Reference Point

Interventional cardiovascular techniques in small animal practice—embolotherapy and chemoembolization

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In 1953, Seldinger1 described a technique for percutaneous arterial catheterization that minimized trauma to the artery, allowing radiologists to perform angiography without surgically exposing the vessel. This technique paved the way for the development of diagnostic angiography. Ten years later, Dotter and Judkins2 described a transluminal method for treatment of atherosclerotic obstruction, marking the transition from use of angiography for diagnosis alone to the development of interventional techniques.

The term interventional radiology was first used in 1967, and since then, interventional radiology has evolved into a separate clinical discipline.3 Current subdisciplines in the field of cardiovascular interventional radiology in human medicine include embolotherapy, chemoembolization, angioplasty and stenting, thrombectomy, and intravascular foreign body retrieval. Each interventional radiology technique has its particular indications.

Several cardiovascular interventional radiology techniques (eg, embolotherapy, chemoembolization, diagnostic angiography, and valvuloplasty) have been adopted by veterinary medicine. In this review, we provide an overview of the use of embolotherapy and chemoembolization in small animal practice. At present, clinical application of embolotherapy and chemoembolization in small animals is in the early stage, with most published reports of these techniques involving a small number of patients. To our knowledge, no randomized clinical trials with adequate follow-up to evaluate efficacy have been published. Thus, data from human medicine are discussed.

Emboloetherapy

Emboloetherapy refers to therapeutic embolization procedures in which target blood vessels are occluded by transcatheter delivery of various embolic agents in an attempt to block vascular anomalies, terminate or reduce blood supply to tumors, and stop or prevent bleeding. Therapeutic embolization requires successful selective or superselective catheterization of the desired vessels and proper selection and precise delivery of embolic agents. Accordingly, a comprehensive understanding of the physical, chemical, and biological characteristics of the currently available embolic agents is needed.

**Embolic agents**—Embolic agents can be divided into 3 broad categories: particulate and solid embolic agents, mechanical occlusion devices, and liquid embolic agents. The particulate embolic agents are further classified as absorbable or nonabsorbable. The absorbable agents, including absorbable gelatin sponges and autologous blood clots, are used for temporary embolization. The nonabsorbable agents, such as polyvinyl alcohol (PVA), trisacryl gelatin microspheres, and silk suture material, are used for permanent embolization.

Once injected into the target vessel, absorbable gelatin incites a thrombogenic reaction, resulting in thrombosis distal to the embolization site. A thrombolytic reaction is initiated following thrombus formation, and thrombolytic enzymes eventually degrade the clot and gelatin material. Occlusion of the treated vessel generally lasts from a few days to several weeks. A histologic study1 suggested that gelatin embolization of an artery caused a severe form of panarteritis with infiltration of leukocytes into all layers of the vessel wall and disruption of the intima and elastic tissues. The panarteritis usually resolved within 4 months.4

Autologous clots are made from the patient’s own blood, and major advantages of autologous clots are their ready availability, low cost, and lack of toxicity. A striking feature of the use of autologous clots is the rapid lysis that occurs following administration into a vessel. In an experimental study,5 lysis of clot emboli was evident within 48 hours in swine and was proposed to be more rapid in dogs because the canine fibrinolytic system is more active. On the one hand, this rapid lysis greatly limits the potential applications of autologous clots to only a few circumstances, such as treatment of renal and gastrointestinal tract hemorrhage. On the other hand, it makes autologous clots the embolic agent of choice when functional damage to the treated organ must be minimized and recanalization of the embolized artery is desired, such as, for instance, during repeated chemoembolization of a nonresectable hepatocellular carcinoma.5

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Polyvinyl alcohol is the most widely used embolic agent for permanent embolization. It is compressible when wet and re-expands to its original shape and size when a dried piece is placed in blood, saline (0.9% NaCl) solution, or contrast medium.1 Thus, PVA particles are frequently used to permanently embolize large vessels. Histologically, PVA embolization causes a mild to moderate transmural inflammatory response, subsequent formation of fibrous connective tissue, and organization of the secondary thrombus.6 Although PVA particles themselves are not absorbable, vessels embolized with PVA have a tendency to recanalize after a few weeks. This is in part attributed to the irregular surface of PVA particles. When administered into target vessels, PVA particles tend to aggregate and clump, and blood clots that form between clumps of PVA particles may eventually recanalize.

