Guide to Administering Platelet-Rich Plasma

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Differentiating Treatment Options for Osteoarthritis in Animals

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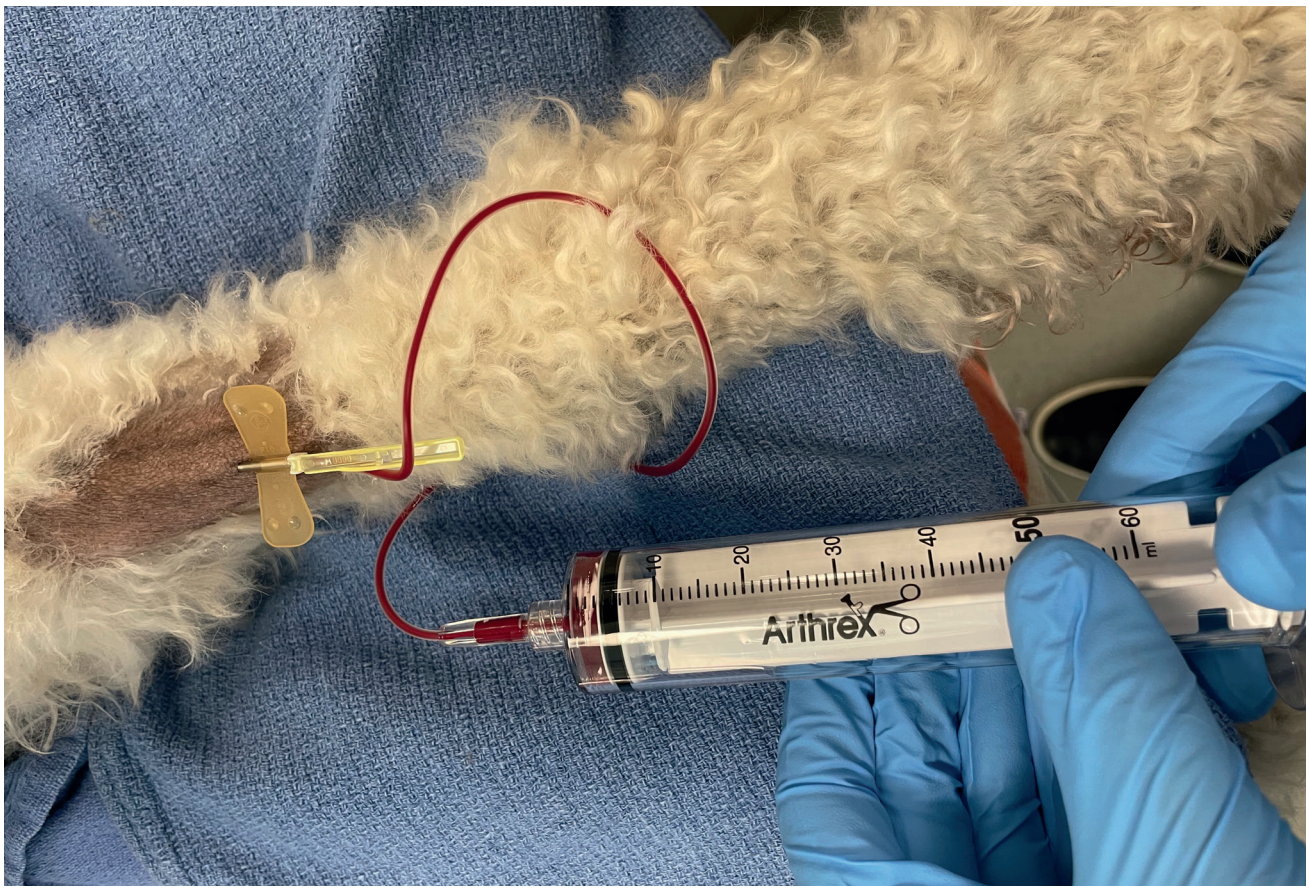
In veterinary medicine, there are a variety of intra-articular injection-based treatments for animals with specific goals for each modality to help combat osteoarthritis (OA)-related changes. These goals can range from pain management to improving the joint environment closer to healthy conditions and attempts at regenerating joint tissues to return native function and structure. Numerous treatment modalities used for human orthopedic pathologies have been hypothesized to benefit animals suffering from similar pathologies that ultimately result in full joint degeneration and disability. Among the long list of treatments, the three that historically have had the most interest in animals are corticosteroids, hyaluronic acid (HA), and platelet-rich plasma (PRP) injections.

Corticosteroid injections provide anti-inflammatory and immunosuppressive effects when administered intra-articularly; however, there is significant debate surrounding their use because of concerns for subsequent degeneration of articular tissues, risks of articular infections, and potential serious systemic effects with repeated use.[1] The types of corticosteroids used for OA treatment include the crystalline (triamcinolone) and noncrystalline (methylprednisolone) forms. While there have not been any physical function studies completed in canines with corticosteroid injections, there have been studies completed in humans, with one showing a 44% improvement in pain in the treatment group and a 31% improvement in the placebo group.[2] There is not a consensus on the safety of corticosteroid injections and its effect on articular cartilage in animals, but one study has shown that the use of triamcinolone injection is cytotoxic to canine cartilage, with a reduction in cell viability during in vitro studies.[3] When a study on an equine model of OA was tested in vivo, injection of methylprednisolone was found to have negative effects on the cartilage compared to controls when the histopathology was analyzed, but in the same study, triamcinolone showed positive results without affecting the underlying bone.[4] While there is not a consensus regarding corticosteroid injections and their toxicity on articular cartilage, studies showing detrimental effects raise serious concerns and veterinarians should look toward other potential options to treat their patients suffering from OA.



