18 hours post-op based on life stage of the canine (puppy, adult, senior) was evaluated to test for any differences in assignment of pain scores. The LS means are presented in Table 11. There was a tendency for senior dogs to have a higher pain score pre-op compared to adult dogs (P=0.0843). Life stage was not a significant factor in the assignment of pain score 6 hours post-op (P=0.9524) or 12 hours post-op (P= 0.4998). Life stage pain scores at 18 hours post operation (P= 0.0995) had a tendency for seniors to have a higher pain score compared to adults. Life stage was a significant factor in the assignment of BCS (P=0.0001). BCS means were higher for adults (5.9 ± 0.070) than puppies (5.4 ± 0.097) as well as being higher for seniors (6.0± 0.118) than puppies.

Dog Size

The effects of dog size (extra small, small, medium, large and extra-large) on pain score pre-op, 6 hours post-op, 12 hours post-op and 18 hours post-op was evaluated to test for any differences in assignment of pain scores. The LS mean pain scores are in Table 11.

Dog size was not a significant factor in assigning pain scores pre-op (P=0.6185). Pain scores were higher for large breed dogs compared to small dogs 6 hours post operation (P=0.0219). Pain scores tended to be higher for large group dogs compared to small and medium group dogs 12 hours post operation (P=0.0637 and P=0.0560, respectively). Similarly, pain scores were higher for large group dogs compared to small and medium group dogs 18 hours post-op (P=0.0874 and P = 0.0482, respectively). Dog size was not a significant BCS factor (P=0.7216).

Color

The effect of color (dark, light and other) on pain score pre-op, 6 hours post-op, 12 hours post-op and 18 hours post-op was evaluated to test for any differences in assignment of pain scores. The mean pain scores can be found in Table 11. There was no association between pain score pre-op and color of dog (P=0.3019). There was no association between pain score 6 hours post-op and color of dog (P=0.2979), or 12 hours post-op (P=0.4911), or 18 hours post-op (P=0.1791). There also was no association between BCS and color of dog (P=0.6717). There were no differences in pain scores of the other group between either light or dark colored dogs respectively (P=0.349; P=0.952).

Breed Comparison

The most numerous three dog breeds (n=158) with reported pain scores (labs, ASTs, GSD) were isolated from the data set and then compared to the remaining dog breed's pain scores (n=305). Labrador retrievers were the number 1 breed undergoing cruciate and hip orthopedic surgeries at the NC State University Veterinary Teaching Hospital during the time of data collection. Pain score pre-op, 6 hours post-op, 12 hours post-op, 18 hours post-op and BCS were evaluated to determine if any differences were seen between Labrador retrievers and all other breeds (Table 12). There was no association between pain score pre-op assigned between Labrador retrievers and all other breeds (P=0.888). Pain score 6, 12 and 18 hours post-op of Labrador retrievers was higher than the pain score of all other breeds (P = 0.003, 0.0414 and 0.019, respectively). There was no association between BCS of Labrador retrievers and all other breeds (P=0.178).

American Staffordshire terrier was the second most numerous breed at the NC State University Veterinary Teaching Hospital during the time of data collection. There was a tendency for AST to have a lower pain score pre-op than all other breeds ($P = 0.1420$). There was no association of pain score 6, 12 and 18 hours post-op between AST and all other breeds ($P = 0.5573$, 0.3767, and 0.2915, respectively). There was no significance of BCS on pain score between AST and all other breeds ($P = 0.2871$)

German shepherd dog was one of the top 3 breeds seen at the NC State University Veterinary Teaching Hospital during the time of data collection. Their mean pain scores and BCS are in Table 12. There was no association between pain score given pre-op for GSD compared to all other breeds ($P=0.4968$) or 6 hours post-op ($P=0.1768$) or 12 hours post-op ($P=.1981$). Pain score given 18 hours post-op for GSD was significantly higher than all other breeds ($P=0.0040$). There was no association between BCS given for GSD compared to all other breeds ($P=0.2375$).

All the surgeries underwent by Labrador retrievers, ASTs and GSDs are listed in Table 13. The most frequent surgery performed on GSD was THR (n=15), for AST's it was TPLO (n=15) and for Labrador retriever's it was TPLO (n=36).

Labrador retrievers, AST and GSD mean pain scores were analyzed among all 3 breeds (Table 14). Pain score pre-op for the GSD was 1.03 ± 0.146 and thus higher than the AST (0.74 ± 0.122) ($P = 0.011$). Labrador retriever pain scores 6 hours post-op (0.96 ± 0.047) also were higher than AST (0.75 ± 0.079) ($P=0.022$). Labrador retrievers had a 12-hour post-op pain score of 0.94 ± 0.072 and was higher than AST (0.73 ± 0.075) ($P=0.041$). American Staffordshire terriers pain score 18 hours post-op was 0.65 ± 0.084 and was lower than both the Labrador retriever (0.92 ± 0.060) ($P=0.021$) and the GSD (1.09 ± 0.116) ($P=0.003$). The association of BCS assignment among the 3 breeds was not significant ($P=0.1396$).

The most numerous surgeries performed were TPLO and THR. Labrador retrievers was the most common dog breed undergoing both surgery types (Table 15 and Table 16).

Sex

Sex of canines that had cruciate or hip surgery during the study data collection period was recorded and are in Table 17. Female spayed canines were the most frequently seen (n=260), followed by castrated males (n=205), then intact males (n=19) and last was intact females (n=15). The pain score means of pre-op females was 0.92 ± 0.041 and males was 0.94 ± 0.048. The pain score means 6 hours post-op of females was 0.82 ± 0.025 and males was 0.85 ± 0.028. The pain score means 12 hours post-op of females was 0.81 ± 0.026 and males was 0.86 ± 0.029. The pain score means 18 hours post-op was 0.82 ± 0.032 and males was 0.79 ± 0.034 (Table 18). There was no difference in pain scores of males or female's pre-op (P=0.869), 6 hours post-op (P=0.544), 12 hours post-op (P=0.294) or 18 hours post-op (P=0.569).

Other Parameters

Many other parameters were recorded and summarized for discussion. Appendix C provides a count of all the ages of all the canines that underwent cruciate or hip surgery from January 2013 through July 2018 with the most frequent age being between 1.0 and 1.9 (n=77) and between 2.0 and 2.9 (n=61). Appendix D shows that the top city that owners traveled from to bring in their canine for surgery was Raleigh (n=103), as that is where the NC State University Veterinary Teaching Hospital is located. The next most common city was Virginia Beach, VA (n=22). Appendix E lists the mileage that was traveled to the NC State University Veterinary Teaching Hospital. Of the 499 canines within the study, 181 (36.3%) traveled over 100 miles to undergo surgery.

The mean weight groups (kg) for the dogs within this study are shown in Table 19. Almost half (n = 243, 48.7%) of the dogs were 30.0 kg or heavier and 147 dogs (29.5%) weighed between 20.0 and 29.9 kg.

Dietary supplements were noted as being provided to some of the canine patients via their owners prior to their initial visit. These are in Appendix F, with glucosamine being the most administered supplement. Previous or ongoing health problems for any of the canine patients also were noted (Appendix G). The majority of the dogs were historically healthy, and the most common health problem listed was generic allergies (less than 4.0% of the population reported these allergies).