To overcome some of the drawbacks of PVA particles, trisacryl gelatin microspheres were developed. Unlike PVA particles, these microspheres have a uniform size and shape and do not change their size in liquid. They also have high deformability. Thus, microspheres that are 700 to 900 µm in diameter can be delivered through catheters with a minimum inner diameter of 280 µm without occluding the catheter, whereas catheter hub accumulation and catheter occlusion occur when 200- to 300-µm-diameter PVA particles are injected through a catheter of similar size. In addition, microspheres penetrate more deeply into the vasculature of target organs than do PVA particles of similar size, which tend to aggregate in the proximal portion of the embolized artery.7,8 However, a major disadvantage of microspheres is the potential for them to pass through a lesion to the pulmonary circulation. Therefore, great care should be taken when microspheres are used to treat lesions with evidence of arteriovenous shunting.

Silk suture material is a nonabsorbable embolic agent that has been used in human medicine for embolization of cerebral and dural arteriovenous malformations, alone or in combination with other embolic agents.9 Although there is, so far, no report on the use of silk suture material for embolization in veterinary medicine, it has great potential for clinical applicability because of its low cost and wide availability. The biocompatibility of silk suture material has been well proved, and it can be used for a variety of purposes, depending on the clinical situation. When proximal embolization is needed, for example, to embolize the feeding artery of a dural arteriovenous malformation, enhance permanent embolization, or prevent passage of an embolic agent through an arteriovenous shunt into the pulmonary circulation, silk suture material might be used simply by cutting the suture material into relatively long (1- to 1.5-cm) threads before delivery. When peripheral embolization is needed to, for example, embolize the nidus of an arteriovenous malformation or tumor, the suture material might be cut to shorter (≤ 1-mm) lengths.

Finally, although particulate embolic agents are classified as absorbable or nonabsorbable, use of nonabsorbable embolic agents does not always lead to permanent embolization.10 On the other hand, permanent embolization may be obtained if an excessive amount of an absorbable embolic agent is used.

Mechanical occlusion devices are generally indicated for embolization of large vessels (arteries and veins). Various mechanical occlusion devices have been developed for use in human medicine, including metallic coils, a double umbrella device, and detachable balloons.11 Metallic coils are most frequently used in human and veterinary medicine and consist of a short stainless steel wire that ranges from 0.025 to 0.038 inches in diameter and is packaged in a straight configuration within an introducer. When the coil is pushed from the introducer into an embolization catheter and, subsequently, into the target vessel, it assumes a spiral or another configuration with specified diameter and length. In theory, deployed coils do not occlude the vessel lumen completely but rather induce thrombosis. To enhance thrombogenicity, some coils are modified by attaching wool strands or synthetic fibers (Figure 1).

Selection of the proper-sized coil is extremely critical to coil embolization. Generally, the diameter of the deployed coil should be approximately 2 mm larger than the diameter of the target vessel. When the coil is too small, it may migrate distally and could potentially enter the pulmonary circulation through an arteriovenous shunt. Conversely, if the coil is too large, it cannot attain its normal coiled form, so that the proximal elongated portion protrudes out of the target vessel.