Hyaluronic acid is a native component of the synovial fluid that bathes the articular surfaces of the articulating joints. HA is a fluid with viscous properties that has been described as helping with shock absorption and lubrication during daily functions. Due to these properties, HA is considered a viscosupplement when administered intra-articularly.[1,5] Native HA has been demonstrated to decrease in concentration in the synovial fluid during the progression of OA. In addition, HA is an important component of the cartilage matrix. Subsequently, HA supplementation seems logical.[6,7] HA is commercially available with formulations that are based on the molecular weight, or size, of the injection formulation. While there is likely a benefit with low and medium molecular weight formulations the literature favors the high molecular weight formulations of HA.[1] These high molecular weight formulations have been shown to provide similar properties to naturally occurring HA while retaining the ability to be cleared from the joint through synovial capillaries.[7,8] HA treatment has also been described as potentially increasing the endogenous production of HA within a pathological joint, further supporting the potential efficacy of HA injections.[7,9]

While HA may be a reasonable treatment option under certain conditions, it is not a cure for OA nor a regenerative injection option. Studies have indicated improvement in kinetic evaluation and limb function with HA treatment with maximum benefit 4-8 weeks following the treatment.[10] Other studies have shown no improvements in cartilage degradation with HA injections when cartilage was analyzed histologically in a cranial cruciate transection model.[7,11] These results indicate that the injection of HA may provide some short-term pain relief through improved joint motion, but it is not actually providing a protective effect for the progression of cartilage damage. The routine use of intra-articular HA is hindered by the short duration of benefits and the need for multiple injections.

Combination therapy of HA and corticosteroids has been suggested as a treatment option due to the separate effects each treatment has independently on the joint to improve joint function with OA. A study of combination treatment in canines with elbow and hip OA showed improved mobility based on client questionnaires at a 6-month timepoint.[12,13] In other studies that looked at this treatment combination, there were improvements in the subjective measures that were reported by the owners, but this combination did not show a significant difference when compared to autologous fluid or stem cell-based treatments.[12,13] These results indicate that these symptom-based treatment modalities may not provide any improved clinical outcomes over autologous treatments such as PRP. Additionally, they do not promote—and may inhibit—the cartilage healing that the autologous fluid treatments may provide.

Learning About PRP

PRP is one of the more clinically examined injectable orthobiologics being used in canine OA. PRP is described as an autologous treatment that is isolated from the patient's own blood and provides potential healing effects on orthopedic pathology by providing growth factors and reducing inflammation in an affected joint.[14] The main growth factors that are consistently found in PRP that help improve the healing capability of damaged cartilage are transforming growth factor β (TGFβ) and platelet-derived growth factor (PDGF).[14] To obtain PRP, a venous puncture is necessary. Up to 9 mL/kg of blood can safely be collected at one time point every 2 weeks.[15,16] A larger volume of blood collection allows for larger volumes of plasma to be concentrated for injection into an injured joint or joints. Once whole blood is collected, it undergoes a species-specific centrifugation process to separate the whole blood into its unique content.[17] Prior to this centrifugation process, an anticoagulant is added. Acid citrate dextrose-A (ACD-A) may be the best option for this application compared to citrate phosphate dextrose-A (CPD-A).[18] A slow-spin centrifugation is usually performed to bring the red blood cells to the bottom with a buffy coat in the middle and plasma at the top. When double centrifugation is used, the plasma is manually removed, avoiding large amounts of buffy coat collection as this is where the leukocytes and immune cells reside. This fluid is then centrifuged at a faster rate to pellet all cellular components and the platelets are separated from the platelet-poor plasma (PPP).

With the collection of PRP completed, the next important step is activating the platelets so the growth factors they contain can be released and are readily available for use by the damaged tissue. Several activation methods have been proposed and investigated for efficacy. The easiest form of activation is through freezing and thawing the PRP. Studies have shown that freezing and thawing does create significant release of growth factors in canines, while 3 cycles may maximize the total release of the growth factors.[19,20] This method becomes useful when the PRP needs to be stored for later use, but this option become less attractive when the PRP needs to be used at the patient bedside in a timely manner. Another activation method that has been investigated is the use of calcium chloride or calcium gluconate.[21] The calcium binds to the anti-coagulant and will results in a gel formation 30 minutes following the activation. A final proposed method for activation without the formation of a gel-like product is the use of human gamma thrombin.[19,22] There are currently no studies on canines for xenogenic use of this protein and the manufacturers of this product do not state it as an indicated use. It has also been suggested that platelets are naturally activated when they are injected into the joint. While there are no studies investigating this claim in canines, there are mixed results in equine studies. One equine study combined PRP with synovial fluid in an ex vivo setting and results suggested it did activate the platelets, but in another equine study the joints were aspirated 5 days after the initial unactivated PRP injection and the authors found intact platelets, indicating that the platelets were not fully activated in vivo.[23,24]

