ULTRASOUND GUIDED VERSUS PALPATION GUIDED INTRA-ARTICULAR INJECTION OF THE CANINE HIP JOINT

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A THESIS

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ABSTRACT

Canine hip dysplasia is a common orthopedic condition that results in progressive and often debilitating osteoarthritis. Intra-articular drug therapy holds much promise in the management of this chronic condition but intra-articular injection of the canine hip joint is challenging using a conventional palpation-guided approach. This thesis describes a feasibility and accuracy study to investigate a novel ultrasound guided imaging technique for intra-articular injection of the canine cadaver hip joint.

Ultrasound-guided hip injection could be performed using a caudoventrolateral approach and excellent correlation was present between the sonoanatomy and gross anatomy. The results show that ultrasound-guided hip injection using a caudoventrolateral approach has similar to or better accuracy than that of a palpation-guided technique. No iatrogenic damage was noted with the procedure.

Ultrasound-guided hip injection using a caudoventrolateral approach is an accurate and minimally invasive technique for injection of the canine cadaver hip joint.
To my beloved parents, brothers and grandma

Jim, Donna, Joseph, Michael and Yvonne

For their unbridled love and support
DECLARATION

This is to certify that

(i) the thesis comprises only my original work towards the Masters except where indicated in the Preface,

(ii) due acknowledgement has been made in the text to all other material used,

(iii) the thesis is 14,188 words in length, inclusive of footnotes, but exclusive of tables, bibliographies and appendices.
PREFACE

Part of this work (Chapter 3) has been published in the following paper:


Part of this work (Chapter 4) has been published in the following paper:

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Chapter 1

INTRODUCTION

1. Motivation

Canine hip dysplasia is a common inherited condition and leads to progressive pain and dysfunction in adult dogs. Both non-surgical and surgical treatments exist but are limited by their cost, variable efficacy and potential side effects. Intra-articular drug therapy has been advocated as a viable treatment alternative however its efficacy depends on accurate delivery of the therapeutic drug within a joint. Ultrasound-guidance is the imaging modality of choice for accurate delivery of drug therapy within the human hip joint. Currently, no simple ultrasound-guided technique for accurate injection of the canine hip exists. In addition, comparisons of accuracy and safety between ultrasound guidance and a conventional palpation-guided technique have not been made. Thus, a simple, safe and accurate ultrasound-guided imaging technique for injection of the canine hip joint is required.

2. Thesis Hypothesis

Ultrasound-guided injection of the canine hip joint is an accurate and safe alternative to conventional palpation-guided injection.
3. Objectives of Thesis

The objectives of the thesis are three-fold:

i) To describe the regional sonoanatomy of the canine hip joint

ii) To develop a novel, simple ultrasound-guided hip injection technique that can be readily adopted in a general practice setting

iii) To compare the accuracy and safety of the newly developed ultrasound-guided technique with a conventional palpation-guided technique in the canine cadaver.

4. Outline of Thesis

The thesis is composed of five chapters. Chapter 1 contains the introduction of this work. The second chapter is a literature review. It provides an overview of the anatomy and physiology of the canine hip joint. This is followed by a discussion of the pathogenesis, diagnosis and treatment of canine hip dysplasia. A detailed review of the current intra-articular drug therapies available for dogs is provided, the current imaging modalities used to guide intra-articular drug therapy, followed by a summary of my conclusions of this review.
In Chapter 3, the sonoanatomy of the canine hip joint is first described. Then a novel, simple, stepwise approach to ultrasound-guided canine hip injection is detailed.

In Chapter 4, a direct comparison of accuracy and safety is made between the newly developed ultrasound-guided hip injection technique and a conventional palpation-guided technique.

In Chapter 5, I draw conclusions from my work before discussing future research recommendations.
Chapter 2

LITERATURE REVIEW

2.1 Anatomy and physiology of synovial joints

The relevant joint anatomy is summarized from Evans (1993, pp. 219-257)\(^1\) and Gerwin et al (2006).\(^2\) All of the definitions used follow the established nomenclature of modern anatomy textbooks and research publications.

A synovial joint (formally known as a diarthrodial joint)\(^3\) is one of the three main groups of joint (the others being fibrous and cartilaginous) found within the canine skeleton. All synovial joints consist of a joint cavity, joint capsule with inner synovial membrane, synovial fluid and articular cartilage.

The joint capsule is composed of an outer fibrous membrane and an inner synovial membrane. The synovial membrane is further divided into an inner layer (intima) and deeper (subintima) layer. Type A and B synoviocytes are the cells that compose the intima and have two separate functions. Type A synoviocytes are macrophages which are responsible for processing and removing debris within the membrane. Type B synoviocytes compromise approximately two thirds of the synovial membrane cells. They are responsible for producing hyaluronic acid (a large glycosaminoglycan), which combines with an ultra-filtrate of plasma to form synovial fluid. The synovial fluid is critical for providing both lubrication between the articular surfaces and nutrients for chondrocyte metabolism. The subintima layer is composed predominantly of adipose, fibrous and areolar tissue.
Hyaline cartilage forms the articular surface of the joints. It is composed of chondrocytes (2%) embedded in an extracellular matrix consisting of 80% water, a collagen type 2 network (approx. 15%) and proteoglycans (approx. 10%). The collagen network provides tensile strength to the cartilage while the hydrophilic proteoglycans absorb water, providing the cartilage with the ability to resist compression and distribute load. Articular cartilage contains no blood vessels or nerves and must receive its nutrition from the synovium.

An interface of calcified cartilage exists between the articular cartilage and the subchondral bone. The calcified cartilage consists of hydroxyapatite encrusted type 2 collagen fibrils and metabolically inactive chondrocytes. A transition zone, known as the “tidemark”, marks the junction between calcified and uncalcified cartilage. The subchondral bone is thinner than cortical bone in other sites and its stiffness modifies the compressive forces that the articular cartilage is subject to. The major bone plates in the supporting cancellous bone are arranged perpendicular to the predominating stress, allowing the subchondral bone to undergo significantly more deformation than the cortical bone shaft.

2.11 Anatomy of the canine hip joint

The hip joint (synonymous with the coxofemoral joint) is a synovial “ball and socket” joint formed from the articulation of the head of the femur with the acetabulum of the pelvis. A band of fibrocartilage applied to the rim of the acetabulum (acetabular lip) increases the depth of the joint which extends across the ventromedial aspect of the
acetabulum as the transverse acetabular ligament. The ligament of the head of the femur originates from the fovea of the head of the femur and inserts onto the acetabulum by blending with the perisoteum of the actabular fossa and the transverse acetabular ligament. The joint is encapsulated by the fibrous joint capsule which attaches medially at the edge of the acetabular lip and laterally on the neck of the femur.

The notable muscles and subcutaneous tissues of the hip and lateral pelvis include:

i)  *Articularis coxae* – a small, spindle-shaped muscle lying on the cranioventral aspect of the hip joint capsule. It arises from the lateral surface of the ilium and inserts on the neck of the femur.

ii)  *Gluteus profundus* – is the deepest of the gluteal muscles. It is covered by the gluteus medius and piriformis. It originates from the shaft of the ilium, converges over the hip joint and inserts via a strong tendon onto the cranial aspect of the greater trochanter of the femur.

iii)  *Gluteus medius* – originates from the gluteal surface of the ilium (cranial to the gluteus profundus) and covers the gluteus profundus. The majority of the muscle is covered by the gluteal fascia and skin, while the caudal aspect is covered by the gluteus superficialis. It is approx. 2.5 to 3.5cm thick and inserts onto the proximal aspect of the greater trochanter of the femur.

iv)  *Piriformis* – a small, fusiform muscle that lies caudal and medial to the *gluteus medius* and inserts at the proximal aspect of the greater trochanter of the femur.
v) *Gluteus superficialis* – the most superficial of the gluteal muscles. It is a small, flat (approx. 1cm thick) muscle that arises from the gluteal fascia and tuber sacrale of the ilium. It covers portions of the gluteus medius and piriformis and its tendon of insertion runs over the greater trochanter before inserting on the smaller third trochanter

vi) *Tensor fasciae latae* – is a triangular shaped muscle that arises proximally from the aponeurosis of the gluteus medius muscle and tuber coxae of the ilium. It fuses distally with a layer of fascia known as the fascia lata.

The deep fascia of the pelvis is composed of the gluteal fascia and fascia lata. The gluteal fascia comes from the lumbosacral fascia over the crest of the ilium. It covers the gluteal muscles and tensor fascia latae before radiating into the fascia lata over the lateral surface of the thigh.

The neurovascular structures that are in close association with the hip joint include the ischiatic nerve, and caudal gluteal and lateral circumflex femoral vessels. Together, the ischiatic nerve and caudal gluteal structures run parallel with the ischiatic spine before running distally underneath the gluteus superficialis muscle. After providing branches to the joint capsule, they pass immediately caudal to the greater trochanter of the femur and cranial to the ischiatic tuberosity of the pelvis, before continuing down the thigh. The lateral femoral circumflex vessels branch from the femoral artery cranioventral to the acetabulum. They send branches to the cranial parts of the joint capsule before continuing dorsally to supply the insertions of the gluteus profundus, gluteus medius and tensor fasciae latae.
2.2 Background of canine hip dysplasia

Canine hip dysplasia (CHD) is one of the most common and well researched conditions in veterinary medicine. Reported prevalence figures vary widely but are as high as 53-73% and 41-69% for two commonly affected breeds.\(^4\) CHD was first described by Schnell in 1937 and was termed \textit{bilateral congenital subluxation}.\(^5\) The term, hip “dysplasia”, derived from Latin, is literally translated as “abnormal growth or development” of the hip. It wasn’t until 1966, that Henricson et al introduced a more descriptive definition; hip dysplasia is a “varying degree of laxity of the hip joint permitting subluxation during early life, giving rise to varying degrees of shallow acetabulum and flattening of the femoral head, finally inevitably leading to osteoarthritis”.\(^6\) It is still widely accepted today that joint laxity at a young age is associated with the subsequent development of osteoarthritis (OA) in dogs with CHD.