Anesthesiologists recorded a pain score to the canine patients before surgery. Their scores were not numerical but rather words and are in Table 20. The most given anesthesiologist pain score was “mild”, with anesthesiologist pain scores ranging from none, mild, moderate and severe. Of the 499 patients, 125 (25%) were not given a pain score by the anesthesiologist.

Duration of anesthesia was recorded with the mean time being 4 hours and 7 minutes (Table 21). Pre-op analgesics and their dosages were recorded and are in Table 22. The most administered pre-op medication was 0.1mg/kg of Hydromorphone.

Diet was recorded by a veterinary professional for 153 (31%) of the canine patients. The most popular diet types / brands are listed in Appendix H. The two most popular brands of food given were Blue Buffalo (n=31) and Purina (n=31). Of the 153 recorded diets, 11.8% listed raw food as part of the diet.

Veterinary student daily comments and checkups along with assigned pain scores are listed in Appendix I. The only pain score associated with a painful comment given over a 2.0, was given to one canine 18 hours post-op.

Discussion

Concern has been raised about the adequacy of pain recognition and management in animals under veterinary care (Epstein et al., 2015). No studies have been published to specifically determine if any biases are present in assignment of pain scores to canines by veterinarians. Potential biases are numerous but are thought to predominantly include color, breed, size, life stage and surgeon (Lum et al.,2013; Gunter et al., 2018). However, no current literature is available on how bias factors affect how pain scores are assigned in a veterinary teaching hospital specifically for orthopedic surgery.

Within the current study, overall pain score given pre-op ranged from 0 to 3.5, with the mean pre-op pain score being very low at 0.93 ± 0.033. No dog received a 4 as a pre-op pain score and only one dog was assigned a 3.5 pain score. The dog who received the 3.5 pre-op pain score was a senior Boxer undergoing an MMP. Out of all the dogs that received a pre-op pain score (n = 463) only 12 dogs received a pain score over a 2.0. Trends of low mean pain scores were continuously seen following surgery as well, with mean pain scores ranging from 0.80 to 0.84. The pre-op pain score was seen to be higher than the post-op pain scores. Assignment of one high score could have skewed the data, resulting in the overall pre-op pain score to be higher. It seems that the full 0.0 – 4.0 pain scale is not being utilized well enough at the NC State Veterinary Teaching Hospital. It is surprising that the mean pain score was below a 1.0 as this translates to most of the dogs coming in for orthopedic surgeries not having serious pain. Conversely in humans, intense pain is the primary motivator for orthopedic surgeries such as total hip replacements (Crawford and Murphy, 1997). It is likely that the true pain of the animal is not being thoroughly recognized. Conversely, the dogs could truly have not been painful although this seems unlikely being that most were not on medications to alleviate pain and their condition was serious enough to require surgery. Another explanation could be pain score subjectivity since whomever assigned the pain score pre-op may not be the same person who assigned the pain score post-op. Pain scoring is primarily accomplished through students at the veterinary school. A pain score might be given by one student in the morning and then another student could be pain scoring 6 hours later after the surgical procedure. Having different individuals give pain score allows for inconsistency as well as unfamiliarity with the canine patient and its condition. Regardless, all pain scorers were scoring low.

Most dogs were given a pain score of 1.0 six hours after surgery. One possible explanation for why the pain scores assigned were lower after surgery (0.84 ± 0.021) than before surgery (0.93 ± 0.033) could be that after surgery the dogs are given medication to help keep them calm and less painful. Medications can cause the dogs to appear as if they have no pain even when they might in fact be experiencing it. There were also a large number of dogs, 107, that did not receive pain scores at all, with only 3 out of those 107 dogs discharged from the hospital. This could be contributed to the year in which the surgery happened. Prior to 2015 at NC State University Veterinary Teaching Hospital there was no designated spot on the paperwork to fill out pain scores, as it was recommended but not required. If pain scores were recorded by the veterinarian, then a column had to be created on the post-op checklist. After 2015, pain scores were recorded much more frequently and were usually included in the post-op instructions. The mean dog pain score was lowered with less assigned pain scores as time after surgery progressed. 132 dogs did not receive pain score 18 hours post-op compared with 107 dogs that did not receive pain scores 6 hours post op. This could be attributed to that more dogs are being discharged 18 hours post-op (33 dogs) compared with 6 hours post-op (3 dogs).

Similar findings are present 30 hours post op as 425 dogs did not receive a pain score and the ones who did received a score of 0. This is why pain scores after 18 hours were not evaluated statistically as most dogs had been discharged and the ones who stayed may have had complications or had owner's that could not pick them up.

To address the problem of not utilizing the entire pain scoring scale, further efforts should be made to educate all veterinary professionals regarding canine pain awareness. This would allow a more uniform and effective use of the scale which in turn would allow it to be a more powerful tool in prescribing analgesics after surgical procedures. This would also allow confidence in scores assigned between differing individuals.

Years since graduation from veterinary school has been shown to affect pain scoring in previous studies (Capner et al., 1999; Lascelles et al., 1999; Bell et al., 2014). One of the more recent studies exploring graduation year found that every 10 years since a veterinarian in the prior survey graduated from veterinary school, pain score would decrease by 0.4 points (Bell et al., 2014).

It does not come as a surprise that the Labrador retriever was the most popular dog seen for surgery as the Labrador retriever is the number 1 most owned dog according to the AKC and has been so since 1991(AKC. Most Popular Dog Breed of 2018). Labrador retrievers are predisposed to orthopedic condition such as cranial cruciate tears being two to five times as likely to suffer a rupture than the average dog (Whitehair et al., 1993, Duval et al., 1999). For the Labrador retriever, every pain score except for the pre-op pain score was significantly higher than the all other breeds grouping. One possible explanation for higher pain scores is that veterinarians are exposed much more frequently to Labrador retrievers which allows them to designate pain to a more specific degree via familiarity. Additionally, as a result of Labradors being so frequently owned, veterinarians could be exhibiting bias toward them. Labrador retrievers are known for being a family friendly and happy dog (Lofgren et al., 2014; McGreevy et al., 2018). It could be possible that since these dogs have such a positive reputation, they are unconsciously presumed to be more painful or needing more help. Higher pain scores may also be contributed to the sample size. Labrador retrievers were the largest group of dogs (n=102), which may have skewed the data results. A way to address the large number of Labrador retrievers in the sample could be to randomly select a smaller sample of those 102 Labrador retrievers and determine what the pain score are of those randomly selected group and see if trends of higher pain scores still apply for the entire data set. Further research can also be conducted to only do pain score analyses on Labrador retrievers due to their popularity. Through a Labrador retriever only analysis, trends can be determined for that breed alone and also can closely focus in on the three main color differences of that breed (black, chocolate and yellow) and how color may impact pain scores.