When isolating the platelets and plasma for PRP, it is important to consider the other components of the blood that may be collected with the process and the effects they may have on the joint that the PRP is being injected into. First, erythrocytes can be collected when removing the plasma after the initial centrifugation. It is generally agreed that erythrocytes have negative side effects on the synoviocytes of the joint, causing an increase in joint inflammation due to synoviocyte death.[25,26] The next component consists of the leukocytes contained within the buffy coat. This component has been shown to increase interleukin-1β and matrix metalloproteinase 9, which have negative side effects on the cells and matrix of the cartilage, leading to increased cartilage degeneration.[27] This has been further supported by an ex vivo study that showed an increase in synoviocyte cell death when there were leukocytes present in the PRP compared to leukocytes not being present.[25]

What to Consider Before Using PRP for a Patient

When considering PRP for a patient, it is important to factor in the time and costs associated with the treatment. The process of collecting PRP can be completed with basic laboratory equipment and clinical supplies but these processes reduce the overall quality of the product compared to commercial systems. A commercial system is a better option for private practice clinicians. While these commercial systems may be more costly to start, the overall price point is reduced when the main reoccurring cost is the disposables associated with each use. This cost may be further reduced as companies may be willing to provide the centrifuge needed while an agreed upon number of disposables are utilized per year. This option may be a beneficial one for clinicians who have a large client base and are likely to perform a significant quantity of these procedures in a given calendar year. It is important to note that not all PRP systems are created equal. A study analyzing 5 separate PRP systems showed a large amount of variability in platelet concentration, from baseline up to a 5-fold increase.[22] Another study showed there is a strong correlation between this concentration and the concentration of the growth factors.[19] This highlights the importance of selecting a system that has been proven to provide a high-quality product to maximize the potential of healing and an improvement in quality of life.

Blood Collection Technique

When needing to collect a significant amount of blood for processing a biologic (generally > 20 mL of blood at a time), sedation of the patient is recommended. This will be needed regardless for injection after processing the blood for PRP/ACP/ACS. The patient is placed in lateral recumbency, and the jugular vein is aseptically prepared. A butterfly needle is useful so that if more than one syringe of blood is collected it is easy to so without having to obtain venous access more than once. For large breed dogs a 19-gauge needle is used. In general, the largest gauge needle that is appropriate should be used for blood collection. If access cannot be gained via the jugular vein, the lateral saphenous vein in the pelvic limb or the cephalic vein in the thoracic limb are alternatives for access.

In general, it is safe to draw up to a maximum of 10% of the patient's total blood volume every 2 weeks for systemically healthy animals, though most recommendations suggest that only 7.5% be drawn at one sitting. A dog's total blood volume is ~7-9% of its body weight. To calculate a dog's blood volume, the following formula is used: patient body weight (kg) * 80 mL/kg. Cats have a slightly lower blood volume at ~6.5% of their body weight. This can then be used to calculate the amount of blood that can be drawn. The amount of blood needed for processing varies by the system being used. Rarely are dogs too small for the volume needed for most systems. However, this needs to be assessed on a case-by-case basis as some systems require 60 mL of blood to process, and in smaller dogs this can become unsafe. In most cats, it is not safe to use a system that requires such a large volume, and a system needs to be utilized that requires less blood volume. If there is concern for a patient's systemic health, blood draws of large volumes should not be performed. In some cases, IV fluid therapy following a large blood draw can be considered, but in routine cases is usually not needed if guidelines for appropriate safe volumes of blood collection are followed.

PRP Preparation

Approximately 10% of a dog's blood volume may be safely acquired every 2 weeks for PRP preparation. This translates to approximately 9 mL/kg of body weight. In a 30 kg dog, this would provide 270 mL of blood for processing. In many patients, significantly more blood can be safely drawn than can be processed by most PRP systems.[15,28]

When considering a 25 kg dog, up to 225 mL can be acquired safely. These large volumes, or greater, are commonly acquired from canine blood donors for the preparation of whole blood transfusions or packed red blood cell and plasma transfusions. Hence, the upper limit of blood that can be safely processed likely greatly exceeds what most PRP preparation systems enable.

PRP Injection Frequency Recommendations

Two protocols are often cited regarding the frequency of PRP administration. There is limited definitive clinical evidence to support one protocol over another.

- Protocol 1:
  Administer PRP and observe for improvement. If there is improvement but lameness returns, consider a second injection
- Protocol 2:
  Administer 3 intra-articular injections 2 to 3 weeks apart
- PRP platelet activation methods:
  - 10% calcium chloride may be added to the PRP; add 23 µL per 1 mL of PRP
  - Activation may be achieved by 1 to 3 cycles of freezing and thawing
  - Aliquot and freeze a solution of bovine thrombin (5000 IU reconstituted); add 1 mL of this solution to every 9 mL of PRP for rapid activation and fibrin formation

PRP Concepts

- PRP is a "platelet-rich" biologic that concentrates important growth factors
- PRP has been extensively evaluated and used for the treatment of osteoarthritis in human and veterinary patients
- The ideal platelet concentration is uncertain and different values have been studied with varying results
- The optimal leukocyte concentration in PRP is also debated
- Most clinicians believe that PRP for intra-articular use should probably have few, if any, erythrocytes
- Platelet activation releases their growth factors and both in vitro and ex vivo methods have been proposed
- The ideal frequency of PRP injection has yet to be determined and may vary between cases
- When saving PRP for later use, it should be stored at -20°C, or as low as -80°C