2.2.1 Pathogenesis

 Unlike in man CHD is not a congenital condition, with the coxofemoral joint beginning as a normal congruent unit at birth.\(^6\) CHD has been shown to have a polygenic mode of inheritance (termed \textit{quantitative} trait) and consequently expresses itself on a continuous scale from normal to severely abnormal.\(^7, 8\) The expression of the disease is not only determined by the frequency and expression of the deleterious genes but also by many environmental influences. For example, Kealey et al (1992) showed that limiting food consumption in juvenile dogs that were genetically susceptible to CHD could reduce the frequency and severity of CHD at an older age.\(^3\) This is important, as two dogs with the
same “dysplastic” genotype may have very different phenotypes depending on their environmental differences.

It is the development of coxofemoral joint laxity that is the inciting factor for the development of a dysplastic joint and subsequent OA. Powerful pelvic and thigh muscles are predominantly responsible for providing stability to the hip joint. Genetically susceptible dogs become dysplastic when these stabilizing muscles fail to mature at the same rate as the skeletal structures.9-11 The critical time period in the development of the canine coxofemoral joint is in the first 60 days of life.10 It is during this time that the peri-articular soft tissues are immature and the muscles and nerves have limited function. These tissues are soft and adaptive to stress but have what is termed an “elastic limit”.10 If the demands from weight bearing and other activities exceeds the strength of the supporting soft tissues then the articular surfaces of the femoral head and acetabulum are forcibly separated. This subsequently leads to incongruency of the hip joint which is irreversible if the elastic limit of the soft tissues is exceeded.10 The resulting instability and abnormal mechanical stresses on the joint lead to the development of OA.

Stretching of the joint capsules and ligament of the head of the femoral head are noted as early as 2 weeks of age. Synovitis, fibroplasia of the ligament of the femoral head and joint effusion are present by 4 weeks, while by 12 weeks changes to both the synovium and cartilage are present.8,12 The articular cartilage changes show a predilection for areas that are prone to weight bearing or shearing forces.8 In the lax hip, subluxation of the femoral head is most severe towards the dorsolateral side. Subsequently, increased load is sustained at the medial aspect of the femoral head and dorsal aspect of the acetabulum
during weight-bearing. These altered forces acting on a plastic and immature skeleton can result in malformation of both the femoral head and acetabulum, further compromising joint stability.\(^8,13\)

Damage to chondrocytes leads to release of enzymes, which degrade the proteoglycan matrix. This degradation then leads to focal swelling and softening of the cartilage secondary to water imbibition.\(^8\) These early changes occur at the cartilage surface and are accompanied by chondrocyte proliferation adjacent to the softened matrix and loss of chondrocytes within the early lesion. The loss of proteoglycan content subsequently leads to a loss of cartilage elasticity and consequent disruption to its shock absorbing capacity. The result is that minor stresses, such as those that occur on the sub-luxated femoral head, lead to the formation of fissures (fibrillation) in the softened and weakened cartilage, leading to more cell damage and loss of elasticity. Initially fissures are orientated parallel to the articular surface, progressing to more vertical clefts and eventually reaching the subchondral bone.\(^2\) Once begun, fibrillation is a self-perpetuating disease.

Continual overloading leads to microfractures in the subchondral bone of the femoral head and dorsal acetabular rim. The bone becomes hard and sclerotic as it attempts to heal which leads to reduced shock absorbing capacity. The subsequent increased force to the overlying cartilage causes more cartilage degeneration. Damage to Sharpey’s fibers (attachments of soft tissues to bone) stimulates osteophyte formation at the acetabulum and femoral neck and the cycle of bone modeling and cartilage degeneration continues. The inevitable consequence of these changes is varying degrees of pain and dysfunction. Sources of pain include microtears in the joint capsule and ligament of the femoral head,
microfractures and collapse of the subchondral bone of the femoral head and acetabulum, vascular engorgement of the bone and synovitis.\textsuperscript{14}

\textbf{2.2.3 Diagnosis}

The clinical presentation of CHD varies but all dogs typically present with some degree of hind limb lameness. Joint manipulation causes pain, especially on extension and abduction of the hip joint. Pelvic muscle atrophy, joint subluxation and crepitus and reduced range of joint motion are common findings. The clinical suspicion of CHD may be confirmed with radiography. Radiographic features of CHD include mild subluxation and widening of the medial joint space in early disease, while peri-articular osteophyte formation, modeling of the acetabulum and femoral head/neck and marked pelvic limb muscle atrophy is present in the advanced disease stages.

\textbf{2.3 Treatments}

The treatment of OA has typically been directed towards the palliation of the painful clinical signs associated with the disease. Treatment for OA can be broadly categorized into conservative and surgical treatments.

\textbf{2.3.1 Conservative treatments}

a) Non-steroidal anti-inflammatory drugs (NSAIDs)

NSAIDs are the current mainstay of pain therapy in canine OA and are one of the most commonly used classes of pharmaceuticals in canine practice, accounting for
approximately US$330 million of the global NSAID market.\textsuperscript{15} The major action of the NSAIDs is the blocking of pro-inflammatory prostaglandin synthesis by binding to and inhibiting the action of cyclo-oxygenase enzymes. Systematic reviews have reported a moderate to high level of evidence supporting the use of NSAIDs for the management of OA in dogs.\textsuperscript{16-18} It should be noted however that these studies were hampered by a low number of reports with placebo controlled groups. The adverse effects of NSAIDs have been well documented and tolerance to the drug over time is a potential consequence of long term use.\textsuperscript{17,19} Two systematic reviews have suggested that serious adverse effects (such as gastrointestinal perforation) occur at a very low frequency, but both reviews concluded that the majority of the assessed studies were of low to moderate quality, rendering accurate conclusions challenging.\textsuperscript{17,20}

b) Weight reduction and Physical Rehabilitation

Current research in humans suggests that obesity is a risk factor for the progression of OA and that weight loss is a useful tool in the management of OA.\textsuperscript{21} Similar findings have been reported in canine patients with both subjective and objective reductions in lameness following institution of a weight loss program.\textsuperscript{22-24} Despite these findings a reluctance to confront owners on the issue of canine obesity and owner non-compliance once a weight loss program has been initiated has likely contributed to the growing prevalence of obesity in the canine population.\textsuperscript{25}
Comprehensive studies investigating the efficacy of therapeutic exercises in dogs with osteoarthritis are lacking. Anecdotal evidence suggests that low-impact exercise is effective in the management of canine osteoarthritis as it is in people. This was recently highlighted in a study that showed that twice weekly swimming for 8-weeks improved lameness, joint mobility, weight-bearing, pain on palpation and overall score.\textsuperscript{26} Further, large-scale studies investigating the use of physical rehabilitation in the management of canine osteoarthritis are needed.

c) Amantadine

Amantadine, an anti-viral drug, is also an N-methyl-D-aspartate (NMDA) antagonist that antagonizes central pain sensitization and is believed to have a role in augmenting the effect of other pain-relieving medications.\textsuperscript{27} In a recent study, a significant reduction in lameness was reported in dogs receiving amantadine in combination with a NSAID compared to dogs receiving the same NSAID alone.\textsuperscript{28} Despite these differences, no objective outcome measures were assessed and it is unclear whether these findings can be extrapolated to other NSAIDs.

d) Omega-3 fatty acids

Omega-3 fatty acids, namely eicosapentaenoic and docosahexaenoic acid, are found in high quantities in fish and flax seed oils. Omega-3 fatty acids are believed to have both direct and indirect anti-inflammatory effects.\textsuperscript{29} Recently, two randomized, double blinded, clinical trials assessed the pain relieving effect of a test diet rich in omega-3 fatty acids to a conventional diet in a group of osteoarthritic dogs.\textsuperscript{30, 31} Both studies revealed a
significant increase in peak vertical force of footfall in dogs receiving the test diet but not the control diet over a 12 and 13-week time period, respectively. Although significant differences were identified in objective outcomes, both study populations were small. In addition, the degree of initial impairment of the dogs in one study was described as only mild-moderate, while the degree of impairment was not noted in the other study. Subsequently, larger and longer term studies with a more heterogeneously impaired study population are required before any definitive conclusions regarding the efficacy of omega-3 fatty acids can be made.

e) Pentosan polysulphate

Pentosan polysulphate is a polysulphated polysaccharide, composed of semisynthetic polysulphated xylan. It has weak anti-inflammatory effects and has the ability to limit cartilage degradation via inhibition of cartilage degrading enzymes and stimulation of chondrocytic proteoglycan synthesis. Two clinical trials have reported the efficacy of pentosan polysulfate for the treatment of osteoarthritis in dogs. The results of both studies were contradictory with the results of one study indicating a positive effect subjectively and the results of the other study indicating no positive effect subjectively. With the contradiction of results and low number of controlled clinical trials, additional studies are required before scientifically sound recommendations can be made regarding the use of pentosan polysulfate for the management of canine OA.
f) Glucosamine and chondroitin sulphate

Glucosamine and chondroitin sulphate are components of many dietary supplements used to manage OA in several species. Two clinical trials have reported the use of glucosamine and chondroitin sulphate for the treatment of canine osteoarthritis.34,35 The first study was a prospective, double-blinded, placebo-controlled study in which changes were assessed objectively and subjectively in 71 dogs. No significant difference in objective parameters were found in the glucosamine-chondroitin group compared to placebo.34 The second study was a prospective, double-blinded trial in which the effects of treatment were compared to a positive control and assessed subjectively in 35 dogs.35 Contrary to the previous study, these dogs showed significant improvements in 3 out of the 5 subjective measures but only at the final assessment point. Evidence to support the use of glucosamine and chondroitin is thus limited; however the superior design, larger study size and objective assessment measures of the study that failed to find an effect of glucosamine and chondroitin administration would provide greater support to these results than to the limited positive results of the smaller study.