There has been a noted negative breed bias against “pitbull” breeds (Lockwood and Rindy, 1997). The American Staffordshire terrier is a breed recognized by the AKC and the canines included in this study were coded in on the computer system at the hospital as an American Staffordshire terrier for all pit type breeds. It is important to note that AST is a breed that most people would identify as a “pitbull” (Hoffman et al., 2014). In this study the pain scores assigned to AST were not significantly different than what was assigned to the all other breed category except for having AST having lower pain scores pre-operation. However, when comparing the AST with only the German shepherd and the Labrador retriever, AST consistently had lower pain scores. Visually looking at the mean pain scores of AST and all other breeds, AST had lower pain scores at every time point. The AST may have experienced a negative bias at the NC State veterinary teaching hospital. It would be interesting to see these numbers evaluated in a larger population and / or at a private veterinary hospital. According to a recent 13-year dog bite human fatality report, Pit-type dog breeds were the number one breed category responsible for fatal dog bites to humans (Dogbites.org, 2018). Thus, media presence could impact the way the public and veterinarian professionals view the breed. The CDC stopped collecting breed data in dog attack fatalities after 1998 since accurately identifying a dog's breed based on visual recognition is not always reliable (Nolen, 2017).

The German shepherd was one of the top 3 breeds seen at the NC State University Veterinary Teaching Hospital for cruciate or hip surgery. The German shepherd is well known for being used in military and police work. It also had the 4th highest incidence of dog bites in 1995 (CDC, 1997). German shepherds rose to the 3rd position in most fatal dog bites to humans in 2018 (Dogbites.org, 2018). However, there was no differences in pain scores assigned to German shepherds versus all other breeds except for the pain score assigned 18 hours post-op. The 18-hour pain score for German shepherds was 1.09 ± 0.116 and thus higher compared to all other breeds (0.76). These differences may be attributed to the fact that German shepherds are one of the breeds to most commonly undergo total hip replacements (Levien, 2017). This was consistent in the current study as 15 out of the 33 German shepherds underwent Total Hip Replacements (Table 13). Since THR is usually a very complicated and extensive surgery, recovery time is typically longer and has increased risks of complications, which could attribute to why the 18-hour post-op score was seen the highest (Henderson et al., 2017). However, THR was not the most painful surgery performed according to pain scores. FHO and TW had higher pain scores than THR.

The most common surgeries performed were TPLO, THR, EXST and TTO, respectively. There were 131 TPLO's performed. TPLO surgery is the most common type of surgery performed on dogs with a cranial cruciate ligament rupture, similar to an ACL surgery in humans (Whitehair et al., 1993, Henderson et al., 2017). The breeds of dogs that are prone to cranial cruciate tears are Labrador retrievers, Rottweilers, Newfoundland's and American Staffordshire terriers (Loder and Todhunter, 2017). 54% of the TPLO's performed in this research were on the top dog breeds prone to cruciate tears, with most being contributed by Labrador retrievers and AST (Table 15). There were 85 THR performed. THR usually occur in dogs with hip dysplasia problems such as German shepherds, Labrador retrievers, Golden retrievers, Rottweilers and Great Danes (AKC, Hip Dysplasia, 2019; Loder and Todhunter, 2017). 56.47% of the THR in this research were in breeds that are prone to hip dysplasia, with German shepherds contributing the most. As a result of the type of surgeries selected for this research it is not uncommon to have large breed dogs (50-70 lbs) dominating these data, especially the top 3 dog breeds in this study being included in these surgeries (Table 16). There was a tendency in the current to have more large dogs (over 50 lbs) undergoing orthopedic cruciate and hip surgery compared to smaller dogs. However, this does not exclude smaller dogs from the same problem, they just do not get them as frequently as large breed dogs do.

Life stage of dog was analyzed as a factor that might affect pain scores veterinary professionals assign to dogs. Puppy numbers were high in this research study as the cutoff for puppies was determined as 15 months of age. It has been seen that small breed dogs typically stop growing after about 9 months of age while large breed dogs do not stop growing until about 15 months (Hawthorne et al., 2004). Thus, this research used the higher number which may need to be adjusted via breed type in the future. However, despite being finished growing, most dogs “act like puppies” until at least 15 months of age and are therefore at an increased risk for orthopedic disease (AKC. Hip Dysplasia, 2019; ACVS, 2019). Senior dog cutoff was breed specific and numbers for each breed were used by a data set determined by Petrics, Inc as previously described. While, not every dog breed is truly considered a senior at the website cut off points, cut offs for senior ages were needed and thus based on available breed data. The high incidence of adult dogs seen for surgeries may be attributed that these surgeries were cruciate and hip surgeries which are prone in large breed dogs (AKC. Hip Dysplasia, 2019). Large breed dogs such as Labrador retrievers and German shepherds are high energy dogs that require lots of exercise, which could be resulting in so many orthopedic problems and eventually surgeries as an adult. Although these dogs were classified as adults, they are still decently young animals. As was true for puppies up to 15 months of age, some dogs categorized as adults could also have puppy like tendencies at 2 years of age. Such tendencies could account for more injury prone activities. The low number of seniors seen is likely due to age of dog. It is risky for veterinarians to perform surgery on geriatric dogs as their bodies have physically deteriorated more than a younger dog as well as being at greater risk of complications when undergoing anesthesia (Hughes, 2008).

Body Condition Score was evaluated to determine what physical condition most dogs were in prior to surgery. The mean BCS of all canines in this study was a 5.8 ± 0.05. The trends from this research with BCS seem to fall toward the higher end of the scale which reflects statistics in 2018 that showed 55.8% of dogs were obese or overweight in the United States (Association for Pet Obesity, 2019) compared with 25.4% of the canines in this study being obese or overweight. Overweight is comprised of a BCS of 6 to 7 while obese is over 7. A dog being overweight may contribute to how pain is assessed in that animal as it is may have more health-related issues due to the added weight. Obesity is a major risk factor for orthopedic disease (German, 2006). Body weight, especially obesity, is a predisposing factor in humoral fractures, cranial cruciate ligament rupture and intervertebral disc disease in cocker spaniels (Brown et al., 1996). Obesity has also been linked to osteoarthritis in canines as evidenced by dogs who were not restricted on their food had higher incidences of osteoarthritis (Kealy et al., 2000). Obesity being viewed as a disease or not also plays a role in how pain scores are assigned. Dog owners who thought obesity was not a disease were more likely to have obese dogs (Munoz-Prieto et al., 2018). Obesity not being viewed as a disease could affects veterinary professionals' feelings about assigning pain scores.

The choice of surgeries in this data compilation could have skewed the data by capturing a greater number of large breed dogs. It seemed that there was an association between size of dog and pain score assigned. Differences in means were visually always seen between a large dog (56- 70 lbs) and small dog (11-25 lbs) or between a large dog and medium dog (26-55 lbs). Large dogs would have significantly higher pain scores than both medium and small breed dogs. While extra-large and extra small breeds were not significantly different, it was likely because there were so few of them. This seems counter intuitive as it would be seen that since large dogs are more prone to these surgeries, veterinarians would rate them lower on the pain scale, but it seems that the opposite is happening, and rather smaller sizes breeds are getting rated lower on the pain scale. It also could be for the same reason that these dogs are so prone to such orthopedic problems that they are rated higher on pain scales because veterinarians are better understanding how painful such conditions are.