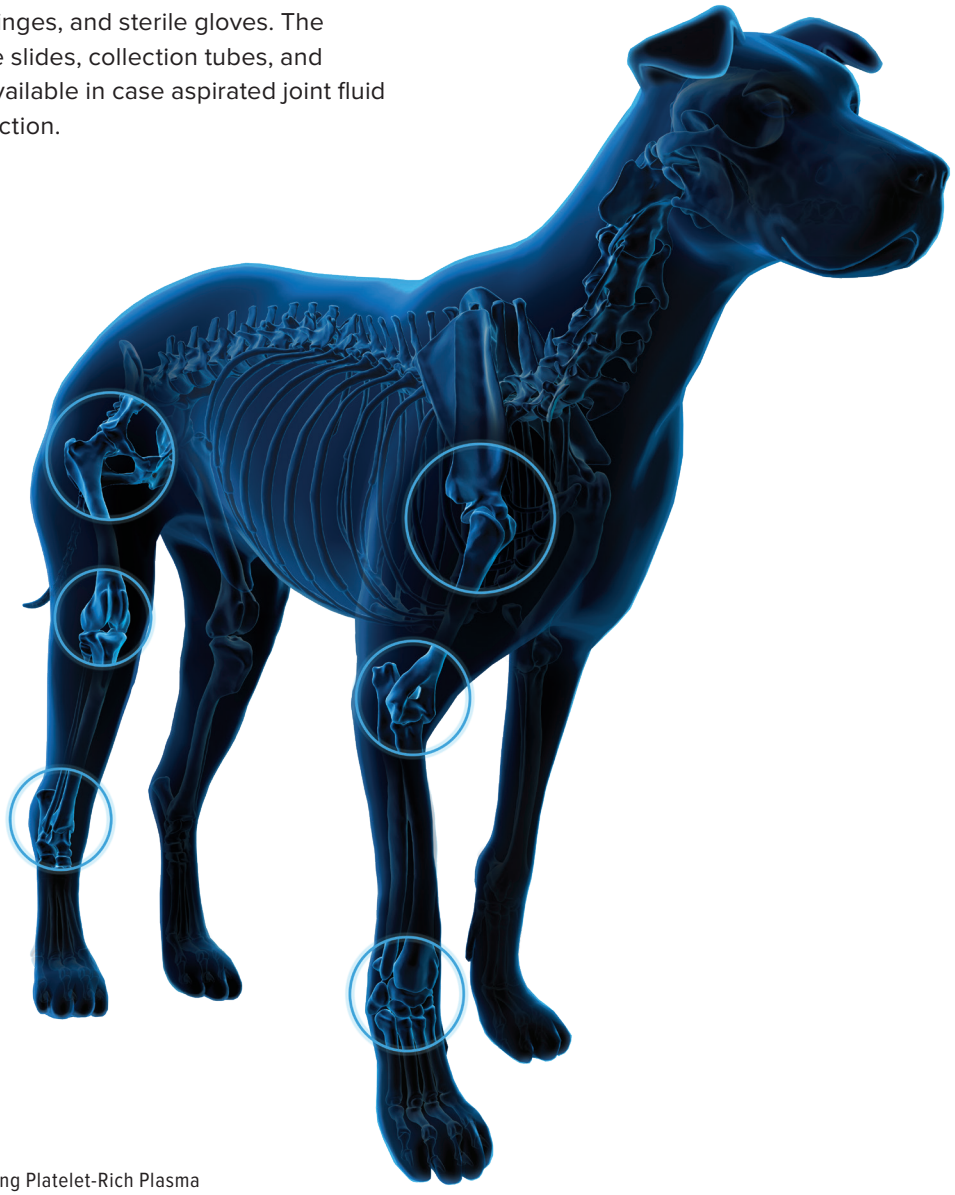
Joint Injection Technique

Joint injections are most frequently performed as adjunct therapy for the treatment of osteoarthritis. Joint injections should be administered under sedation and aseptically. Reversible sedation is ideal, as the procedure itself is relatively rapid. An opioid like butorphanol, coupled with dexmedetomidine given intravenously, can be reversed with intramuscular atipamezole. Care must be taken to ensure these medications are safe for each individual patient. Alternatives such as alfaxalone can be used when needed, particularly in patients with cardiac disease.

Aseptic technique is used to decrease the risk of inducing septic arthritis during the procedure. The fur should be clipped over the area, to include palpable local landmarks. The authors prefer to perform an initial dirty prep using chlorhexidine or betadine solution and then completing a final sterile prep. The injection can then be administered.