2.3.2 Surgical Treatments

a) Femoral head and neck excision

Femoral head and neck excision (FHNE) is a salvage procedure that is reserved for dogs with hip dysplasia when pain cannot be controlled with conservative treatment or when other surgical therapies are either not indicated or cost prohibitive. Removing the femoral head and neck allows for the development of a fibrous pseudoarthrosis which
theoretically leads to pain free ambulation. Limb shortening, muscle atrophy, reduced range of motion and persistent pain during passive range of motion are often seen post-operatively.\textsuperscript{36, 37} Scientifically sound assessments of the efficacy of FHNE are difficult due to the retrospective nature of many of the studies and the lack of objective outcome measures.\textsuperscript{38-40} The results of gait analysis in the only objective study revealed functional impairment in all 17 dogs that were assessed and unsatisfactory results in 42\% of animals after FHNE.\textsuperscript{37} The authors of this study concluded that FHNE should be restricted to exceptional circumstances in which joint preservation is not possible or joint replacement is contraindicated.

b) Total hip replacement

Total hip replacement (THR) is considered the procedure that most effectively reestablishes normal joint mechanics and pain-free function in dogs with hip OA. Greater than 90\% of dogs undergoing THR have good or excellent function after surgery.\textsuperscript{41-43} Despite excellent long-term results, the procedure is not without risks, with complication rates of 12 to 17\% being reported.\textsuperscript{44, 45} Reported complications include hip dislocation, implant loosening, implant failure, femoral fracture, infection and sciatic neuropaxia.\textsuperscript{46} Furthermore, THR places a heavy financial burden on the owner with the procedure being significantly more expensive than other surgical treatment options.

c) Hip denervation

Hip denervation involves curettage of the perisoteum along the acetabular rim, with transection of microscopic nerves supplying the joint capsule and subsequent reduced
pain sensation. The procedure is advocated as a simple, low cost alternative to FHNE or THR. Despite “improvement” in 90-96% of dogs, prospective, blinded and randomized clinical trials are lacking. In addition the majority of studies lack any objective assessment outcomes leading to debate regarding the efficacy of the procedure. Two objective, albeit small studies, reported gait analysis results in osteoarthritic dogs pre and post hip denervation. Both studies reported no significant difference in peak vertical force between pre and post-operative evaluations. Evidence to support the use of hip denervation is thus limited and until larger, prospective studies are conducted, hip denervation cannot be currently considered a valid option for the treatment of canine hip OA.

2.3.3 Intra-articular therapy

Intra-articular (IA) therapy is widely used in both human and equine patients for the treatment of OA. Unlike many other diseases, the management of OA is amenable to both systemic and local intra-articular therapy. While most efforts in canine medicine have concentrated on the development of systemic treatments, such agents bear risk of systemic side effects or poor efficacy. IA drug therapy is an attractive treatment alternative as the drug can be injected directly into the affected joint, ensuring appropriate drug concentrations at the site of action and minimising systemic side effects. Because of the current therapeutic deficiencies in the management of canine OA, several IA
agents have been recently investigated in a clinical setting as potential treatment alternatives in the dog.

a) Mesenchymal stem cells

Regenerative medicine, including mesenchymal stem cell (MSC) based tissue engineering has become one of the most intensively research fields in both human and veterinary medicine. Mesenchymal stem cells are a population of undifferentiated multipotent cells harvested from a variety of sources, including bone marrow and adipose tissue. These cells have the potential to differentiate into a number of cell lines, (e.g. bone, cartilage, fat and muscle) and have the ability of self-renewal via replication. The action of MSCs is complex and incompletely understood but is thought to occur by two mechanisms: 1) Differentiation into specific cellular phenotypes such as chondrocytes or fibroblasts, 2) The production of various bioactive proteins such as growth factors and chemotactic agents. These factors then act locally producing anabolic effects, enhancing neovascularization and recruiting additional stem cells to the site of injury.

Due to the easy and repeatable access of subcutaneous tissue, the simple isolation procedure and larger cellular yield compared to bone marrow, the majority of clinical studies in canine OA patients have investigated the use of adipose derived mesenchymal stem cells (AD-MSCs). In a multicenter study, Black et al (2007) reported a significant improvement in subjective outcome measures in a population of 14 dogs with elbow OA treated with intra-articular AD-MSCs. Unfortunately, no control group was used and the sample size was small. The same authors followed this first study with a randomized,
double blinded, multicenter, controlled clinical trial. They demonstrated a significant improvement in lameness score compared to controls in osteoarthritic dogs receiving a single intra-articular hip injection of AD-MSCs.\textsuperscript{57} This effect was seen at all time points during the 90 day trial. Although results are encouraging, the sample population was again small and no objective outcomes were assessed.

In the first objective study reported, Vilar et al (2013) documented a significant improvement in peak vertical force and vertical impulse in a group of osteoarthritic dogs receiving a single intra-articular injection of AD-MSCs.\textsuperscript{58} This effect however was only evident at the first time point (30 days post injection) after which values returned to baseline. Further research from the same authors supported these findings.\textsuperscript{59} Vilar et al (2016) documented a significant improvement in peak vertical force and vertical impulse in a small group of clinically affected dogs, however, once again this effect did not persist past the first time point (30 days post injection).

b) Hyaluronan

Hyaluronan (hyaluronic acid) is a high molecular weight, unbranched polysaccharide, produced by chondrocytes and synoviocytes and found within articular cartilage and synovial fluid. Normally, hyaluronan acts as a major lubricant and a shock absorber and provides joints with a frictionless smooth gliding motion. However, hyaluronan in osteoarthritic joints has been shown to be of abnormally low molecular weight and of reduced concentration, hastening the degenerative changes of the osteoarthritis pathway.\textsuperscript{60} The mechanisms by which intra-articular hyaluronan may lead to
improvement in clinical signs are complex but are believed to include restoration of viscoelasticity and lubrication, anti-nociceptive and anti-inflammatory effects, enhancement of anabolic processes and inhibition of catabolic processes. Results in people indicate that intra-articular hyaluronan administration significantly reduces symptoms and improves patients’ mobility, and beneficial modifications in the progression of joint damage have been documented in canine animal models.

Although intra-articular hyaluronan has been used experimentally in canine osteoarthritis models, reports of its use in clinical patients are sparse. In the only clinical study to date, 36 dogs with clinical OA were randomly assigned to receive either 2 doses (separated by 3 weeks) of intra-articular hyaluronan or a NSAID (positive control) over a 42 day period. At the 6-week time point approximately twice the proportion of dogs which received hyaluronan compared to the control group improved in lameness scores and this difference was statistically significant. There were no reported adverse effects in the hyaluronan group. Although no objective outcomes were measured, initial findings are encouraging and future research is required to determine whether the improvement in subjective outcomes correlate with improved objective data.

c) Botulinum toxin type A

Botulinum toxin type A (BoNTA) is a potent neurotoxin produced by *Clostridium botulinum*. Its primary mechanism of action is the inhibition of acetylcholine release into the synaptic cleft in cholinergic nerve terminals resulting in muscle paralysis. In addition, BoNTA has been found to inhibit several neurotransmitters involved with
peripheral pain perception in OA.\textsuperscript{68,69} This finding has led to considerable interest in the use of BoNTA as a potential intraarticular agent for the management of the painful osteoarthritic joint with early human studies showing much promise.\textsuperscript{70,71}

A pilot study investigated the use of intra-articular BoNTA in a group of osteoarthritic dogs.\textsuperscript{72} The authors reported improvement in both subjective and objective outcomes in 45 (80\%) of dogs with the only potential adverse effect being mild temporary swelling at the injection site. Recently, a randomized, double-blinded, placebo controlled clinical trial was performed investigating the efficacy and safety of intra-articular BoNTA in 36 osteoarthritic dogs.\textsuperscript{73} The authors reported a statistically significant improvement from baseline to week 12 in the treatment group for the main outcome variables of peak vertical force, vertical impulse and owner-evaluated assessment, but there was no coincident improvement in the subjective pain score. No significant differences were detected in the control group. Adverse effects were not detected in either group. The results of this report suggest that intraarticular BoNTA is safe and has some efficacy in the treatment of osteoarthritic joint pain. Long-term studies using a larger population of dogs are required to confirm these initial findings and determine the duration of effective pain relief.

d) Autologous platelet concentrate

Autologous platelet concentrate (APC), which is a platelet rich filtrate of blood, holds promise as a potential intra-articular therapy for canine OA. The therapeutic effects of APC are believed to be as a result of anti-inflammatory and anabolic properties
attributable to numerous growth factors and cytokines released from platelet alpha granules.\textsuperscript{74} Recently, a randomized, double-blinded clinical trial was performed investigating the use of a single intra-articular injection of ACP in a group of 20 dogs affected with OA.\textsuperscript{75} For the treatment group, there was a significant improvement in subjectively assessed lameness/activity scores and a significant increase in peak vertical force values for the clinically affected limb at 12 weeks post-injection. No significant differences were detected within the control group at 12 weeks post-injection. No adverse effects were noted in either group. These initial results are very encouraging, and further studies are required to determine the optimal dose and the duration of effect.