Color of dog was a primary factor to be studied to determine its association with pain score assignment. There were more dark dogs seen than light colored dogs at the NC State

University Veterinary Teaching Hospital. However, there were still 109 dogs that could not be put into a dark or light group because their primary color description did not make it clear as to what color grouping, they predominantly were classified in, such as tri colored. While light colored dogs numerically did have higher pre-op pain scores than dark colored dogs, statistically there was no difference (P=0.302). Thus, color of dog did not have any effect on pain score assignment both pre and post operation. These results went against the trends that are seen in human medicine, where individuals from darker races are seen as having much lower pain recognition and treatment when compared to lighter skin individuals (Drwecki, 2015; Todd et al., 2000). Reasons for no differences in pain scores assigned between dark and light dogs might be that pain is actually being recognized similarly regardless of color. Most pain scoring techniques require visual and behavioral signs from the animal so just using behaviors from the animal can lead to accurate pain recognition and as a result the most representative pain score. It also can be attributed to the large group of dogs that were classified as other. If the large group of unidentified colored dogs were more easily determined to be either a dark or light-colored dog, analysis could have been more precise as well as a larger sample size to be used. Addition of photos to each canine file could be useful for future coat color research.

Unlike a previous study where analgesics where not commonly prescribed, all dogs in this study received analgesics during and after their surgical procedure (Hansen and Hardie, 1993). The most common analgesic prescribed after surgery was hydromorphone followed by dexmedetomidine which differs from earlier studies conducted in Canada where meloxicam was the most commonly prescribed perioperatively, specifically most frequently administered during and right after surgery (Reimann et al., 2017). Canada approved the use of meloxicam in 2003, therefore previous to 2003 other alternatives were used. These findings also differed from earlier studies in New Zealand in which carprofen and butorphanol were the 2 most commonly used analgesics (Williams et al., 2011). Hydromorphone is more commonly used as it is a more effective opioid and has a longer duration of action (2-4 hours) than butorphanol (Pascoe, 2000). Efforts have been made by the FDA to try and control and educate veterinarians about opioid prescription by encouraging use of nonopioid alternatives whenever possible (Nolen, 2018).

Anesthesiologist pain scores although not numerical, also indicated the lack of use of the entire scale. Anesthesiologist pain scores range from none to severe, which translate to none being a 0 on the scale and severe being a 4.0. Only 7 dogs were given a pain score by the anesthesiologist of severe. Not only were numerical pain scores low, but anesthesiologist pain scores were low as well. The pain score given by the anesthesiologist is given right before the canine is about to start their surgical procedure, hence most canines are probably very nervous and unfamiliar with their surroundings making it hard to determine if they are truly painful or nervous. It is important for the anesthesiologist to know the painful state of the canine as their job is too monitor how much anesthesia to give as well as monitoring vital signs. If given improper amounts, the anesthesia can interfere with medications given before and during the procedure resulting in health problems (Bouillon and Shafer, 1998).

Diets of canines were provided in some cases by the owner, however this was not very common as 346 canines diets out of 499 animals were not provided. Blue Buffalo and Purina were the two most common brands of food given, however there were a few diets that were grain free and raw that were being fed. Raw food diets were more common than grain free which is interesting as raw food diets may be a pathogen risk to both owner and canine (Ahomaa et al., 2017). Additionally – grain free diets are the center of a recent health concern (Freeman, 2018)

Conclusion

This study summarizes the trends of pain score assignment to 499 dogs at the NC State University Veterinary Teaching Hospital. This study analyzed several potential biases that could alter pain scoring in canines. Although color bias was not identified as a factor in this study, further research should focus on expanding how to identify truly dark dogs and true light-colored dogs more accurately. The color of canines written on files make it very difficult to determine if a dog is primarily white for example with black spots, if it is written as white and black. Having a category for indicating dark or light dog would have made it easier to group canines properly. This could also be a reason why color was not a big contributing factor to pain score assignment as it was difficult to determine which dogs were truly dark and light. This study also identified that the full pain scale is not being fully utilized as evidenced by very low pain scores. Breed was seen to be an influencing factor in the determination of pain scores as some breeds seen as "bully" breeds were consistently ranked low in pain compared to all other breeds. Life stage of dog was seen to affect pain scoring as well, with senior dogs having higher pain score than adults. Size was seen to have the most consistent effect on pain score as large breed dogs had higher pain scores consistently compared to all other size groupings, especially to small and medium sized dogs. Sex of dog seemed to not have an effect on the pain scores assigned. This is the first study to collect information on several potential biases affecting pain scoring procedures in canines. More research could be accomplished to evaluate the trends in pain score assignments by expanding into different types of surgeries to better encompass all breeds and size categories, such as routine castration and extremes such as thoracotomy and limb amputations. These pain score trends could provide some insight on what factors contribute to a pain score assignment and how they can be better managed to provide the most representative pain score.

Some limitations of this study were missing data. 21% of 6-hour post-op pain scores, 22.4% of 12-hours pain scores and 26.5% of 18-hour pain scores were not recorded on patient files simply due to not doing the pain score. Missing pain scores can be due to matter of importance to the veterinarian and how important he or she thinks providing a pain score is post-operatively, i.e. if an animal is obviously painful or had some complications postoperatively, including a pain score might be more important in such a situation (Reid et al.,2007). Including all those missing pain scores could have contributed to more accurate mean pain scores. Another limitation of the study was sample size. Although 499 dogs is a very large study and more than a similar study used in their retrospective studies (Hansen and Hardie, 1993), in hindsight either adding more years or more surgeries to increase the data set is recommended. Additionally, future studies should focus on comparing the analgesics prescribed with pain scores assigned on how all the identified biases play a role on the interaction between pain score and analgesics.

Although analgesics pre-op, intra-op and post-op were recorded for this study, analyses were not able to be conducted to determine the interaction between analgesics and pain score.

Identification of bias factors can play a significant role in not only the assignment of pain score but also the treatment of pain in canines with proper analgesic prescriptions. Elimination of biases is not an easily achievable task, but spreading awareness of such biases and encouraging education can limit their effects.

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TABLES

Table 1: Type of orthopedic surgery performed on canines at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Type of Surgery	**Total Number**
Extracapsular Stabilization (EXST)	79
Femoral Head Ostectomy (FHO)	28
Medial Patellar Luxation (MPL)	12
Modified Maquet Procedure (MMP)	55
Tibial Plateau Leveling Osteotomy (TPLO)	131
Tibial Tubercle Osteotomy (TTO)	73
Tibial Tuberosity Transposition (TTT)	32
Tibial Wedge (TW)	3
Total Hip Replacement (THR)	85
Not indicated	1
Total	**499**

Table 2: Top breeds of dogs for each orthopedic surgery type performed at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.[1]

Surgery Type	Breed of dog	Count
Extracapsular Stabilization (EXST)	Labrador retriever	5
	Toy Poodle	5
	American cocker spaniel	4
	Beagle	4
	Bichon frise	4
Femoral Head Ostectomy (FHO)	German shepherd	4
	Labrador retriever	4
	Yorkshire terrier	3
Modified Maquet Procedure (MMP)	Labrador retriever	16
	Rottweiler	8
	American Staffordshire terrier	5
	German shepherd	4
Tibial Plateau Leveling Osteotomy (TPLO)	Labrador retriever	36
	American Staffordshire terrier	16
	Boxer	10
Tibial Tubercle Osteotomy (TTO)	Labrador retriever	17
	Boxer	6
	American Staffordshire terrier	5
Tibial Tuberosity Transposition (TTT)	American Staffordshire terrier	4
	Labrador retriever	3
	Boxer	3
	Cavalier King Charles spaniel	3
Total Hip Replacement (THR)	German shepherd	15
	Golden retriever	13
	Labrador retriever	16

[1] There were not enough MMP & tibial wedge surgeries conducted to include them in the surgical analyses.