Since the 1990s, smaller coils made of platinum have been available. The small platinum coils are 0.010 to 0.018 inches in diameter and can be delivered through a microcatheter into tiny vessels to achieve peripheral occlusion. Although some newer coils and other mechanical occlusion devices are safe and effective in human clinical practice, considering the high price of these products, they currently are not practical for routine use in veterinary medicine. Detachable balloons are relatively inexpensive and might potentially be used in the future in veterinary medicine (Figure 2). The major advantages of these detachable balloons include the ability to occlude a vessel at a precise location, the ease with which a partially inflated balloon can be placed at the target site by flow direction, and the fact that balloons can be delivered with low-profile (5-F) catheters. The major disadvantage of detachable balloons is that they can deflate within 2 to 4 weeks,
Emboloetherapy for treatment of patent ductus arteriosus—Patent ductus arteriosus (PDA) refers to the persistence of a fetal structure, the ductus arteriosus, that shunts blood from the fetal pulmonary artery to the aorta. Patent ductus arteriosus is one of the most common congenital heart diseases in dogs, accounting for 5% to 10% of all heart deformities. It occurs twice as often in females as in males, and numerous breeds are predisposed, including Poodles, Collies, German Shepherd Dogs, and Cocker Spaniels. The prevalence of PDA in cats (0.2/1,000) is significantly less than the prevalence in dogs (4.7/1,000). About half of untreated dogs with a PDA develop left-sided heart failure by 8 months of age, and about two thirds are expected to die within 1 year after diagnosis if they are not treated. Currently, surgical ligation is the gold standard for treatment of PDA; however, various embolotherapy techniques developed for use in humans have been adapted for treatment of PDA in small animals.

Transcatheter occlusion of a PDA in a human patient was first reported by Porstmann et al. in 1967. Subsequently, a variety of transcatheter occlusion techniques for treatment of PDA have been developed. Initially, only the Rashkind double umbrella PDA occluder and the Sideris buttoned device were accepted in clinical practice. However, transcatheter PDA closure gained popularity when a technique for using Gianturco steel coils to occlude small PDAs was developed. This technique was later modified to allow use of a detachable coil system. More recently, use of the Amplatz duct occluder has been reported. Transcatheter closure of PDAs has many advantages over conventional surgical closure, including eliminating the need for general anesthesia and thoracotomy, reducing the need for blood transfusions, lowering morbidity rates, shortening hospitalization time, and decreasing hospitalization cost.

Endovascular techniques for transcatheter closure of PDAs potentially could be advantageous in veterinary medicine. However, not all devices and techniques used in human patients are suitable for use in small animals. Placement of the Rashkind double umbrella occluder or the Sideris buttoned device requires that a long, large (8 or 11 F for the Rashkind occluder and 7 F for the Sideris buttoned device) sheath be introduced into the femoral vein and passed through the PDA into the descending aorta. Placement of the sheath may be difficult if the pathway between the right heart and the ductus has a tortuous course or is at an acute angle. Introduction of the Amplatzer duct occluder only requires a 6-F sheath, but the sheath must also be advanced from the femoral vein into the descending aorta. More importantly, all of these devices are rather expensive, which may preclude their routine use in animals. In contrast, coils used for closure of PDAs are relatively inexpensive and can be delivered through a 4- or 5-F catheter.

Use of Gianturco coils for transcatheter closure of PDAs in dogs has been described. These early reports indicated that the technique was feasible and effective in occluding PDAs in dogs and that the procedure was relatively simple. In the procedure, only femoral arterial access with a 4- or 5-F introducer sheath is needed. Thoracic aortography is performed to delineate the
Anatomy of the PDA and allow measurement of minimum ductal diameter. If the PDA is considered amenable to coil occlusion, retrograde pulmonary artery catheterization is performed by advancing the catheter through the aorta and across the ductus. Correct positioning of the catheter is verified by injecting a small amount of contrast agent under fluoroscopic control or by measurement of oxygen saturation and blood pressure. A Gianturco coil of the proper size is then introduced with a delivery catheter. Proper delivery of the Gianturco coil is critical to successful closure of the PDA. After delivery of the coil, aortography is performed to document the extent of occlusion.

Inherent disadvantages to the use of Gianturco coils for closure of PDAs are their poor steerability and the relatively high rate of dislodgment, most frequently into the pulmonary arteries, resulting in pulmonary embolization. Even with experience, poor positioning and embolization of coils may occur. Thus, various modifications of the technique have been developed in an attempt to improve safety of transcatheter closure of PDAs with coils. For instance, Fox et al described use of an Amplatz gooseneck snare device to assist with placement of Gianturco coils for closure of PDAs in 2 dogs. The snare device was advanced from the femoral vein into the main pulmonary artery and was used to snare the first loop of the Gianturco coil as it was delivered to optimize positioning of the coil. Saunders et al reported use of a balloon occlusion catheter to facilitate Gianturco coil occlusion of PDA in 2 dogs. However, use of these techniques increases the overall expense of the procedure because of the additional devices that are needed.