\textbf{2.4 Existing Imaging Guidance Techniques for Intra-articular Injection}

In humans, studies have reported a direct correlation between the accuracy of intra-articular injection and therapeutic outcome.\textsuperscript{76, 77} In addition, accurate intra-articular injections are associated with significantly less procedural pain than inaccurate injections.\textsuperscript{76} The deep location and close proximity to important neurovascular structures makes intra-articular injection of the hip challenging. Intra-articular injection may be achievable via the use of palpable landmarks; however the failure rate in humans is high.\textsuperscript{78} To date, the accuracy of palpation guided intra-articular injection of the canine hip has not been reported. Siegfried et al (2005) investigated the accuracy of palpation-guided percutaneous synovial biopsy of several joints in the dog. An accuracy rate of
only 7.5% was achieved when targeting the hip joint and the authors concluded that, consistent with the findings in people, imaging guidance is recommended.\textsuperscript{79}

Ultrasound and fluoroscopy are the imaging modalities of choice to guide intra-articular injections of the human hip, with reported accuracy rates of up to 100%.\textsuperscript{80, 81} Despite comparable accuracy rates, ultrasound has several advantages over fluoroscopic guidance, including: lack of ionizing radiation, greater availability, visualization of neurovascular structures, and the ability to visualize the needle entering the joint in “real time”.

In the only canine ultrasound-guided hip injection study to date, Bergamino and colleagues (2015) investigated the use of ultrasound-guidance for intra-articular injection of the canine hip joint using a dorsolateral approach in a group of cadavers.\textsuperscript{82} Although the technique was both feasible and accurate (81.8% accuracy rate), these authors’ description of the technique can be criticized, as it is challenging to interpret. In addition, their assessment of injection was not blinded and no comparison of accuracy or safety with a conventional palpation-guided approach to the hip joint was performed. Given that the use of an ultrasound-guided hip injection technique has huge potential in general practice, where experience with ultrasound-guided procedures is more limited, there remains a clear need for a simple, step-wise description to localizing and targeting the canine hip joint with ultrasound-guidance. Finally, if such a technique is going to be readily adopted in general practice the accuracy and safety of the technique needs to be robustly compared to a conventional palpation-guided intra-articular hip injection technique.
2.5 Summary

The treatment of chronic OA in dogs poses many challenges to veterinarians. Whilst NSAIDs are currently the mainstay of pain therapy, they can be associated with insufficient pain control and adverse effects. Intra-articular therapy has recently been advocated as an attractive therapeutic alternative, and although further research is required, early results are encouraging. A growing body of evidence supports the theory that the therapeutic outcome of intra-articular agents is dependent on accuracy of injection. Due to its deep location and close proximity to neurovascular structures accurate injection into the hip joint space is challenging. Imaging guidance is commonly employed in humans to assist with intra-articular hip injection and in that species is significantly more accurate than palpation-guided methods. Both fluoroscopy and ultrasound are the imaging modalities of choice, however the greater availability, lack of ionizing radiation and ability to visualize the needle dynamically make ultrasound guidance the logical choice for application in veterinary practice. Currently, there is no simple, step-wise technique described to assist general practitioners with ultrasound guided hip injection in the dog. In addition, there are currently no reports comparing such an ultrasound-guided technique to a conventional palpation-guided method of hip injection.
Chapter 3

A SIMPLE ULTRASOUND-GUIDED APPROACH FOR INTRA-ARTICULAR INJECTION OF THE CANINE HIP JOINT
A simple ultrasound-guided approach for intra-articular injection of the canine hip joint

BGI Wernham, D Tyrrell, T Whitten and S Ryan

AIMS To describe the sonography of the canine hip joint and determine the feasibility of an ultrasound-guided technique for intra-articular hip injection.

METHODS Six fresh-frozen canine cadavers and five live dogs were used to describe the sonography of the hip and develop an ultrasound-guided intra-articular injection technique of the hip joint. The hip joints of five canine cadavers were injected with 1 ml of coloured liquid latex under ultrasound guidance. The results of injection were determined via dissection after injection and the injection technique modified and refined. Once an appropriate technique had been developed, a single cadaver was frozen, sectioned and the anatomical and sonographical landmarks compared.

RESULTS The regional sonography of the canine hip joint could be easily determined and correlated well with the anatomy. The hip joint could be accurately injected under ultrasound guidance using a caudoventrilateral approach. Initial imaging of the hip joint was achieved by placing the transducer immediately proximal to the palpable greater trochanter, perpendicular to the spine. Appropriate transducer positioning for targeting the hip joint was then achieved by rotating the transducer approximately 90 degrees clockwise or anticlockwise to inject the left or right hip, respectively.

CONCLUSIONS Ultrasound-guided hip injection using a caudoventrilateral approach is feasible in the canine cadaver.

CLINICAL RELEVANCE Although this technique remains to be performed in clinical cases, it has the potential to facilitate the diagnosis of coxofemoral pain, septic arthritis and the accurate delivery of intra-articular therapeutic agents.

KEYWORDS dogs; hip joint; intra-articular injection; ultrasound

ABBREVIATIONS CHD, canine hip dysplasia; FHO, femoral head and neck osteotomy; NSAIDs, non-steroidal anti-inflammatory drugs; OA, osteoarthritis; THR, total hip replacement

Available treatments for CHD in the mature dog can be broadly categorised as surgical and non-surgical. Surgical options include femoral head and neck osteotomy (FHO), total hip replacement (THR) and denervation of the coxofemoral joint. The long-term function after FHO can be unpredictable and in one study functional results were rated as poor in 42% of animals.3 THR is generally considered to be the procedure that most effectively provides pain relief and results in the best performance in dogs with CHD; good or excellent (no or mild lameness) outcomes have been reported in 91–98% of animals following THR.4–8 Although THR has been shown to provide excellent long-term results, the procedure places a heavy financial burden on the owner and complication rates of 12 to 17% have been reported.9 The relatively low cost and complication rate and the simplicity of coxofemoral denervation has seen it advocated as an attractive alternative to FHO and THR. Recent reports of its efficacy, however, have been underwhelming.10

The current non-surgical recommendations are to promote weight control, activity restriction and long-term continuous use of drugs such as non-steroidal anti-inflammatory drugs (NSAIDs) as part of a multimodal approach.11,12 However, despite proven efficacy, the adverse effects of NSAIDs have been well documented and the duration of effective alleviation of pain can be short-lived.13,14

Because of the current therapeutic limitations in the management of canine OA, intra-articular drug therapy has been recently investigated as a potential treatment alternative. Reported intra-articular injectates in the dog include mesenchymal stem cells,15 hyaluronic acid,16 botulinum toxin17 and autologous platelet concentrate18 with all injectates showing promise. The local nature of OA makes intra-articular drug administration an attractive therapeutic option, because the drug can be injected directly into the affected joint, allowing targeted drug therapy and minimising systemic side effects.

In humans, a growing body of evidence supports the hypothesis that the therapeutic outcome of intra-articular injectates depends on the accuracy of agent delivery into the joint.20,21 Intra-articular injection of the canine hip is challenging compared with other joints, because of the relatively deep location of the joint and the close proximity of the sciatic nerve and the caudal gluteal and lateral femoral circumflex vessels.22 Although intra-articular hip injection may be performed “blindly” using palpable landmarks, the failure rate in human patients is significant.23 The accuracy rate of palpation-guided intra-articular hip injection in the dog has not been reported; however, Siegfried et al24 reported that the accuracy of palpation-guided percutaneous synovial biopsy of the canine hip joint was significantly less than for any other joint. With an accuracy of only 75%, those authors concluded that, consistent with humans, imaging guidance is recommended.

Fluoroscopy and ultrasound are the imaging modalities of choice to guide intra-articular injections of the human hip and have shown accuracy rates of up to 100%.25,26 Ultrasound-guided injection accuracy rates in the equine hip joint of 90% have also been demonstrated.27

Canine hip dysplasia (CHD) is a common inherited orthopaedic condition with a prevalence of up to 73% in certain breeds.1 CHD results in instability and subluxation of the hip joint, causing erosion of the articular cartilage and synovitis. Secondary osteoarthritis (OA) develops, causing progressive pain and lameness in adult dogs.

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Ultrasound has several advantages over fluoroscopic guidance: no exposure of the patient or operator to ionising radiation; no requirement for the use of contrast agents or cumbersome equipment; visualisation and avoidance of neuromuscular structures; can be performed in a general practice setting; and allows the operator to visualise the needle entering the joint in real time.

A recent study performed in a group of cadavers reported the feasibility and accuracy of injecting the canine hip joint via a dorsolateral approach using ultrasound guidance. Although those authors demonstrated that ultrasound-guided hip injection was both feasible and accurate, we found the description of the technique difficult to interpret. Given that the use of this technique has huge potential in general practice, where experience with ultrasound-guided procedures is more limited, we believe that a step-wise description to localising and targeting the hip joint is required.

Therefore, the objectives of our study were to describe the regional sonoanatomy of the canine hip, to illustrate an ultrasound-guided approach for coxofemoral intra-articular injection and to provide a clear description of the method that will facilitate it being readily adopted in the general practice setting.

MATERIALS AND METHODS

All procedures were approved by and in accordance with the requirements of the University of Melbourne Animal Ethics Committee. Six fresh-frozen canine cadavers and five live dogs were used to develop the ultrasound-guided approach to the hip joint. All cadavers were euthanased humane ly for reasons unrelated to hip disease. Live patients were sourced from staff and students of the University of Melbourne Veterinary Teaching Hospital. All dogs were skeletally mature and weighed between 14 and 33 kg.