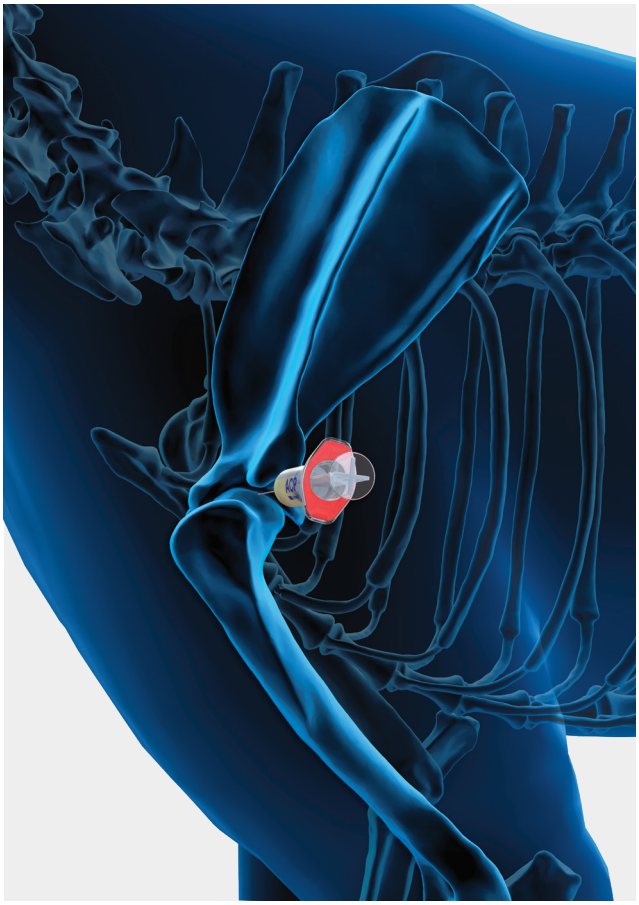
General supplies needed to perform a joint injection include needles, syringes, and sterile gloves. The clinician should have slides, collection tubes, and culturettes readily available in case aspirated joint fluid is suspicious for infection.

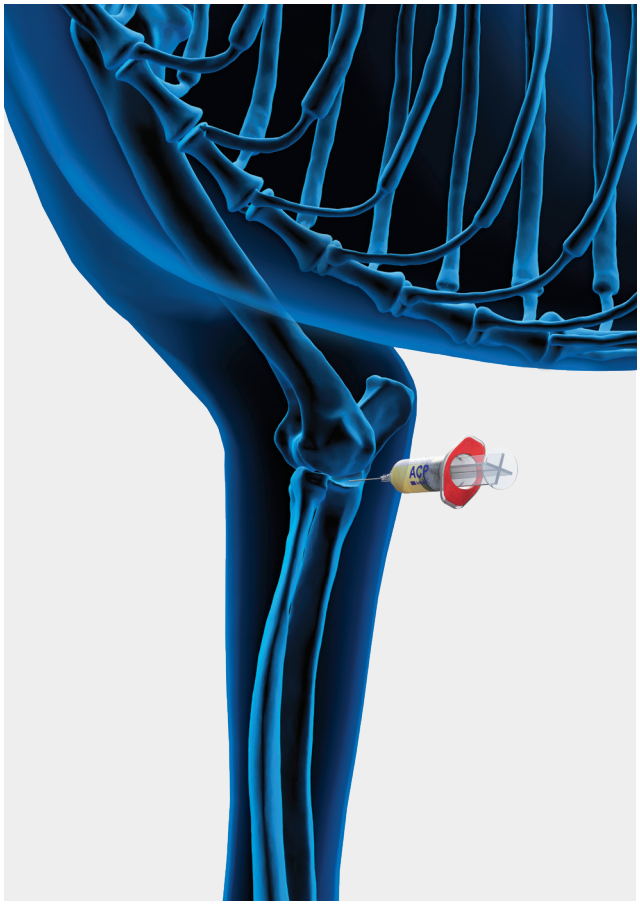
After sterile prep of the joint, when the injectate is ready, sterile gloves are donned, and a needle is inserted into the joint. Joint fluid should be aspirated in a syringe to confirm the joint space has been entered. Gross evaluation of the joint should be performed, and if any concern for infection or pathology aside from osteoarthritis is suspected, cytology should be performed prior to joint injection. In general, joint fluid should be straw-colored, clear, and viscous. Loss of viscosity will be seen in patients with osteoarthritis. If there is an excessive volume of turbid fluid or serosanguinous fluid, cytology is indicated. Common reasons for not being able to obtain joint fluid include improper technique (reinsert needle), shallow or deep joint, eg, a shoulder joint (back needle out and try again, or use a longer needle), tissue plugging the needle in joints with significant synovitis (rotate needle, reposition, and re-aspirate), or there is little fluid in the joint, eg, chronic hip joint.



Shoulder

Place the patient in lateral recumbency for shoulder injections. The acromion is the main anatomic landmark used to locate the shoulder joint. Shave the fur proximal, distal, cranial, and caudal to the acromion so that it can be palpated during the injection. Observing the morphology of the dog's acromion on radiographs prior to injection can be useful, as some dogs have a very low-hanging acromion while others are more proximal. The limb is maintained in a neutral position. On average, however, in a large breed dog, the joint space will be approximately 0.5-1 cm distal to the acromion with the needle inserted perpendicular to the skin. If bone is hit, the needle can be "walked" and angled proximally or distally off the humerus or glenoid to enter the joint space. Typically, in a large breed dog, a 1.5-inch length needle can reach the joint space, though in well-muscled dogs, or obese animals and giant breed dogs, a longer spinal needle may needed.