Table 3: Life stages for all canines that underwent cruciate or hip surgery at NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Life Stage	Total Number
Adult	268
Puppy	137
Senior[1]	94
Total	**499**

[1]Senior cutoff ages were used by a dataset developed by Petrics Inc. Wilmington, NC.

Table 4: Size category of all canines that underwent cruciate or hip surgery at NC State University Veterinary Teaching Hospital from January 2013 through July 2018.[1]

Size	Number of Individuals
Extra Large[2]	30
Large[3]	250
Medium[4]	126
Small[5]	49
Extra Small[6]	27
Not Identified[7]	17
Total	**499**

[1]All individuals were grouped into size categories via breed identification as provided by the owner and then using American Kennel Club official breed dimensions to determine the size.
[2]Extra-large canines are over 71 pounds.
[3]Large canines are between 56-70 pounds.
[4]Medium canines are between 26-55 pounds.
[5]Small canines are between 11-25 pounds.
[6]Extra small canines are less than 10 pounds.
[7]Canines in this group belonged to a breed category identified as only hound or terrier which are not official AKC breeds and are very broad definitions of a specific breed.

Table 5: Body condition score (BCS) frequency and summary stats for all canines that underwent cruciate or hip surgery at NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

BCS	Number of Individuals
2.0	1
3.0	2
3.5	1
4.0	35
4.5	4
5.0	191
5.5	2
6.0	117
6.5	9
7.0	84
7.5	2
8.0	29
9.0	8
NO BCS	14
Total	**499**
Mean BCS (485 dogs)	**5.8 ± 0.05(SEM) – Min (2.0) – Max(9.0)**

Table 6: Color category for all canines that underwent cruciate or hip surgery at NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Color Category	Number of Individuals
Dark	223
Light	164
Other[1]	109
Not provided	3
Total	**499**

[1] Canines in this group could not be identified from dark or light based on their primary color description.

Table 7: Pain score means (± SEM) and number of canines receiving each pain score category pre through 30 hours (hr) post operation (post op) for all canines having cruciate or hip surgery at NC State University Veterinary Teaching Hospital from January 2013 through July 2018.[1]

Pain Score	Pre-op	6 hrs post-op	12 hrs post-op	18 hrs post-op	24 hrs post-op	30 hrs post-op
0	105	54	55	77	65	40
0.5	39	51	50	46	31	7
1.0	235	266	259	210	127	26
1.5	10	12	15	14	4	1
2.0	61	9	7	19	4	0
2.5	1	0	0	0	0	0
3.0	11	0	1	1	0	0
3.5	1	0	0	0	0	0
No Pain Score[2]	36	107	112	132	268	425
Mean Pain Score ± SEM	**0.93 ± 0.033 (n =463)**	**0.84 ± 0.021 (n = 392)**	**0.84 ± 0.022 (n = 387)**	**0.80 ± 0.031 (n = 367)**	**0.68 ± 0.031 (n = 231)**	**0.42 ± 0.056 (n = 74)**

[1] A pain score of 0 means no pain, 1 some pain, 2 mild pain, 3 moderate pain and 4 severe pain.
[2] No Pain Score = no pain score was recorded, or the dog was already discharged prior to this timepoint.

Table 8: List of pain medications administered as first or second dose after surgery to canines (n = 499) at NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Name of Medication	Number of canines provided dose of medication	
	First Dose	Second Dose
Acepromazine	1	0
Atiparazole	1	0
Buprenorphine	0	1
Butorphanol	5	0
Carprofen	48	21
Cefazolin	0	1
Cephalexin	1	2
Cerenia	0	2
Deramaxx	0	1
Dexmedetomidine	62	176
Fentanyl	9	21
Fentanyl CRI	8	0
Fentanyl Patch	3	25
Gabapentin	0	6
Galliprant	0	1
Hydromorphone	347	193
Meloxicam	5	2
Methadone	3	3
Morphine	1	0
Previcox	0	1
Rimadyl	3	2
Tramadol	0	1
Trazodone	0	2
Not Provided	2	38

Table 9: Head surgeons by case numbers for the type of cruciate or hip surgeries at NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Head Surgeon	Case Number Total
Surgeon 1	249
Surgeon 2	97
Surgeon 3	65
Surgeon 4	16
Surgeon 5	16
Surgeon 6	11
Other[1]	45
Total	**499**

[1]These surgeons contributed less than 10 surgeries each for the entire time frame.

Table 10: Surgery type pain score means (± SEM) of canine's pre-op and up to 18 hours post-op cruciate or hip surgery at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.[1, 2, 3]

Surgery Type	Pain Score Pre-op	6 hrs post-op	12 hrs post-op	18 hrs post-op
Extracapsular Stabilization (EXST) (n=75)	0.87 ± 0.622[a]	0.81 ± 0.379[a]	0.81 ± 0.429	0.79 ±0.46[x]
Femoral Head Ostectomy (FHO) (n=25)	1.30 ± 0.825[b]	0.89 ± 0.514[a,b]	0.80 ± 0.634	0.93 ± 0.510[a,b,x,y]
Medial Patellar Luxation (MPL) (n=11)	0.90 ± 0.892[a,b,x]	0.88 ± 0.500[a,b]	0.87 ± 0.250	0.81 ± 0.500[a,b,x,y]
Modified Maquet Procedure (MMP) (n=53)	0.93 ± 0.892[a,b]	0.87 ± 0.424[a,b]	0.86 ± 0.347	0.90 ± 0.532[b]
TPLO (Tibial Plateau Leveling Osteotomy) (n=119)	0.95 ± 0.671[a,b]	0.85 ± 0.432[a,b]	0.80 ± 0.411	0.69 ± 0.496[a]
TTO (Tibial Tubercle Osteotomy) (n=68)	0.90 ± 0.539[a,b]	0.78 ± 0.362[a,b]	0.86 ± 0.313	0.91 ± 0.532[b]
TTT (Tibial Tuberosity Transposition) (n=28)	0.55 ± 0.515[c,y]	0.83 ± 0.432[a,b]	0.87 ± 0.405	0.83 ± 0.491[a,b,x,y]
TW (Tibial Wedge) (n=3)	1.30 ± 0.577[a,b]	1.00 ± 0.00[b]	0.83 ± 0.288	1.30 ± 0.577[b,y]
THR (Total Hip Replacement) (n=81)	0.93 ± 0.661[a,b]	0.80 ± 0.402[a,b]	0.84 ± 0.417	0.82 ± 0.571[a,x]

1 Differing superscripts ([a,b]) in mean columns are significantly different at (p = 0.05) or a tendency at (p=0.1) with differing superscripts ([x,y]).
2 A pain score of 0 means no pain, 1.0 some pain, 2.0 mild pain, 3.0 moderate pain and 4.0 severe pain.
3 There were not enough MMP & tibial wedge surgeries conducted to include them in the surgical analyses.