All cadavers were thawed at room temperature for 48 h prior to scanning. Ultrasonographic scans were performed of the left and right hips of all dogs. All scans were performed by the first author who had approximately 3 months of ultrasound experience prior to the commencement of the study. Manual restraint without sedation was used to scan the live patients. Animals were positioned in lateral recumbency with the hip to be examined positioned uppermost. The hip joint of the limb to be examined was positioned in a weight-bearing position (no load was applied to the limb) with the femur perpendicular to the long axis of the pelvis and parallel to the sagittal plane. The hair from the hip and pelvic region was clipped, the skin cleaned with alcohol and coupling gel applied. Scanning was performed with either an 8–13 MHz linear array or 5–8 MHz curvilinear array transducer using a Siemens Acuson X300 ultrasound machine (Mountain View, CA, USA). By convention, scanning was performed with the transducer reference marker directed either cranially or dorsally. The heel of the transducer was defined as the end of the transducer opposite the reference marker. All dogs were used to determine the sonoanatomy of the hip region and the sonoanatomical landmarks for intra-articular hip injection. In addition, the live patients were used to assess the proximity of regional vascular structures using colour and power Doppler interrogation for the proposed approach and to allow a direct comparison of image quality with the cadavers.

Once an appropriate transducer location and orientation had been identified, ultrasound was used to guide the placement of a 22g 1.5-inch needle into the coxofemoral joint. In five of the cadavers, 1 ml of coloured liquid latex (Dalchem Pty Ltd, VIC, Aus) was injected into the left and right coxofemoral joints. All injections were performed by the first author. Cadavers were then chilled at 3°C for 48 h prior to evaluation of injectate distribution via dissection. The results of dissections were evaluated after each dog and used to modify and refine needle positioning techniques for subsequent dogs. A single cadaver was then frozen for 48 h at −20°C and cryosections made in a dorsal plane through the coxofemoral joint. Photographs of the anatomical section were taken to correlate the anatomical structures to the corresponding sonoanatomy.

RESULTS

The hip joint could be imaged from the lateral aspect of the patient and the joint could be targeted successfully using a caudoventrilaterial
approach. Both the linear array and curvilinear array transducer could be used to visualise the hip joint; however, the superior resolution of the higher frequency linear array transducer enabled better visualisation of the joint space. Initial imaging of the hip was achieved by placing the linear transducer on the lateral surface of the dog, with the heel of the transducer immediately proximal to the palpable greater trochanter and the long axis of the transducer perpendicular to the long axis of the spine. This position was referred to as the ‘12 o’clock’ position, using a clock-face analogy (Figure 1a). By positioning the transducer at the 12 o’clock position, osseous sonoanatomical landmarks visualised consistently were: the acetabulum, femoral head, femoral neck and proximal portion of the greater trochanter (Figure 1b). These structures were represented by a hyperechoic subchondral bone layer that cast a strong distal acoustic shadow. The articular cartilage of the femoral head was identified as a thin, hypechoic layer while the joint capsule was represented as a thin (approx. 1 mm in thickness) hyperechoic band that inserted dorsally on the acetabular rim and ventrally on the neck of the femur. The hip joint space was identified as a small, hyperechoic triangle between the femoral head and acetabulum. Superficially, the osseous structures were covered by the hyperechoic striated muscle bellies of the gluteal musculature, which was in turn were covered by the hyperechoic gluteal fascia and skin layer.

After initially placing the transducer at the 12 o’clock position, depending on the hip being imaged, the transducer was then rotated 30 degrees anticlockwise to the 11 o’clock position (Figure 2a) when imaging the left hip or 30 degrees clockwise to the 11 o’clock position when imaging the right hip. The rotation was performed while maintaining the heel of the transducer immediately proximal to the greater trochanter. This rotation orientated the long axis of the transducer into a caudoventral to craniodorsal direction. The rotation of the transducer was required because initial positioning of the transducer at the 12 o’clock position imaged the femoral head and coxofemoral joint space obliquely. The 30-degree rotation positioned the ultrasound beam in a dorsal plane relative to the femoral neck and approaching the long axis of the pelvis. The operator could be satisfied the transducer was correctly positioned when the femoral head assumed a more normal convex shape (Figure 2b). There was good correlation between the ultrasonographic images and the cryosections (Figure 3).

The ischial nerve and the caudal gluteal and lateral femoral circumflex vessels were not visible in the field of view at the 1 or 11 o’clock position. Both the ischial nerve and caudal gluteal vessels were located dorsal and caudal to the greater trochanter, with the lateral circumflex vessels located cranioventral to the acetabulum. In addition, no vasculature was detected in the field of view under colour and power Doppler interrogation from the vessels’ respective branches.

Injection of the joint space could be achieved by performing the following steps: (1) placing the needle tip between the greater trochanter and heel of the transducer (caudoventrolateral to the joint space); (2)
aligning the length of the needle so that it was parallel to the longitudinal axis of the transducer; (3) angling the needle at approximately 60 degrees relative to the skin surface (the angle adjusted according to the angle of the needle on the corresponding ultrasound image); and (4) advancing the needle through the skin, gluteal fascia and gluteal muscles in a craniodorsomedial direction towards the joint space (Figure 4a, b). Care was taken to keep the needle aligned parallel to the longitudinal axis of the transducer, with the needle being represented sonographically as a distinct hyperechogenic line while it passed through the hypoechoic muscle layers. A very subtle loss of resistance was felt as the needle pierced the joint capsule, at which point the needle tip could be seen and felt hitting the femoral head. Injection of the liquid latex occurred with minimal resistance; however, if resistance occurred, the needle tip was retracted slightly allowing injection to commence. Small echogenic speckles could be visualised exiting the tip of the needle as the latex was injected, although no visible joint capsule distension occurred with the volume of injectate used. Accurate placement of the injection was confirmed at dissection in 10 cadavers (10 hip joints) (Figure 5). A small amount of latex was consistently identified on the ventral surface of the deep gluteal muscle and was considered likely to be from contamination of the soft tissues when the needle tip exited the joint.

The large footprint of the linear array transducer and the small body weight (approx. 14 kg) of one cadaver made needle placement challenging. In this case there was only a very small distance between the greater trochanter and the heel of the transducer. This meant that the needle had to be placed more perpendicular to the skin surface in order to target the joint space, which subsequently made visualisation of the needle more challenging. There was variation in image quality between cadavers, but not in the live patients. Although the osseous structures were always visible, poor image quality in two cadavers meant that visualisation of the joint space was challenging. The poor image quality was presumed to be related to variations in the speed of autolysis post thawing. The two dogs weighed 17 kg and 20 kg, respectively. The author (Wernham) found that in these cases, injecting saline into the joint space could confirm accurate needle placement. By distending the joint with an appropriate volume of saline (approx. 3 mL), the joint space would enlarge and the joint capsule could be visualised separating from the femoral head.

**DISCUSSION**

The results of this study in the canine cadaver indicated that coxofemoral joint injection using an ultrasound-guided caudoventrolateral approach was feasible. The greater trochanter could be used as an initial landmark to guide transducer positioning, imaging of the osseous landmarks of the hip joint was possible in all cadavers and the sonography was consistent with previous reports. Coxofemoral joint injection could be successfully achieved by directing the needle into the joint space, in real time, from a caudoventrolateral to craniodorsomedial direction.

Although ultrasound guidance is commonly used to accurately deliver intra-articular therapeutics into the human hip joint, its use is not limited to this purpose. Intra-articular anaesthesia has been

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*(Image of a cadaver in lateral recumbency depicting the transducer (black rectangle) and needle (black arrow) alignment when injecting the left hip joint. The needle enters the lateral skin surface from a caudoventral position, between the greater trochanter (solid white dot) and the heel of the transducer. The needle is then directed along the long axis of the transducer in a craniodorsomedial direction towards the joint space (not depicted).)

*(Image illustrating accurate injection of the injectate into the left hip joint. The hip joint has been dissected, revealing the smooth articular surface of the femoral head ( ). Solid coloured latex is being teased from the hip joint.)*

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**FIGURE 4.** Photograph of a cadaver in lateral recumbency depicting the transducer (black rectangle) and needle (black arrow) alignment when injecting the left hip joint. The needle enters the lateral skin surface from a caudoventral position, between the greater trochanter (solid white dot) and the heel of the transducer. The needle is then directed along the long axis of the transducer in a craniodorsomedial direction towards the joint space (not depicted).

**FIGURE 5.** Photograph illustrating accurate injection of the injectate into the left hip joint. The hip joint has been dissected, revealing the smooth articular surface of the femoral head ( ). Solid coloured latex is being teased from the hip joint.
used to differentiate hip pain from lumbosacral pain with a high
degree of accuracy in people.9,10 Similar diagnostic dilemmas may
be seen in canine patients11 and although diagnostic intra-articular
anesthesia is not used commonly in small animal practice, a recent
study highlighted the benefit of this approach in diagnosing elbow
pain in dogs.12 Ultrasound guidance may also be of benefit in the
diagnosis and treatment of arthropathies. Ultrasonic guidance greatly
improves the rate and volume of diagnostic synovial fluid aspiration
and has also been shown as effective in obtaining synovial fluid from
joints that were considered ‘dry’ when using conventional palpation
techniques.13,14 Repeated aspiration and irrigation of the hip joint under
ultrasound guidance had a success rate in 86% of children diagnosed
with septic arthritis.15 With a mean number of aspirations of 3.6, those
authors concluded it was simple and a highly successful approach that
removed the need for general anesthesia and surgery associated with
more conventional treatment.16

Bergamino et al.17 recently described a dorsolateral approach
to ultrasound-guided injection of the canine hip joint. They describe
imaging the hip from a dorsolateral approach and injecting the joint
from a dorsalobial to ventroaxial direction. A first-time injection
accuracy rate of 88.2% was achieved using radiographic iodinated
contrast agent as an injectate. Both the greater trochanter and ilia
crest were considered useful initial landmarks for hip localisation
in their study. Those authors stated that inexperienced operators found
it easier to localise the hip joint using the ilium as an initial landmark,
but we found the greater trochanter was the most useful initial landmark
to guide transducer placement. Initial transducer positioning was easily
achieved by using the consistently palpable greater trochanter and a
clock-face analogy to place the transducer at the 12 o’clock position. An
accurate representation of the hip joint space could then be achieved
by rotating the transducer 30 degrees antiaxially to the 11 o’clock
position or 30 degrees clockwise to the 1 o’clock position to image the
left and right hips, respectively. Once the correct transducer alignment
was obtained, needle placement into the hip joint could be performed
in a caudoverentral to craniothirdoral direction.