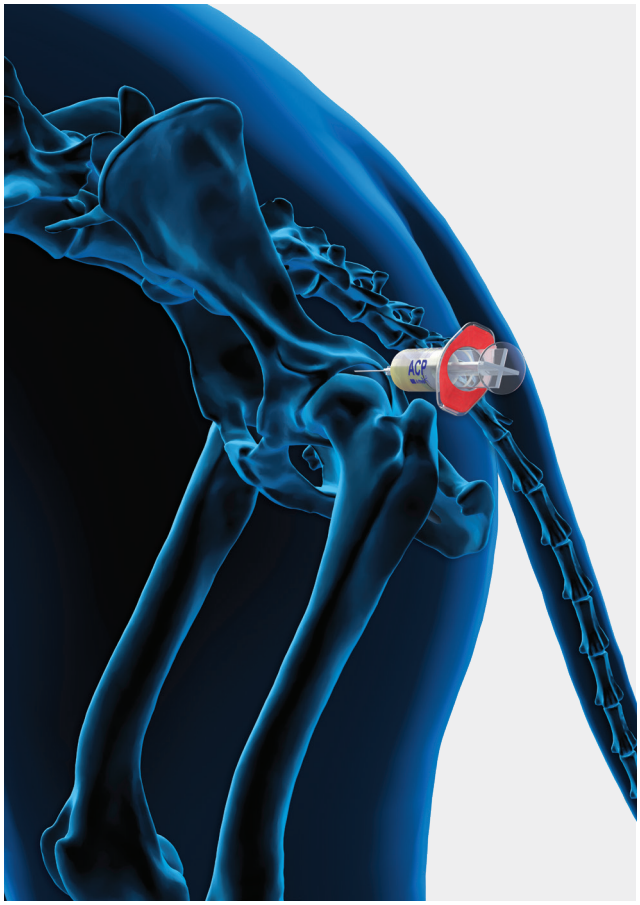


Elbow

The elbow can be injected via a lateral or medial approach, though the authors prefer a medial approach. Place the dog in lateral recumbency with the limb to be injected down. The medial epicondyle is the landmark used for this approach, and fur is shaved around the landmark. Extend and pull the limb from the body wall, while restraining the upper limb along the body wall. It can be helpful to place a rolled towel below the joint on the lateral aspect to apply a valgus stress to open the joint space medially. The joint space is distal to the medial epicondyle in line with the axis of the humerus, approximately 1.5-2 cm distal to the epicondyle in the average large breed dog. Radiographic measurements can be made to help determine distance to the joint from the epicondyle if needed. If performing a lateral injection, place the affected limb up and shave the fur from cranial and proximal to the epicondyle and caudally past the olecranon. The joint is entered from halfway between the lateral epicondyle and olecranon. Aim the needle distomedial along the parallel axis of the ulna.

Carpus

Place the patient in lateral recumbency with the affected limb up. The radiocarpal joint is most accessible due to its size and can be accessed from the dorsal aspect of the limb. Palpate the distal radius and shave the fur surrounding the joint space just distal to this. Locate the joint space by flexing and extending the carpus. Holding the joint in some flexion (typically ~45[238/92]) helps to open the joint space. Palpate the distal aspect of the radius to find the joint space just distal to it. The joint space is accessed just medial or lateral (most commonly medial) to the cephalic vein and the common digital extensor tendon that runs across the joint. Aim the needle in a dorsal to palmar direction parallel to the joint surface of the radius.



Hip

Place the patient in lateral recumbency with the affected limb up. The greater trochanter is the primary landmark for this injection. Shave the fur proximal, distal, cranial, and caudal to the greater trochanter. The joint space is just cranial and proximal to the greater trochanter. Place the limb in slight abduction and apply distal traction to help open the joint space. Insert the needle perpendicular to the skin and long axis of the femur just proximal and cranial to the trochanter. As in the shoulder joint, if bone is hit, the needle can be "walked" proximally or distally to find the joint space. The joint should not be accessed from the caudal to the greater trochanter to avoid iatrogenic damage to the sciatic nerve.

Stifle

Place the patient in lateral recumbency with the affected limb up or in dorsal recumbency in a trough. Shave the fur from proximal to the patella and distal to the tibial tuberosity. Flex the joint to an approximately 90° angle. In lateral recumbency, this is accomplished by having an assistant flex the stifle and abducting the limb, and placing the foot on the table. Insert the needle parallel to the tibial plateau. This angle will vary based on the tibial plateau angle and should be assessed on radiographs prior to injection. The needle is inserted approximately a third to half of the distance from the patella to the tibial tuberosity, either medial or lateral to the patellar tendon. Some variability exists in the tibial tuberosity and patellar tendon insertion, so this should also be assessed on radiographs to help determine the location of needle insertion. Aim the needle slightly axially toward the intercondylar notch.

Tarsus

Place the patient in lateral recumbency with the affected limb up or down. Shave the fur from the entire region surrounding the tarsus to extend 360° around the joint, distal to the tibiotarsal joint, and proximal to the malleoli. The joint can be accessed from the lateral and medial, both cranial and caudally. Flexing and extending the hock helps to identify the joint space. From dorsally, the joint is accessed distal to the tibia and proximal to the talus, either lateral or medial to the saphenous vein and extensor tendons. From caudally and laterally, the joint is accessed distal to the lateral malleolus (distal fibula), angling from caudodistal to cranioproximal and distalateral to proximomedial.