Recently, use of a detachable coil for transcatheter closure of PDAs in dogs has been described. This detachable coil is a modification of the standard Gianturco coil and has a screw mechanism for controlled release of the coil. The detachable coil device allows the coil to be retrieved and repositioned if initial positioning is not optimal. It is also more steerable than the standard Gianturco coil and is relatively inexpensive, compared with other devices such as the Amplatz gooseneck snare. However, once the coil is detached, even if correctly positioned, migration of the coil may occur if a properly sized coil is not selected.

In addition to accidental embolization, the other major complication of transcatheter coil occlusion of PDAs is stenosis of the pulmonary artery or aortic coarctation secondary to protrusion of the coil into the pulmonary artery or descending aorta. To minimize the possibility of this, selection of a coil of the proper size is extremely important. Generally, coil diameter should be at least twice the minimum diameter of the PDA to decrease the risk of coil embolization; coil length should be sufficient to produce at least 3 loops after coil delivery. However, in dogs with short PDAs, it is necessary to ensure that the coil diameter is not greater than the ductus length. The coil is not always deployed in horizontal alignment with the ductus, and if a too-long coil is deployed in vertical alignment in a short PDA, the coil may protrude into the aorta and cause coarctation. For this reason, careful examination of the angiographic anatomy of the PDA and its configuration and measurement of its minimum diameter and length are imperative before a coil is selected.

Careful selection of appropriate patients is critical to a successful outcome for transcatheter coil occlusion of PDAs. In humans, transcatheter coil occlusion is indicated in patients with a small or moderate PDA. There is a general agreement that a single coil can be used with a small PDA (minimum diameter ≤ 2.5 mm), whereas 2 or more coils may be needed with a moderate PDA (2.6 to 4.0 mm in diameter).

Hemolysis is an important complication after coil implantation in humans and dogs. It is believed to be mainly a result of RBC destruction caused by a high-velocity jet of blood passing through the residual PDA shunt. Hemolysis may be noticed within 24 hours after coil embolization of a PDA and can resolve spontaneously. However, if hemolysis persists, implantation of an additional coil to close the residual shunt, surgical removal of the coil, or ligation of the ductus should be considered.

More recently, Sisson reported a prospective study of endovascular closure of PDAs with an Amplatzer duct occluder in 23 dogs. In these dogs, the minimum diameter of the ductus ranged from 2.0 to 8.5 mm, and most dogs had moderate- to large-volume left-to-right shunts. Study results indicate that the Amplatzer duct occluder can be successfully used to manage dogs with PDA, especially those with a large-sized ductus, although the high cost of the Amplatzer device is of concern.

Embolotherapy for treatment of portosystemic shunts—Portosystemic shunts (PSSs) are abnormal vascular communications that permit portal blood flow to bypass the liver and enter the systemic circulation. They reportedly are more common in dogs than in cats and may be congenital or acquired, intrahepatic or extrahepatic, and single or multiple. Congenital PSSs are mostly single and typically are extrahepatic in small-breed dogs and intrahepatic in large-breed dogs. Approximately 20% of all dogs with PSSs have multiple PSSs, which are generally believed to be acquired lesions secondary to portal hypertension.

Most dogs and cats with a PSS will improve with medical management, and about a third can survive long-term with medical management alone. However, the long-term prognosis for animals with PSSs treated medically alone typically is poor, with more than half eventually euthanatized because of uncontrolled neurologic signs or progressive liver damage. Hence, medical management is currently indicated only for those animals with acquired or microvascular shunts and for those for which surgical treatment is not available.