The higher frequency linear transducer provided superior visualisation
of the coxofemoral joint space compared with the curvilinear transducer
and allowed easy guidance of the needle into the joint space in the
majority of dogs. However, the larger footprint of the linear transducer
and interference by the greater trochanter made needle placement
challenging in the smaller cadavers. This is because visualisation of
the needle is dependent on the angle of incidence of the sound wave
emitted by the transducer relative to the needle. Maximum visualisation
of the needle is achieved when the needle is perpendicular to the sound
wave.18 The greater the needle deviation from 90 degrees relative to the
sound wave, the poorer the visualisation of the needle. In the smaller
dogs, less space between the heel of the probe and greater trochanter
required the needle to be angled more acutely. Although image
resolution would be reduced, the use of the lower frequency curvilinear
transducer would overcome this issue in smaller breeds because the
smaller footprint and sector-shaped ultrasound beam would allow the
needle to be placed more perpendicular to the sound wave.

The ischiatic nerve and the caudal gluteal and lateral femoral circumflex
vessels are in close proximity to the coxofemoral joint. None of these
neurovascular structures were located in the field of view when using
the 11 o’clock or 1 o’clock transducer position in live patients
for the left or right hip joint, respectively. In addition, the cranial
and caudal branches to the joint capsule that arise from the lateral femoral
circumflex and caudal gluteal arteries, respectively, were not observed
under Doppler interrogation. It is likely that the ultrasound equipment
used in this study was not sensitive enough to detect these small,
low-flow peri-articular vessels, because the use of more advanced
ultrasound technology has enabled clinicians to delineate very small
intra-articular and peri-articular vasculature.19,20 Regardless, the lack of
notable blood supply in the field of view and the ability to visualise
the needle in real-time suggest that our technique is unlikely to cause
significant iatrogenic vascular damage. Further studies in live patients
are required to confirm this.

Although the technique was successful in delivering an injectate
within the coxofemoral joint in all dogs, larger, standardised studies
are required to confirm its accuracy. Poor image quality prevented an
accurate depiction of the joint space in two cadavers. All cadavers had
been frozen immediately after euthanasia and thawed in a standardised
fashion, so individual variation in autolysis during the thawing process
was believed to be responsible for the variation in image quality. We
found that when visualisation of the joint space was problematic,
confirmation of accurate needle placement could be achieved by
injecting saline into the joint prior to the injectate. Distension of the
joint space and separation of the joint capsule from the femoral head
confirmed accurate intra-articular needle placement. The superior
image quality in the live patients compared with the cadavers was not
surprising and similar image quality limitations have been described in
human cadavers.21 Although excellent image quality was present in all
of the live patients, the use of the technique in larger breeds and obese
patients needs to be further investigated.

The limitations of the current study are based on its cadaveric nature. In
order for this ultrasound-guided approach to be adopted in the clinical
setting, both the accuracy of the technique and its feasibility in clinical
patients need to be further investigated. We are currently investigating
the accuracy of the ultrasound-guided technique compared with a
conventional palpation-guided technique in a large group of cadavers.
Although this technique remains to be performed in clinical cases, it
has the potential to facilitate the diagnosis of coxofemoral pain, septic
arthritis and the accurate delivery of intra-articular therapeutic agents.

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Chapter 4
A COMPARATIVE CADAVERIC STUDY OF ULTRASOUND GUIDED VERSUS PALPATION GUIDED INTRA-ARTICULAR INJECTION OF THE CANINE HIP JOINT

4.1 Summary

AIMS: To compare the accuracy of ultrasound-guided and palpation-guided hip injections in the canine cadaver when ultrasound-guided injections are performed using a caudoventrolateral approach.

METHODS: Ultrasound-guided and palpation-guided hip injections of coloured liquid latex were performed in 18 dog cadavers by a single operator. The specimens were dissected by a blinded pathologist and injection accuracy assessed for each hip. Secondary outcome measures also assessed for each technique were: 1) Total time taken to complete injection, 2) Number of needle repositioning attempts before injection, 3) Aspiration of joint fluid, 4) Location of any extra-articular injectate relative to the dorsal acetabular rim and ischiatic nerve, and 5) Presence of iatrogenic needle damage to the femoral head or sciatic nerve.

RESULTS: Accuracy for ultrasound-guided and palpation-guided hip injections were 83% (15/18) and 72% (13/18), respectively (difference 11%; 95% confidence interval -9% to 31%; P = 0.16). Time to complete the ultrasound-guided injections was
significantly longer than for palpation-guided injections (medians: ultrasound = 70 secs, palpation = 40 secs, P = 0.0033). Significantly more positive joint fluid aspirations were achieved with ultrasound guidance (ultrasound = 7/18, palpation = 1/18, difference 33%; 95% CI 6% to 61%; P = 0.014). Neither technique resulted in iatrogenic damage to the femoral head or sciatic nerve in any of the 18 cadavers.

CONCLUSIONS: Accuracy of ultrasound-guided injection of the canine hip joint using a caudoventrolateral approach is not markedly worse than, and is probably similar to or better than accuracy of palpation-guided injections when used in dog cadavers.

CLINICAL RELEVANCE: Given that ultrasound-guided injection may have higher accuracy in live patients, further research is required to compare these techniques with clinical patients.

4.2 Introduction

Canine hip dysplasia is a common inherited orthopaedic condition that causes secondary osteoarthritis and progressive pain and lameness in adult dogs. Currently, conservative management consists of a multi-modal approach involving weight control, activity restriction and long term continuous use of systemic drugs such as non-steroidal anti-inflammatory drugs (NSAIDs). However, despite proven efficacy of this therapy,
responses vary between dogs. In addition, the adverse effects of NSAIDs have been well documented, and the duration of effective alleviation of pain can be short-lived.\textsuperscript{19, 84}

Intra-articular drug therapy has been recently investigated as a potential treatment alternative for the management of canine osteoarthritis. Intra-articular drug therapy is an attractive therapeutic alternative to systemic therapy as injection of the drug directly into the joint ensures appropriate drug concentrations at the site of action whilst minimising systemic side effects.\textsuperscript{2} Intra-articular injections of mesenchymal stem cells,\textsuperscript{58, 59} hyaluronic acid,\textsuperscript{66} Botulinum toxin\textsuperscript{72} and autologous platelet concentrate\textsuperscript{75} have been recently investigated. Although large clinical trials are required, initial results are very encouraging.

When performing intra-articular injections, accuracy (defined as the injection of all of the injectate within the joint) is clinically important for several reasons. In humans, accurately placed injections result in less procedural and post-procedural pain, and have lower reported complication rates.\textsuperscript{76, 85} In addition, the therapeutic benefits of intra-articular medications rely on their accurate placement within the joint.\textsuperscript{76, 77}

Due to its deep location and close proximity to neurovascular structures, intra-articular injection of the canine hip is challenging. Intra-articular canine hip injection is typically performed “blindly” via palpable landmarks but to the authors’ knowledge, the accuracy of palpation-guided intra-articular hip injection in the dog has not been reported. However, Siegfried et al 2005 reported that the accuracy of palpation-guided percutaneous synovial biopsy of the canine hip joint was significantly less than for any
other joint. With an accuracy of only 7.5%, the authors concluded that imaging guidance is recommended for dogs,\textsuperscript{79} as is recommended for humans.\textsuperscript{12,14}

Fluoroscopy and ultrasound are the imaging modalities of choice for guiding intra-articular injections of the human hip and accuracy up to 100% has been reported.\textsuperscript{80,81} Ultrasound offers several advantages over fluoroscopic guidance in that it does not expose the patient or operator to ionising radiation, does not require the use of contrast agents or cumbersome equipment, can be performed in a general practice setting, and allows the operator to visualise the needle entering the joint in “real time”.

A recent study reported the feasibility and accuracy of injecting the canine hip joint via a caudoventrolateral approach using ultrasound-guidance in 6 cadavers.\textsuperscript{86} The authors demonstrated that ultrasound-guided hip injection was both feasible and accurate. However, for this technique to be adopted for clinical patients, the accuracy of the technique has to be similar to or superior to that of the conventional palpation-guided technique. To the authors' knowledge, no studies have compared the accuracy of ultrasound-guided and palpation guided canine hip injections using a caudoventrolateral approach.

Therefore, the primary objective of our study was to compare the accuracy of ultrasound-guided and palpation-guided hip injections in the canine cadaver when ultrasound-guided injections were performed using a caudoventrolateral approach. Proportions where joint fluid aspiration was achieved, injection times and number of repositionings were also compared between these techniques.
4.3 Materials and Methods

Study overview

Ultrasound-guided and palpation-guided hip injections of coloured liquid latex were performed in 18 dog cadavers by a single operator. Within each cadaver, both injection techniques were used, with each technique randomly allocated to one hip. The specimens were subsequently dissected by a pathologist blinded to technique and sequence of injection, and injection accuracy assessed.