Needle Size for Average Large Breed Dog

Joint	Needle Size
Shoulder	20 g, 1.5 in Hypodermic Needle / 2 in Spinal Needle
Elbow	20 g, 1.5 in Hypodermic Needle
Carpus	20 g, 1 in Hypodermic Needle
Hip	20 g, 2-3 in Spinal Needle
Stifle	20 g, 1.5 in Hypodermic Needle
Tarsus	20 g, 1 in Hypodermic Needle

Needle Size for Average Small Breed Dog

Joint	Needle Size
Shoulder	22 g, 1.5 in Hypodermic Needle
Elbow	22 g, 1.5 in Hypodermic Needle
Carpus	25 g, 1 in Hypodermic Needle
Hip	20 g, 1.5 in Hypodermic Needle / 2 in Spinal Needle
Stifle	22 g, 1 in Hypodermic Needle
Tarsus	25 g, 0.5 in or 1 in Hypodermic Needle

Maximum Allowable Blood Volume Draw for Canines

Weight (lb)	Weight (kg)	Maximum blood draw volume (mL)
5	2.3	30
10	4.5	60
15	6.8	90
20	9.1	120
25	11.3	150
30	13.6	180
35	15.9	210
40	18.1	240
45	20.4	270
50	22.7	300
55	24.9	330
60	27.2	360

Maximum Allowable Blood Volume Draw for Felines

Weight (lb)	Weight (kg)	Maximum blood draw volume (mL)
2.5	1.1	12
3	1.4	18
3.5	1.6	22
4	1.8	25
4.5	2	28
5	2.3	30
5.5	2.5	35
6	2.7	38
6.5	2.9	42
7	3.2	45
7.5	3.4	48
8	3.6	50

PRP Volumes to Inject ≤ mL

	Weight	Shoulder	Elbow	Carpus	Hip	Stifle	Tarsus
Toy / Cat	5 kg	0.5 mL	0.25-0.5 mL	0.25 mL	0.5 mL	0.5 mL	0.25 mL
Small	5-10 kg	0.5-1 mL	0.5-1 mL	0.25-0.5 mL	0.5-1 mL	0.5-1 mL	0.25-0.5 mL
Medium	10-20 kg	1-1.5 mL	1-1.5 mL	0.25-1 mL	1-1.5 mL	1-1.5 mL	0.25-1 mL
Large	20-50 kg	1.5-2 mL	1.5-2 mL	0.75-1 mL	1.5-2 mL	1.5-2 mL	0.75-1 mL
Giant	50+ kg	2-3 mL	2-2.25 mL	1 mL	2-3 mL	2-3 mL	1 mL