Surgical management consisting of partial or complete ligation of the shunt is considered the treatment of choice for most dogs and cats with PSSs, particularly those with a single extrahepatic shunt. In a study of 49 dogs with extrahepatic PSSs that underwent surgical ligation, mortality rate was only 2% and liver function returned to normal in 92% of dogs in which the shunt was completely ligated and 70% of dogs in which the shunt was partially ligated. Generally, complete ligation results in a more favorable outcome than partial...
ligation. However, it is not always possible to completely ligate the shunt because in animals with hypoplasia of the intrahepatic portal vasculature, the sudden increase in blood flow following complete ligation of the shunt can result in fatal portal hypertension.\textsuperscript{23} Unfortunately, partial ligation can lead to only short-term clinical improvement and clinical signs can recur in up to 50% of patients 2 to 6 years after surgery.\textsuperscript{24} To improve the outcome following partial ligation but avoid fatal portal hypertension, it has been suggested that complete ligation of the shunt be performed 1 to 2 months after the initial partial ligation, by which time the liver should have adapted to the additional blood flow.\textsuperscript{31}

Recently, use of ameroid constrictors has been gaining increased interest in treatment of dogs and cats with single extraplastic PSSs.\textsuperscript{33,36} This device is made of dehydrated casein surrounded by a metal ring. The casein swells when immersed in water, blood, or serum. Thus, when an ameroid constrictor is placed around a shunt vessel, swelling of the casein causes gradual closure of the shunt. Typically, complete closure occurs within 4 to 5 weeks. Ameroid constrictors have been reported to be as effective as surgical ligation in the treatment of PSS but are associated with shorter surgical times and a lower risk of fatal portal hypertension, compared with complete ligation of a PSS.\textsuperscript{37}

Although long-term complications were encountered in 15% of animals in which an ameroid constrictor was used, this was lower than the complication rate for animals undergoing partial ligation (42%).\textsuperscript{20} Gradual attenuation of single extraplastic PSSs can also be achieved with cellophane bands,\textsuperscript{32} with complete occlusion expected within 3 weeks after surgery.

Unfortunately, surgical management of intrahepatic PSSs is still a challenge for veterinary surgeons. Surgical identification and isolation of intrahepatic shunts are technically demanding, and hemorrhage is common.\textsuperscript{38} Not surprisingly, reported mortality rates associated with surgical ligation of intraplastic PSSs are high (18% to 23%).\textsuperscript{36,39} Thus, embolotherapy may be an appealing alternative to surgical ligation of intrahepatic PSSs.

Transvenous coil embolization for treatment of a dog with an intraplastic PSS was first described by Partington et al.\textsuperscript{42} and additional published reports\textsuperscript{34,40} of the procedure are limited. A transjugular approach has been used most frequently because the larger diameter of the jugular vein, compared with the femoral or saphenous vein, permits easier introduction of embolization devices. However, femoral and saphenous approaches for percutaneous embolization and a mesenteric venous approach for intraoperative embolization have also been reported.\textsuperscript{35,40}

Under fluoroscopic guidance, a catheter is placed into the shunt, and retrograde portography can be used to delineate the shunt's anatomy, diameter, and length. Coil embolization has the potential to allow for gradual occlusion of the shunt. Thus, the risk of fatal portal hypertension is expected to be low. However, transvenous coil embolization carries a risk of migration of the coils into the heart or lungs, which might be fatal if the coils lodge in the main pulmonary artery.\textsuperscript{32} Other major complications include hemolysis and acute portal hypertension following embolization.

The limited clinical reports\textsuperscript{34,40} that have been published suggest that the complication rate may be higher following coil embolization of extraplastic, rather than intraplastic, PSSs. The reported complications in management of extraplastic PSSs include coil migration, acute portal hypertension, hemolysis, and death.\textsuperscript{34,40} Thus, transvenous coil embolization may not be suitable for treatment of animals with extraplastic PSSs, and surgical closure may be a better option. Although insertion of a stent in the caudal vena cava may help prevent coil migration,\textsuperscript{32} the high cost of stents limits their use in veterinary medicine. In contrast, coil embolization for treatment of animals with an intraplastic PSS appears to be safe. In a report\textsuperscript{34} of 7 animals with intraplastic PSSs, coil migration occurred in only 1 and did not cause any clinical signs. No other major complications were reported.