Table 11: Pain score (PS) means ± SEM pre-op, 6 hours post-op, 12 hours post-op, 18 hours post-op and body condition score (BCS) of canines receiving cruciate or orthopedic hip surgery from January 2013 through July 2018 based on categorical information including life stage, size, and color hue of the canines. [1, 2]

Category	Category Details	PS pre-op	6 hrs post-op	12 hrs post-op	18 hrs post-op	BCS
Life Stage	***Adult (n=268)***	0.89 ± 0.041[a]	0.83 ± 0.029	0.82 ± 0.028	0.75 ± 0.036[x]	5.9 ± 0.070[a]
	Puppy (n=137)	0.90 ± 0.065[a, b]	0.84 ± 0.043	0.88 ± 0.047	0.84 ± 0.053[x, y]	5.40 ± 0.097[b]
	Senior[3](n=94)	1.10 ± 0.081[b]	0.84 ± 0.045	0.82 ± 0.049	0.90 ± 0.066[y]	6.00 ± 0.118[a]
Size	***Extra Large (n=30)***	1.00 ± 0.091	0.79 ±0.893[a,b]	0.86 ± 0.067[a, b]	0.79 ± 0.088[a, b]	5.31± 0.204
	Large (n=250)	0.98 ± 0.046	0.88 ± 0.084[a]	0.88 ± 0.025[a]	0.87 ± 0.035[a]	5.85± 0.074
	Medium (n=126)	0.87 ± 0.061	0.82 ± 0.034[a, b]	0.78 ± 0.039[b]	0.73 ± 0.046[b]	5.77 ± 0.096
	Small (n=49)	0.84 ± 0.090	0.70 ± 0.065[b]	0.74 ± 0.069[b]	0.70 ± 0.072[b]	5.83± 0.176
	Extra Small(n=27)	0.85 ± 0.174	0.76 ± 0.074[a, b]	0.83 ± 0.132[a, b]	0.76 ± 0.081[a, b]	5.44± 0.202
Color	***Dark (n=223)***	0.90 ± 0.049	0.85 ± 0.039	0.85 ± 0.034	0.83 ± 0.034	5.84 ± 0.078
	Light (n=164)	0.98 ± 0.056	0.79 ± 0.038	0.81 ± 0.039	0.74 ± 0.049	5.79 ± 0.091
	Other (n=109)	0.90 ± 0.069	0.86 ± 0.030	0.85 ± 0.037	0.83 ± 0.044	5.63 ± 0.110

1 Differing superscripts (a,b) within the same category column are significantly different at (p = 0.05) or a tendency at (p=0.1) has differing superscripts (x,y,z).

2 A pain score of 0 means no pain, 1 means some pain, 2 means mild pain, 3 means moderate pain and 4 means severe pain

3Senior cutoff ages were used by a breed specific dataset developed by Petrics Inc. Wilmington, NC.

Table 12: Pain score (PS) means (± SEM) pre-op, 6 hours post-op, 12 hours post-op, 18 hours post-op and body condition score (BCS) of top three breeds individually compared to all other breeds undergoing cruciate or hip surgery from January 2013 through July 2018 at the NC State University Veterinary Teaching Hospital. [1, 2, 3]

Comparison Category	Breed Type	PS pre-op	6 hrs post-op	12 hrs post-op	18 hrs post-op	BCS
Labrador retriever vs Other	***Labrador retriever***	0.93 ± 0.065 (n=97)	0.96 ± 0.047[a] (n=82)	0.92 ± 0.044[a] (n=80)	0.92 ± 0.060[a] (n=78)	6.0 ± 0.109 (n=98)
	Other	0.94 ± 0.041 (n=305)	0.80 ± 0.026[b] (n=258)	0.81 ± 0.028[b] (n=256)	0.76 ± 0.033[b] (n=239)	5.7 ± 0.068 (n=319)
American Staffordshire terrier (AST) vs Other	***AST***	0.74 ± 0.122[x] (n=31)	0.75 ± 0.079 (n=28)	0.73 ± 0.075 (n=28)	0.65 ± 0.084 (n=27)	5.50 ± 0.141 (n=36)
	Other	0.94 ± 0.041[y] (n=305)	0.80 ± 0.026 (n=258)	0.81 ± 0.028 (n=256)	0.76 ± 0.033 (n=239)	5.80 ± 0.067 (n=319)
German shepherd vs Other	***German shepherd***	1.03 ± 0.146 (n=30)	0.92 ± 0.072 (n=24)	0.94 ± 0.072 (n=23)	1.09 ± 0.116[a] (n=23)	5.50 ± 0.170 (n=32)
	Other	0.94 ± 0.041 (n=305)	0.80 ± 0.026 (n=258)	0.81 ± 0.028 (n=256)	0.76 ± 0.033[b] (n=239)	5.80 ± 0.068 (n=319)

[1] Differing breed type superscripts ([a,b]) within the same comparison category columns are significantly different at (p = 0.05) or a tendency at (p=0.1) has differing superscripts (x,y,z).
[2] Other category does not include Labrador retrievers, AST or German shepherds.
[3] A pain score of 0 means no pain, 1 means some pain, 2 means mild pain, 3 means moderate pain and 4 means severe pain

Table 13: Type of orthopedic cruciate or hip surgeries performed on American Staffordshire terrier, German shepherd dog and Labrador retrievers at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Type of Surgery	American Staffordshire terrier	German shepherd dog	Labrador retriever
Extracapsular Stabilization (EXST)	1	2	6
Femoral Head Osteotomy (FHO)	0	3	4
Modified Maquet Procedure (MMP)	6	4	19
Total Hip Replacement (THR)	3	15	16
Tibial Plateau Leveling Osteotomy (TPLO)	15	5	35
Tibial Tubercle Osteotomy (TTO)	5	2	17
Tibial Tuberosity Transposition (TTT)	4	1	4

Table 14: Mean pain scores (PS) pre-op, 6 hours post-op, 12 hours post-op, 18 hours post-op and body condition score (BCS) of Labrador retriever, Staffordshire terrier and German shepherds undergoing cruciate or hip surgery from January 2013 through July 2018 at the NC State University Veterinary Teaching Hospital compared with one another.[1, 2]

Breed	PS Pre	PS 6 hr	PS 12 hr	PS 18 hr	BCS
Labrador retriever (n=102)	0.93 ± 0.065[a]	0.96 ± 0.047[a]	0.93 ± 0.044[a]	0.92 ± 0.060[a]	6.0 ± 0.109[a]
German shepherd (n=33)	1.03 ± 0.146 [a]	0.92 ± 0.072[a]	0.94 ± 0.072[a]	1.09 ± 0.116[c]	5.5 ± 0.170[b]
American staffordshire terrier (n=36)	0.74 ± 0.122 [b]	0.75 ± 0.079[b]	0.73 ± 0.075[b]	0.65 ± 0.084[b]	5.6 ± 0.191[b]

[1] Differing breed type superscripts ([a,b]) within the same comparison category columns are significantly different at (p = 0.05)