References

1. Ayhan E, Kesmezacar H, Akgun I. Intraarticular injections (corticosteroid, hyaluronic acid, platelet rich plasma) for the knee osteoarthritis. *World J Orthop.* 2014;5(3):351. doi:10.5312/wjo.v5.i3.351
2. Jüni P, Hari R, Rutjes AWS, et al. Intra-articular corticosteroid for knee osteoarthritis. *Cochrane Database Syst Rev.* 2015;2015(11). doi:10.1002/14651858.cd005328.pub3
3. Euppayo T, Siengdee P, Buddhachat K, et al. In vitro effects of triamcinolone acetonide and in combination with hyaluronan on canine normal and spontaneous osteoarthritis articular cartilage. *In Vitro Cell Dev Biol Anim.* 2016;52(7):723-735. doi:10.1007/s11626-016-0022-4
4. Frisbie DD, Kawcak CE, Trotter GW, Powers BE, Walton RM, Mcilwraith CW. Effects of triamcinolone acetonide on an in vivo equine osteochondral fragment exercise model. *Equine Vet J.* 1997;29(5):349-359. doi:10.1111/j.2042-3306.1997.tb03138.x
5. Brockmeier SF, Shaffer BS. Viscosupplementation therapy for osteoarthritis. *Sports Med Arthrosc Rev.* 2006;14(3):155-162. doi:10.1097/00132585-200609000-00007
6. Gupta RC, Lall R, Srivastava A, Sinha A. Hyaluronic acid: molecular mechanisms and therapeutic trajectory. *Frontiers Vet Sci.* 2019;6. doi:10.3389/fvets.2019.00192
7. Marshall KW, Manolopoulos V, Mancer K, Staples J, Damyanovich A. Amelioration of disease severity by intraarticular Hylan therapy in bilateral canine osteoarthritis. *J Orthop Res.* 2000;18(3):416-425. doi:10.1002/jor.1100180313
8. Kuroki K, Cook JL, Kreeger JM. Mechanisms of action and potential uses of Hyaluronan in dogs with osteoarthritis. *J Am Vet Med Assoc.* 2002;221(7):944-950. doi:10.2460/javma.2002.221.944
9. Moreland LW. Intra-articular hyaluronan (hyaluronic acid) and hylans for the treatment of osteoarthritis: mechanisms of action. *Arthritis Res Ther.* 2003;5(2):54. doi:10.1186/ar623
10. Pashuck TD, Kuroki K, Cook CR, Stoker AM, Cook JL. Hyaluronic acid versus Saline intra-articular injections for amelioration of chronic knee osteoarthritis: a canine model. *J Orthop Res.* 2016;34(10):1772-1779. doi:10.1002/jor.23191
11. Smith GN, Myers SL, Brandt KD, Mickler EA. Effect of intraarticular hyaluronan injection in experimental canine osteoarthritis. *Arthritis Rheum.* 1998;41(6):976-985. doi:10.1002/1529-0131(199806)41:6<976::aid-art4>3.0.co;2-r
12. Franklin SP, Franklin AL. Randomized controlled trial comparing autologous protein solution to hyaluronic acid plus triamcinolone for treating hip osteoarthritis in dogs. *Frontiers Vet Sci.* 2021;8. doi:10.3389/fvets.2021.713768
13. Franklin SP, Cook JL Prospective trial of autologous conditioned plasma versus hyaluronan plus corticosteroid for elbow osteoarthritis in dogs. *Can Vet J.* 2013;54(9):881-884.
14. Arnoczky SP, Shebani-Rad S. The basic science of platelet-rich plasma (PRP). *Sports Med Arthrosc Rev.* 2013;21(4):180-185. doi:10.1097/jsa.0b013e3182999712
15. Diehl K-H, Hull R, Morton D, et al. A good practice guide to the administration of substances and removal of blood, including routes and volumes. *J Appl Toxicol.* 2001;21(1):15-23. doi:10.1002/jat.727
16. Morton DB, Abbot D, Barclay R, et al. *Removal of Blood From Laboratory Mammals and Birds*. Vol 3. Laboratory Animals Ltd.; 1993.
17. Perazzi A, Busetto R, Martinello T, et al. Description of a double centrifugation tube method for concentrating canine platelets. *BMC Vet Res.* 2013;9(1):146. doi:10.1186/1746-6148-9-146
18. Marx RE. Platelet-rich plasma (PRP): what is PRP and what is not PRP? *Implant Dentistry.* 2001;10(4):225-228. doi:10.1097/00008505-200110000-00002
19. Franklin SP, Birdwhistell KE, Strelchik A, Garner BC, Brainard BM. Influence of cellular composition and exogenous activation on growth factor and cytokine concentrations in canine platelet-rich plasmas. *Frontiers Vet Sci.* 2017;4. doi:10.3389/fvets.2017.00040
20. Hagen A, Lehmann H, Aurich S, et al. Scalable production of equine platelet lysate for multipotent mesenchymal stromal cell culture. *Frontiers Bioengin Biotech.* 2021;8. doi:10.3389/fbioe.2020.613621
21. Silva RF, Álvarez ME, Ríos DL, López C, Carmona JU, Rezende CMF. Evaluation of the effect of calcium gluconate and bovine thrombin on the temporal release of transforming growth factor beta 1 and platelet-derived growth factor isoform BB from feline platelet concentrates. *BMC Vet Res.* 2012;8(1):212. doi:10.1186/1746-6148-8-212
22. Franklin SP, Birdwhistell KE. Assessment of canine autologous conditioned plasmatm cellular and transforming growth factor-1 content. *Front Vet Sci.* 2018;5. doi:10.3389/fvets.2018.00105
23. Textor JA, Willits NH, Tablin F. Synovial fluid growth factor and cytokine concentrations after intra-articular injection of a platelet-rich product in horses. *Vet J.* 2013;198(1):217-223. doi:10.1016/j.tvjl.2013.07.020
24. Textor JA, Tablin F. Intra-articular use of a platelet-rich product in normal horses: clinical signs and cytologic responses. *Vet Surg.* 2013;42(5):499-510. doi:10.1111/j.1532-950x.2013.12015.x
25. Braun HJ, Kim HJ, Chu CR, Dragoo JL. The effect of platelet-rich plasma formulations and blood products on human synoviocytes. *Am J Sports Med.* 2014;42(5):1204-1210. doi:10.1177/0363546514525593
26. Everts PA, Malanga GA, Paul RV, Rothenberg JB, Stephens N, Mautner KR. Assessing clinical implications and perspectives of the pathophysiological effects of erythrocytes and plasma free hemoglobin in autologous biologics for use in musculoskeletal regenerative medicine therapies. A review. *Regen Ther.* 2019;11:56-64. doi:10.1016/j.reth.2019.03.009
27. Sundman EA, Cole BJ, Fortier LA. Growth factor and catabolic cytokine concentrations are influenced by the cellular composition of platelet-rich plasma. *Am J Sports Med.* 2011;39(10):2135-2140. doi:10.1177/0363546511417792
28. Hawk T, Leary SL, Morris TH. *Formulary for Laboratory Animals*. Blackwell Publishing; 2005.

Notes

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This description of technique is provided as an educational tool and clinical aid to assist properly licensed medical professionals in the usage of specific Arthrex products. As part of this professional usage, the medical professional must use their professional judgment in making any final determinations in product usage and technique. In doing so, the medical professional should rely on their own training and experience, and should conduct a thorough review of pertinent medical literature and the product's directions for use. Postoperative management is patient-specific and dependent on the treating professional's assessment. Individual results will vary and not all patients will experience the same postoperative activity level and/or outcomes.

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