Unlike PDA, congenital PSSs are rare vascular anomalies in humans. Thus, little is known about the results of transvenous coil embolization of PSSs in humans. Veterinarians must face a variety of challenges, such as developing criteria for appropriate diameter and length of embolization coils for a given shunt and methods to prevent coil migration, before transvenous coil embolization of PSSs can be routine.

Embolotherapy for treatment of tumors—In human medicine, transcatheter arterial embolization is a well-established method for the treatment of benign and malignant neoplasms. Transcatheter arterial embolization involves embolizing the arteries supplying a tumor, resulting in ischemia of the tumor and subsequent tumor necrosis. Transcatheter arterial embolization has been accepted as an alternative to surgery in the treatment of various benign tumors, such as uterine leiomyomata and hepatic cavernous hemangioma. Following transcatheter arterial embolization in patients with uterine leiomyomata, uterine size can be expected to decrease by 40% to 50% with improvement in or resolution of clinical signs in 90% to 95% of patients.\textsuperscript{41} Similarly, clinical improvement has been documented in patients with hepatic cavernous hemangiomas following transcatheter arterial embolization.\textsuperscript{20}

In patients with malignant tumors, transcatheter arterial embolization is frequently used as a palliative method of pain control or an adjunctive approach before surgery to decrease intraoperative blood loss and reduce surgical morbidity rates.\textsuperscript{24} In a study\textsuperscript{24} of 29 human patients with unresectable bone metastases, tumor necrosis was detected by means of computed tomography and magnetic resonance imaging in all patients after transcatheter arterial embolization, with the amount of tumor necrosis ranging from 30% to 80% (mean, 50%). In a study\textsuperscript{25} of rabbits with experimentally induced VX2 sarcoma, mean ± SD percentage necrosis for tumors that underwent transcatheter arterial embolization was 62 ± 22%, compared with spontaneous necrosis of 19 ± 7% in control rabbits. In 1 rabbit that underwent transcatheter arterial embolization, no active tumor cells could be detected during histologic examination of the residual tumor. In veteri-
nary practice, application of transcatheter arterial embolization has been reported in 4 cases, including 3 dogs and 1 goat, and a decrease in tumor size and clinical improvement have been achieved in 3 animals.\(^{13,14}\)

**Chemoembolization**

The term transcatheter arterial chemoembolization refers to intra-arterial delivery of chemotherapeutic drugs in combination with embolization of malignant tumors. The use of transcatheter arterial chemoembolization for the treatment of malignant tumors has several theoretical advantages. First, intra-arterial delivery of chemotherapeutic drugs can result in extremely high drug concentrations at the target tumor, compared with systemic administration. For instance, hepatic drug exposure was estimated to be increased by a factor of 2 for doxorubicin, a factor of 7 for cisplatin, a factor of 8 for mitomycin, a factor of 10 for 5-fluorouracil, and a factor of 400 for 5-fluorodeoxyuridine when drugs were delivered directly in the hepatic artery, rather than IV.\(^{2}\) Second, intra-arterial delivery of chemotherapeutic drugs in combination with embolization further increases drug concentration within tumors, with tumor tissue concentrations of drugs found to be up to 40 times the concentration in surrounding tissues.\(^{74}\) Third, embolization renders the tumor ischemic, depriving it of nutrients and oxygen and inducing necrosis and fibrosis. Fourth, blockage of arterial flow to tumors prolongs the time that chemotherapeutic agents are in contact with the tumor, compared with systemic administration. For instance, hepatic drug exposure was estimated to be increased by a factor of 2 for doxorubicin, a factor of 7 for cisplatin, a factor of 8 for mitomycin, a factor of 10 for 5-fluorouracil, and a factor of 400 for 5-fluorodeoxyuridine when drugs were delivered directly in the hepatic artery, rather than IV.\(^{2}\) Second, intra-arterial delivery of chemotherapeutic drugs in combination with embolization further increases drug concentration within tumors, with tumor tissue concentrations of drugs found to be up to 40 times the concentration in surrounding tissues.\(^{74}\) Third, embolization renders the tumor ischemic, depriving it of nutrients and oxygen and inducing necrosis and fibrosis. Finally, because most of the drug is retained within the tumor following transcatheter arterial chemoembolization, systemic toxicoses associated with chemotherapeutic drugs are minimized.