[2] A pain score of 0 means no pain, 1 means some pain, 2 means mild pain, 3 means moderate pain and 4 means severe pain

Table 15: Top 5 breeds of canine patients who underwent tibial plateau leveling osteotomy surgery (TPLO) at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Breed	Count of Breed
American Staffordshire terrier	16
Boxer	10
Labrador retriever	36
Newfoundland	2
Rottweiler	7
Total	**71**

Table 16: Top 4 breeds of canine patients who underwent total hip replacement (THR) at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Breed	Count of Breed
German shepherd	15
Golden retriever	13
Labrador retriever	16
Rottweiler	4
Total	**48**

Table 17: Sex of canines that underwent cruciate and hip surgery at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Sex of dog	Count of Dog
Female still intact[1]	15
Female spayed[2]	260
Male still intact[3]	19
Male castrated[4]	205
Total	**499**

Table 18: Pain score of male and female canines undergoing cruciate or hip surgery at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Sex	PS Pre	PS 6 hours	PS 12 hours	PS 18 hours
Female[1] (n=275)	0.92 ± 0.041	0.82 ± 0.025	0.82 ± 0.026	0.82 ± 0.032
Male[2] (n=224)	0.94 ± 0.048	0.85 ± 0.028	0.86 ± 0.029	0.79 ± 0.034

[1]All females in this category include both spayed and non-spayed female canines.
[2]All males in this category include both castrated and uncastrated male canines.

Table 19: Weight (kg) of canine patients (n=499) who underwent cruciate or hip surgery at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Weight (kg)	Number of dogs
$0 < 9.9$	63
$10.0 \leq 19.9$	57
$20.0 \leq 29.9$	136
$30.0 \leq 39.9$	147
40 and over	96
Total	**499**

Table 20: Anesthesiologist pain scores assigned to canines prior to the beginning of cruciate or hip surgery at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Pain Score	Total Number of Pain Scores
Mild	209
Mild / moderate	1
Moderate	137
Severe	7
No PS done[1]	125
None[2]	20
Total	**499**

[1] No PS done indicates that no pain score was indicated by the anesthesiologist.
[2]None meaning that the dog was experiencing no pain.

Table 21: Duration of anesthesia for canines undergoing cruciate or hip surgery at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Duration of Anesthesia (hours)	**Total Number of Surgeries**
≥ 1	1
≥ 2	55
≥ 3	177
≥ 4	166
≥ 5	81
≥ 6	18
≥ 7	1
Total	**499**
Mean Duration of Anesthesia	**4 hours 7 minutes**

Table 22: List and dosages of first pre-op medication given to canines undergoing cruciate or hip surgery at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Medication	**Total**
Dexmedetomidine 0.05mcg/kg	1
Dexmedetomidine 5mcg/kg	1
Fentanyl 3mcg/kg	6
Fentanyl 5mcg/kg	3
Hydromorphone 0.05mg/kg	10
Hydromorphone 0.15mg/kg	24
Hydromorphone 0.1mg/kg	444
Methadone 0.4mg/kg	2
Methadone 0.5mg/kg	7
Methadone 0.7mg/kg	1
Total	**499**

FIGURES

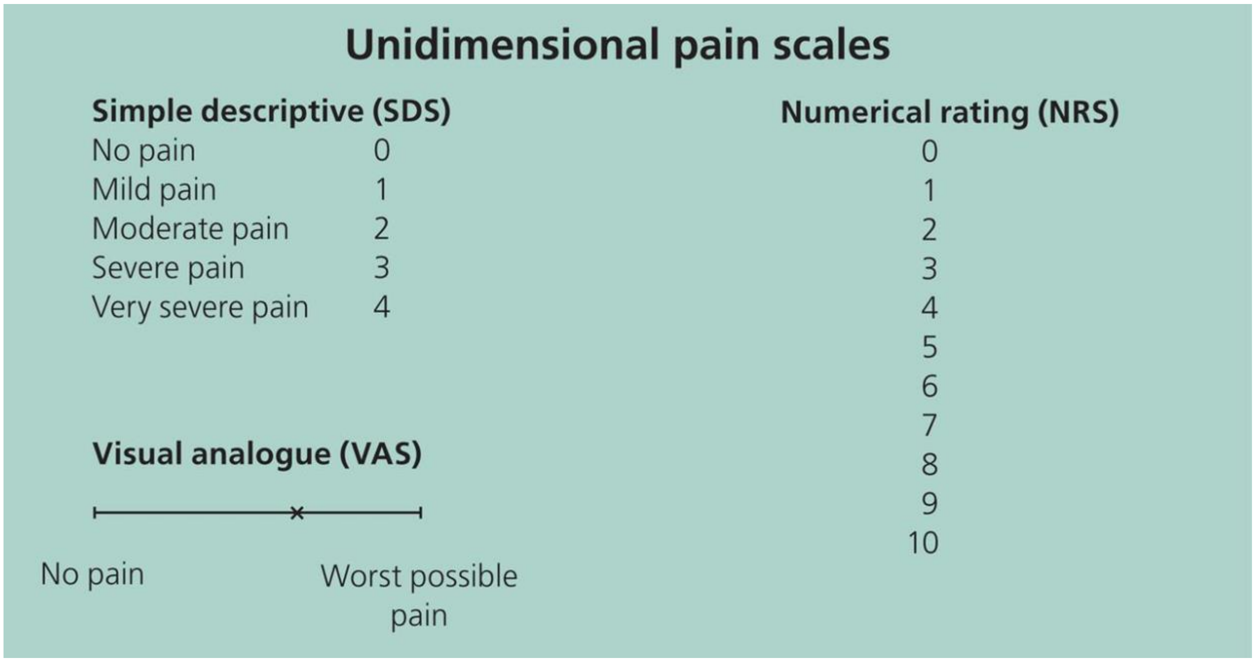

Figure 1: Pain assessment intensity scales. (Adapted from Reid, J., Scott, M., Nolan, A., Wiseman-Orr, L. (2013) Pain assessment in animals. Companion Animal. 34:2-6.)

APPENDICES

<u>Appendix A:</u> Count of canine breeds that underwent cruciate or hip surgery at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Canine Breed	Number of Individuals
Airedale Terrier	2
Akita	4
Alaskan Malamute	3
American Bulldog	2
American Cocker Spaniel	6
American Eskimo	2
American Staffordshire Terrier	36
Australian Cattle Dog	6
Australian Shepherd	10
Beagle	6
Beauceron	1
Belgian Malinois	4
Bernese Mountain Dog	3
Bichon Frise	4
Border Collie	7
Border Terrier	1
Boston Terrier	2
Bouvier Des Flandres	1
Boxer	28
Brittany Spaniel	1
Bullmastiff	3
Cane Corso	5
Carolina Dog	1
Cavalier King Charles Spaniel	5
Chesapeake Bay retriever	1
Chihuahua	6
Chow Chow	6
Collie	2
Dalmatian	3
Doberman Pinscher	3
English Bulldog	3
English Setter	1
English Springer Spaniel	2
Flat-coated retriever	1
Fox Terrier	2
German Shepherd	33
German Shorthaired Pointer	2
Golden Retriever	28
Goldendoodle	4
Great Dane	2