All procedures were approved by and in accordance with requirements of the University of Melbourne Animal Ethics Committee. Eighteen fresh-frozen canine cadavers were sourced. All cadavers were from dogs that had been euthanised humanely for reasons unrelated to hip disease. All dogs were skeletally mature and weighed between 12 and 35kg (mean weight 23.6kg).

Sample size calculations:
The desired sample size was calculated using the -power paired_proportions- command in Stata (version 13, StataCorp, College Station, Texas, USA). For 80% power and two-sided alpha of 0.05, if accuracy was 99% for one technique and 80% for the other and the correlation in accuracy between hips within dog was 0, 0.05, 0.1, 0.15, and 0.2, 43, 42, 41, 40 and 39 cadavers, respectively, were required, with one hip from each cadaver allocated to each of ultrasound-guided and palpation-guided injection. These calculations were based on the large-sample McNemar's test. Accordingly, the target number of cadavers was 44. However, due to limited access to cadavers, the study was terminated
after only 18 cadavers were enrolled. If sample size had been larger, the study would have had greater statistical power for detecting smaller differences between groups.

**Equipment:**

Ultrasound-guided injections were performed with an 8-13MHz linear array transducer using a Siemens Acuson X300 ultrasound machine (Mountain View, California, USA). A 22 gauge 1.5-inch spinal needle was used for the injections and 1ml of coloured liquid latex (Dalchem Pty Ltd, Melbourne, VIC, Australia) was used as the injectate.

**Injection procedures:**

One investigator performed both ultrasound- and palpation-guided injections (BGJW). The investigator had performed approximately 10 injections by each technique over the 12 month period immediately prior to the study commencement. Within cadaver, both injections were completed in immediate succession (i.e. within 3 minutes of each other on the same day) before the next cadaver was injected. Cadavers were injected on 11 separate days over 8 months from December 2014 to July 2015, with between 1 and 4 cadavers injected on the same day.

Each cadaver was thawed at room temperature for 48 hours prior to hip injection. Cadavers were positioned in lateral recumbency with the hip to be injected positioned uppermost. The hip joint of the limb to be injected was positioned in a weight-bearing position (i.e. no load was applied to the limb) with the femur positioned perpendicular to the long axis of the pelvis and parallel to the sagittal plane. The hair from the hip and
pelvic region was clipped, the skin cleaned with alcohol and, for ultrasound injections, coupling gel was applied.

For the palpation-guided technique, the needle was introduced just cranioproximal to the greater trochanter, almost perpendicular to the skin surface, and directed slightly caudally towards the joint. The needle was advanced until a loss of resistance was appreciated at which point aspiration of the joint was attempted with a 2ml syringe, after which 1ml of injectate was injected.

Ultrasonographic injections were performed using a recently described technique. Briefly, initial imaging of the hip was achieved by placing the linear ultrasound transducer on the lateral surface of the cadaver with the heel of the transducer immediately proximal to the palpable greater trochanter, and the long axis of the transducer perpendicular to the spine. This position was referred to as the “12 o’clock” position, using a clock face analogy. Depending on the hip being imaged, the transducer was then rotated 30-degrees anti-clockwise to the 11 o’clock position when imaging the left hip or 30-degrees clock-wise to the 1 o’clock position when imaging the right hip. The hip joint was identified as a small hypoechoic triangle between the femoral head and acetabulum. The needle was introduced between the greater trochanter and heel of the transducer and advanced in a craniodorsomedial direction towards the joint. After imaging the tip of the needle apparently within the joint, imaging was ceased, aspiration of the joint attempted and 1ml of injectate injected. For both techniques, whether or not joint fluid could be aspirated was recorded immediately after each injection was completed.
**Allocations:**

A blocked design was used with cadaver as blocks, and order of injection (ultrasound-guided or palpation-guided performed first) and initial injection side (left or right hip injected first) randomized within cadavers using computer-generated random numbers. Pre-prepared numbered (1 to 44) opaque envelopes were provided to the primary investigator by an independent person; each listed which technique and injection side to perform first and second. Cadavers were numbered sequentially in order of enrolment; for each cadaver, the correspondingly numbered envelope was used.

**Procedure evaluation:**

The primary outcome measure was accuracy of injection where accurate was defined as all of the injectate being within the joint and inaccurate was defined as some or all of the injectate being outside the joint. Secondary outcome measures were: 1) Total time taken to complete injection, 2) Number of needle repositioning attempts, 3) Positive/negative aspiration of joint fluid, 4) Location of extra-articular injectate relative to the dorsal acetabular rim and ischiatic nerve, and 5) Presence of iatrogenic needle damage to the femoral head or sciatic nerve. After injections, each cadaver was chilled at 3°C for 48 hours prior to evaluation of accuracy, location of extra-articular injectate, and evidence of iatrogenic needle damage. The cadavers were dissected and assessed by a pathologist blinded to injection technique and sequence of injection within cadaver. The results of injections were recorded, tabulated and provided to the primary investigator once all cadavers had been assessed.
**Statistical Analyses:**

All analyses were performed with standard software (Stata, version 14, StataCorp, College Station, Texas, USA). Proportions of hips where the injection was accurate, and proportions where aspiration was achieved, were compared between ultrasound- and palpation-guided techniques using McNemar's chi-square test. Differences between proportions that accounted for pairing were estimated as described by Fleiss et al (2003)\(^8\). These analyses were performed using Stata's `-mcci-` command.

Differences in injection times between ultrasound- and palpation-guided techniques within cadaver were not normally distributed, as per the Shapiro-Wilk test, so these were compared with Wilcoxon matched-pairs signed-rank tests using Stata's `-signrank-` command. The 95% confidence interval for the median of the 18 differences (one difference for each of the 18 cadavers) was calculated using Stata's `-centile-` command. Differences in number of repositionings between ultrasound and palpation-guided techniques within dog were normally distributed so these were compared with paired t-tests using Stata's `-ttest-` command.

Data from both techniques were pooled for all analyses of the diagnostic validity of joint fluid aspiration. Considering joint fluid aspiration as a diagnostic test for accuracy, 95% confidence intervals for sensitivity and negative predictive value were calculated using Stata's `-proportion-` command with the `-svy-` (survey) prefix to account for clustering of hip within cadaver. Taylor-linearized variance estimation was used. As the observed
specificity and positive predictive value were both 100%, exact one-sided 97.5% confidence intervals were used; these did not account for clustering of hip within cadaver.

One cadaver (the 8th cadaver injected) had the longest injection time for palpation (305s; range for other cadavers 16 to 72s) and the shortest injection time for ultrasound (40s; range for other cadavers 46 to 120s). There was no obvious reason for this discordant pattern with this cadaver but because these times differed so markedly from other cadavers, statistical analyses were performed with and without this cadaver included. Results with and without this cadaver included were similar so those results using all 18 cadavers are presented.

Statistical significance was set at two-sided P < 0.05.

4.4 Results

The results of the analyses are summarised in Table 1. Ultrasound image quality was considered adequate for all dogs; however there were small variations in image quality between dogs. For 9 of the 18 cadavers, ultrasound-guided injection was performed first, and 11 of the 18 ultrasound-guided injections were performed in the left hip. Accuracy for ultrasound- and palpation-guided injections were 83% (15/18) and 72% (13/18), respectively (difference ultrasound minus palpation: 11%; 95% confidence interval for the difference: -9% to 31%). Accuracy did not differ significantly between the two injection techniques (P = 0.16). Assuming there was no prior knowledge about this difference, these results indicate that accuracy for ultrasound-guided injection is unlikely to be more than 9% worse than that for palpation-guided injection.
Overall, the ultrasound-guided technique took significantly longer to perform than the palpation-guided technique with a median injection time to completion of 70 and 40 seconds for ultrasound and palpation, respectively (P = 0.0033). However for the ultrasound-guided technique, injection time diminished with cadaver sequence number (and therefore with operator experience; Figure 1).
Table 1. Comparisons of outcome measures between ultrasound-guided and palpation-guided hip injections in 18 cadavers

<table>
<thead>
<tr>
<th></th>
<th>Ultrasound-guided</th>
<th>Palpation-guided</th>
<th>Difference (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy (%)</strong></td>
<td>83</td>
<td>72</td>
<td>11</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-9 to 31)</td>
<td></td>
</tr>
<tr>
<td><strong>Time to complete injection (secs).</strong></td>
<td>100, 70</td>
<td>53, 40</td>
<td>41¹</td>
<td>0.0033</td>
</tr>
<tr>
<td>Mean, median (range)</td>
<td>(40 to 270)</td>
<td>(16 to 305)</td>
<td>(28 to 78)</td>
<td></td>
</tr>
<tr>
<td><strong>Number of repositioning attempts. Mean, median (range)</strong></td>
<td>4.8, 4</td>
<td>5.3, 4.5</td>
<td>- 0.5²</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>(0 to 12)</td>
<td>(2 to 12)</td>
<td>(-2.5 to 1.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Positive joint fluid aspiration (%)</strong></td>
<td>39</td>
<td>6</td>
<td>33</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(6 to 61)</td>
<td></td>
</tr>
</tbody>
</table>

CI, confidence interval

¹ Difference between means not compared; Wilcoxon matched-pairs signed-rank test was used; median (95% CI) of the 18 differences is reported.