Transcatheter arterial chemoembolization has been extensively studied in the treatment of hepatocellular carcinoma, one of most common lethal malignancies in humans. Surgical resection of hepatocellular carcinoma continues to be the best treatment; unfortunately, few patients (10% to 30%) are candidates, and transcatheter arterial chemoembolization is regarded as the treatment of choice for patients with unresectable hepatocellular carcinoma. For these patients, various chemotherapeutic drugs mixed with lipiodol are administered, followed by embolization with absorbable gelatin. Most commonly, a single agent such as doxorubicin or cisplatin is used, although a combination of cisplatin, doxorubicin, and mitomycin C is also frequently used.\(^{59}\) Mixing the drug with lipiodol has 2 effects. First, because lipiodol is a liquid embolic agent, it slows down the arterial circulation. Second, lipiodol can be used as a carrier of anticancer drugs. It is well observed that lipiodol, when injected intra-arterially, preferentially flows to and is retained in hypervascular tumors. This is probably secondary to the siphoning effect of hypervascular tumors attributable to hemodynamic differences between the tumor and surrounding unaffected tissue. Hence, if a mixture of an anticancer drug with lipiodol is infused into the hepatic artery in a patient with hepatocellular carcinoma, the drug will be selectively delivered to the tumor. Furthermore, the drug will be released slowly from the lipiodol emulsion, resulting in a longer contact time between the drug and tumor.\(^{13,60}\) This effect is further enhanced by subsequent administration of a particulate embolic agent such as absorbable gelatin, which temporarily blocks arterial inflow, delaying washout of the anticancer drug. In addition, if a sufficient amount of lipiodol is injected into the hepatic artery, it will travel to the distal arterioles and through the shunts at the presinus level to fill the peripheral portion of the portal vein around the tumor. Thus, embolization at both ends of the tumor (ie, the hepatic arterioles and portal venules) can be achieved.\(^{59}\) There is no doubt about the effectiveness of transcatheter arterial chemoembolization in the management of hepatocellular carcinoma in people. The extent of tumor necrosis after chemoembolization has been reported to range from 60% to 100%,\(^{61}\) and numerous retrospective studies have demonstrated a benefit in terms of survival time and rate. As an example, a nonrandomized trial\(^{66}\) revealed a significantly longer survival time for patients treated with transcatheter arterial chemoembolization, compared with untreated patients. Survival rates in treated patients were 64%, 38%, 27%, and 27% after 1, 2, 3, and 4 years, respectively, whereas survival rates in patients receiving only supportive care were 18%, 6%, and 5% after 1, 2, and 3 years, respectively.

**Chemoembolization in small animals**—In 2002, Weisse et al\(^{57}\) reported on results of transcatheter arterial chemoembolization in a dog with hepatocellular carcinoma, and in 2003, Cave et al\(^{58}\) reported on results of transcatheter arterial chemoembolization in 2 dogs with hepatocellular adenoma. In all 3 dogs, transcatheter arterial chemoembolization was performed as a palliative treatment in an attempt to decrease tumor growth or alleviate pain. Although the procedure was technically successful in all 3 dogs, clinical improvement was not seen.

**Conclusions**

Embolotherapy is a safe and minimally invasive method for treating PDAs and PSSs in dogs and cats. Selection of coils of the proper diameter and length and precise delivery are critical to obtaining an optimal outcome. At present, embolotherapy in animals with PSSs should be limited to those with intrahepatic shunts. Transcatheter arterial embolization and transcatheter arterial chemoembolization have proved to be useful as palliative or adjunctive treatments of neoplasms in humans. However, these techniques are in their early stages in veterinary medicine, and clinical efficacy and safety are yet to be evaluated.

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d. Sideris buttoned device, Custom Medical Devices Inc, Amarillo, Tex.
e. Amplatz duct occluder, AGA Medical Corp, Golden Valley, Minn.

g. Amplatz gooseneck snare, Microvena Inc, Saint Paul, Minn.
h. Cook detachable PDA coil, Cook Inc, Bloomington, Ind.
References