Great Pyrenees	6
Havanese	1
Hound	13
Irish Setter	1
Italian Greyhound	1
Jack Russell Terrier	3
Japanese Chin	1
Labradoodle	7
Labrador Retriever	102
Lakeland Terrier	1
Lhasa Apso	1
Maltese	6
Mastiff	9
Miniature Poodle	3
Newfoundland	5
Norwegian Elkhound	1
Papillon	3
Pembroke Welsh Corgi	1
Perro De Presa Canario	2
Plott Hound	2
Pointer	2
Pomeranian	2
Portuguese Water Dog	2
Pug	2
Puli	1
Rat Terrier	2
Redbone Coonhound	2
Rhodesian Ridgeback	2
Rottweiler	25
Saint Bernard	2
Samoyed	1
Shar-Pei	2
Shetland Sheepdog	1
Shih Tzu	4
Siberian Husky	10
Tamaskan Wolfhound	1
Terrier	4
Tibetan Terrier	1
Toy Poodle	9
Vizsla	1
Weimaraner	1
West Highland White Terrier	4
Whippet	1
Yorkshire Terrier	7

[1]Not all categories listed are AKC defined breeds

<u>Appendix B</u>: NC State University Veterinary Teaching Hospital cruciate or hip surgery study dog colors as reported by their owners and their study assigned color category .[1]

Color	Number of Dogs	Assigned Color Category
Apricot	4	Light
Beige	2	Light
Bi-color	9	Other
Black	67	Dark
Black and brindle	2	Dark
Black and brown	14	Dark
Black and cream	1	Other
Black and gray	1	Dark
Black and red	2	Dark
Black and tan	56	Dark
Black and white	34	Other
Black, brown and white	7	Other
Black, tan and white	4	Other
Blonde	2	Light
Blue	5	Dark
Blue and white	1	Other
Blue brindle	3	Dark
Blue merle	4	Other
Brindle	17	Dark
Brindle and white	4	Other
Brown	17	Dark
Brown and white	18	Other
Champaign	2	Light
Chocolate	15	Dark
Cream	5	Light
Fawn	14	Light
Fawn and white	2	Light
Golden	25	Light

Gray	6	Other
Gray and white	3	Light
Light deadgrass	1	Light
Merle	2	Other
Red	13	Other
Red and tan	2	Other
Red and white	4	Other
Red brindle	1	Other
Sable	8	Dark
Sable and white	2	Light
Silver	3	Light
Tan	16	Light
Tan and white	5	Light
Tri color	8	Other
White	39	Light
White and buff	1	Light
White and cream	2	Light
Yellow	36	Light
Not indicated	9	None
Total	**499**	**499**

[1]All color are listed by the dogs' primary color first followed by the secondary and third color.

<u>Appendix C:</u> Age of canines that were included in cruciate or hip surgeries studied at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Age	Dog Count
<1	9
1-1.9	77
2-2.9	61
3-3.9	48
4-4.9	49
5-5.9	43
6-6.9	48
7-7.9	49
8-8.9	45
9-9.9	18
10-10.9	17
11-11.9	22
12-12.9	7
13-13.9	3
14-14.9	2
15 and up	1
Total	**499**

<u>Appendix D</u>: Top 10 cities that owners traveled from to bring their canine to have cruciate or hip surgery at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

City	Number of Individuals
Apex	9
Cary	15
Chapel Hill	12
Charlotte	15
Durham	8
Fayetteville	19
Greensboro	9

Holly Springs	8
Raleigh	103
Virginia Beach	22
Total	**220**

Appendix E: **Mileage traveled by owners of dogs who underwent cruciate or hip surgery at NC State University Veterinary Teaching Hospital from January 2013 through July 2018.**

Mileage traveled (miles)	Number of individuals
<24	173
25-49	43
50-74	57
75-99	41
Over 100	181
NA[1]	4
Total	**499**

[1]City was not indicated on the file hence could not figure out mileage.

Appendix F: **List of supplements provided by owners of dogs who underwent cruciate or hip surgery at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.**

List of supplements	Number of dogs
Cosequin	2
Daily multivitamin	1
Dasuquin	3
Fatty acid supplement	1
Fish oil	13
Fish oil + another supplement	11
Glucosamine	22
Glucosamine + another supplement	7
Hemp protein	1
Jing Tang herbal supplement	1
Joint supplement	3
Nupro joint supplement powder	1
Omega 3 fatty acid supplement	13
Pancreatic enzyme powder	1
Probiotic	4
Salmon oil	1

Vitamin E	2
Not provided or none	412
Total	**499**

Appendix G: Noted health problems of canines who had cruciate or hip surgery performed at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.[1]

Noted health problem	Number of dogs
Addison's disease	1
Allergies	18
Allergies and arthritis	1
Amputation	1
Atopic dermatitis	3
Bradycardia	1
Bronchitis	1
Chronic kidney disease and heart murmur	1
Chronic vomiting and diarrhea	1
Cleft palate, oronasal fistulas, eye enucleation	1
Colitis	1
Collapsing trachea and enlarged heart	1
Conjunctivitis	1
Cushing's Disease	1
Diabetes mellitus, arthritis and cataracts	1
Heart murmur	5
Heartworm	1
Hypothyroidism	2
Inflammatory Bowel Disease	1
Intervertebral Disc Disease	1
Lyme disease	2
Mass on chest	1
Mass on neck	1

Mitral valve endocarditis	1
Obese	1
Osteoarthritis	8
Penile amputation and scrotal ablation	1
Seizures	5
Skin lesion	1
Skin rash	2
Squamous cell carcinoma	1
Subcutaneous masses	1
UTI	2
None	428
Total	**499**

[1] All noted health problems were provided by the owner on the day of consultation for cruciate or hip surgery

<u>Appendix H:</u> Most popular diet manufacturer of canines who had cruciate or hip surgery performed at the NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Type of diet	Number of canines on diet
Beneful	10
Blue Buffalo	31
Grain free	7
Hills	8
Iams	11
Pedigree	6
Purina	31
Royal Canin	13
Science Diet	12
Taste of the Wild	6
Raw diet	18
Not provided	346
Total	**499**

<u>Appendix I:</u> List of comments provided after observing canine patients after hip or cruciate surgery at NC State University Veterinary Teaching Hospital from January 2013 through July 2018.

Comments	Pain score 6 hours	Pain score 12 hours	Pain score 18 hours
Muzzle was used for restraint.	1.0	1.0	0.5
Dog regurgitated hydromorphone.	0.0	1.0	1.0
Dog was painful and agitated. Attempted to bite. Sling was bothering the dog.	0.5	0.5	2.0
Dog bit the technician.	0.5	2.0	No Pain Score
Incision is swelling.	1.0	1.0	1.5
Dog was very painful when walking.	1.0	1.0	No Pain Score
Dog would not walk and was painful.	1.0	1.0	1.0
Caution, dog is painful and will bite.	1.0	1.0	1.5
Dog is hesitant to stand up.	1.0	1.0	1.0
Very reactive and screams bloody murder when moved out of cage. Very anxious and whiney.	1.0	1.0	No Pain Score
Significant pain and vocalization.	1.5	1.5	3.0
Very painful. Panting and whining.	2.0	1.0	No Pain Score