² Difference between means and associated 95% CI

a Within dogs: Both methods accurate, n = 13; both methods inaccurate, n = 3; Ultrasound accurate and palpation inaccurate, n = 2

b Within dogs: Both methods had positive aspiration, n = 1; neither method had positive aspiration, n = 11; Ultrasound had positive aspiration and palpation did not have positive aspiration, n = 6
Significantly more positive joint aspirations were achieved with ultrasound-guided injections than palpation-guided injections {ultrasound 39% (7/18; palpation 6% (1/18); P = 0.014} Considering joint fluid aspiration as a diagnostic test for accuracy, when the results of both techniques were combined, none of the 8 joints with inaccurate injections had a positive joint fluid aspiration (i.e. specificity was 100%; exact one-sided 97.5% CI 63% to 100%) while of the 28 joints with accurate injections, 8 had a positive joint fluid aspiration (i.e. sensitivity was 29%; 95% CI 14% to 49%). All 8 joints with a positive joint fluid aspiration had an accurate injection. Thus, at this prevalence of accuracy (28/36 or 78%), the positive predictive value was 100% (8/8; exact one-sided 97.5% CI 63% to 100%) whereas only 29% of all negative joint fluid aspirations had an inaccurate injection (8/28; 95% CI 11% to 56%).
Figure 1. Times to complete ultrasound-guided and palpation-guided hip injections by cadaver sequence number (where the first study cadaver injected was 1 and the final cadaver was 18). Lines represent lowess (locally-weighted regression) smoothing.
Of the 3 ultrasound-guided injections that were not accurate, the mean distances between the extra-articular latex and each of the dorsal acetabular rim and sciatic nerve were 0mm (all 3 injections) and 14mm (3, 16 and 23mm), respectively. Of the 5 palpation-guided injections that were not accurate, the mean distances between the extra-articular latex and each of the dorsal acetabular rim and sciatic nerve was 3.4mm (0 (2 cadavers), 1, 2 and 14mm) and 12mm (3, 4, 17 (2 cadavers) and 19mm), respectively. The numbers of inaccurate injections were too small to compare these means statistically. For both techniques pooled, the latex for 7 of the 8 inaccurately placed injections was located dorsal to the acetabular rim with only one injection located ventrally. The inaccurately placed latex was located cranial (6/8) or dorsal (2/8) to the sciatic nerve. Iatrogenic damage to the femoral head or sciatic nerve by the needle was not detected for either technique.

### 4.5 Discussion

The findings of our study demonstrated that ultrasound-guided hip injection accuracy in dog cadavers is not markedly worse than, and is probably similar to or better than that for palpation-guided hip injection. Positive joint fluid aspiration was achieved more commonly with ultrasound guidance (39% of hips, compared with only 6% after palpation guidance). Our findings also show that the mean number of repositioning attempts is not markedly worse for ultrasound-guided hip injection, and, for the 18 attempts with each technique, neither technique resulted in iatrogenic damage to the femoral head or sciatic nerve. However, the time to complete the ultrasound-guided
injections was significantly longer than for palpation-guided injection, although time for ultrasound-guided injections reduced with increased operator experience.

The ultrasound-guided accuracy in the current study (83%) is similar to that from a similar cadaver study in which accuracy was 81.8%.\textsuperscript{82} Those workers used an ultrasound-guided dorsolateral hip injection technique rather than the caudoventrolateral approach as used in the current study. However, ultrasound-guided hip injection accuracy of up to 100% has been reported in humans.\textsuperscript{80, 81} and a recent systematic review concluded that accuracy is greater with ultrasound-guidance compared with palpation-guided injection of joints in humans, regardless of the anatomical site.\textsuperscript{89} Although image quality was considered adequate for all cadavers, image quality varied, probably due to differences between cadavers in the autolysis process during thawing. It is possible that image quality is better in live patients, and limited use in clinical patients suggests that this is the case. If so, accuracy of ultrasound-guided injections in live patients may be higher than that observed in the cadavers in the current study. Studies in live patients are required to determine the role of image quality on the accuracy of ultrasound-guided hip injection in live clinical patients. Further, the observed difference in accuracy between the ultrasound-guided and palpation-guided techniques may have been reduced due to our study design. Our use of a single operator to perform both techniques may have influenced the results. A single operator was chosen to avoid any confounding effects of experience and other operator factors that may have occurred had each operator performed only one of the techniques. However it is possible that the act of performing the first injection may have inadvertently assisted the operator in placing and directing
the needle during the subsequent injection of the same cadaver. Attempts were made to mitigate any such effects of order of injection by randomising order of injection technique, and for 50% of the cadavers, palpation was used first. Thus it is unlikely that the comparisons between ultrasound-guided and palpation-guided techniques were confounded by any 'order of injection' effects. However, it is possible that the act of performing the ultrasound-guided technique may have inadvertently assisted the operator in placing and directing the needle during the subsequent palpation-guided technique in the opposite hip in the same cadaver, but palpation did not benefit the subsequent ultrasound-guided technique in the same cadaver. If so, our accuracy for palpation would have been increased, so reducing the observed differences between techniques. Finally, under our study design, after imaging the tip of the needle apparently within the joint, imaging was ceased and the operator did not visualise the injection of latex from the needle tip during ultrasound-guided injections. This design was chosen so that the operator did not alter their ultrasound-guided technique for subsequent study injections based on their knowledge of results from the previous ultrasound-guided injections in the study. However, it is likely that in a clinical situation, the advantage of visualising the injection with ultrasound guidance would aid in increased joint injection accuracy.

No iatrogenic damage to the femoral head or sciatic nerve was detected with either technique. With ultrasound guidance, the ability to visualise the peri-articular soft tissues and guide the needle in “real time” would be expected to reduce risk of piercing important neurovascular structures relative to palpation. However, as there were relatively few inaccurate injections, no useful comparisons between the effects of these
techniques on either risk of iatrogenic damage to the femoral head or sciatic nerve, or in
damage to important neurovascular structures was possible with the current study.

Ultrasound guidance resulted in significantly greater number of positive joint fluid
aspirations compared to palpation guidance in our study. Although this potential
advantage needs to be corroborated in live patients, this finding is consistent with human
reports which document that ultrasound guidance results in significantly greater
probability of aspiration, and greater volumes of synovial fluid aspirated.\textsuperscript{76, 90} Although
not performed in this study, documentation of accurate needle placement can also be
confirmed by injecting a test dose of saline and identifying joint capsule distension. This
additional advantage is particularly useful when a negative joint sample aspiration ("dry
tap") is obtained and allows one to be confident that the needle tip is indeed within the
joint.

The notable negative aspect of ultrasound-guided injections in this study was the
increased injection time. Ultrasound-guided injections took approximately twice as long
as palpation-guided injections in study subjects and similar findings have been reported
in humans.\textsuperscript{76} This result is not surprising given the additional time required to image the
joint, optimise the image and process the additional information that is received when
using ultrasound-guidance. Regardless, the increase in procedural time in study subjects
was only modest (increase in medians of 30 seconds) and is unlikely to negatively affect
the patient. Furthermore, even though the operator had performed approximately 10
injections by each technique over the 12 month period immediately prior to the study
commencement, our results suggest procedural time for ultrasound guidance decreases
with operator experience and as such this difference in procedural time may become negligible with increased use of that technique.

One limitation of the current study was our use of cadavers without hip disease rather than live clinical patients. For ethical reasons, before these injection techniques are compared in live patients, their accuracy and safety needed to be firstly documented in a cadaveric population. We attempted to maximise the clinically applicability by using fresh-frozen specimens to replicate tissue consistency, and we used equipment and supplies that would be routinely available in a clinical setting. It should be noted that all cadavers were free from hip osteoarthritis. Hip disease-free specimens were chosen to eliminate any variability between hips associated with asymmetric pathology and possible consequential confounding of our comparison of techniques. However it is possible that exuberant peri-articular osteophyte formation in clinical canine hip osteoarthritic patients may reduce the accuracy of ultrasound-guided hip injection by impeding access to the joint. space This dilemma is likely to be problematic for both techniques however, and due to the ability to visualise these changes with ultrasound and guide the needle in “real time”, ultrasound guidance may be advantageous in these situations. In contrast, it is possible that increased joint effusion associated with osteoarthritic hips may allow for easier identification of the joint space and thus negate the potential problems associated with exuberant osteophyte formation surrounding the joint for both techniques. In conclusion, the accuracy of ultrasound-guided injection of the canine hip joint using a caudoventrolateral approach is not markedly worse than, and is probably similar to or better than that for palpation-guided injection when used in dog
cadavers. Given that ultrasound-guided injection may have higher accuracy in live patients, further research is required to compare these techniques with live clinical patients.
Chapter 5

5.1 Summary, conclusions and future investigations

Despite the vast number of medical and surgical therapeutic options for the management of canine hip dysplasia, limitations of these treatments still remain. Intra-articular drug therapy is an attractive and promising therapeutic alternative but its efficacy relies on accurate intra-articular administration. In order for an ultrasound-guided hip injection technique to be adopted in a clinical setting it has to be simple, clearly illustrated and have comparable accuracy and safety to that of a conventional palpation-guided technique.

This thesis has demonstrated that ultrasound-guided hip injection in the canine cadaver using a caudoventrolateral approach is a simple and safe technique that can be performed in a stepwise fashion with accuracy rates similar to or better than a conventional palpation-guided approach. The information gained from this research can be used as a benchmark for future research investigating the feasibility and accuracy of this novel technique in clinical patients. In addition, the effect of operator experience and the variability of patient body weight/condition on intra-articular injection accuracy can also be assessed.

In conclusion, ultrasound-guided injection of the canine cadaver hip using a caudoventrolateral approach has been shown to be a safe and effective technique, and it is anticipated that this new technique will allow advances in the efficacy of current and future intra-articular drug therapy.
References


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