3D Computed Tomography Angiography (CTA) in a Dog

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Abstract

Technical advances in CT imaging offer higher image resolution with shorter rotation times. High-end CT scanners that integrate this technology allow for extremely accurate imaging of blood vessels, pathological changes in tissue, and the beating heart – and thus for extremely rapid generation of highly detailed 3D images of diseased coronary vessels. The main human-medicine application of this technology is stenosis detection with a view to detecting potential life threatening heart attacks before they occur and managing these scenarios, or taking the relevant precautionary measures. This article describes 3D imaging applications for dogs, using a 64 slice CT scanner.

Introduction

Discovery of blood circulation

For approximately 1500 years beginning in 200 AD, Western medicine was dominated by the Greek physician Galen's theory of the threefold circulation of the blood according to which blood is produced in the liver, is enriched by air in the lungs and then flows into the blood vessels through pores in the heart chamber walls. This theory, which also held that the vessels carried the blood to the organs and nourished them, was not dislodged until William Harvey (1578-1657) presented his new theory of blood circulation at a lecture in London on 17 April 1616. Harvey demonstrated his theory via a simple experiment in which he cut off the bloodflow from a subject's arteries and veins by tying a tight ligature onto their upper arm. The resulting swelling of the arm above the ligature showed that the blood could not flow back into the veins below the ligature. In 1628 Harvey published his 72 page treatise titled *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus* or *De Motu Cordis* for short (Anatomical Studies on the Motion of the Heart and Blood). Until the early 20th century, blood vessels could only be imaged via anatomical studies.

Discovery of x-rays

Shortly before the discovery of x-rays by Conrad Röntgen in November 1895 the first experiments with radiographic imaging of blood vessels were carried out (Beck, 1992). A description of the first angiography of the hand of a human cadaver was published in early 1896 by Haschek and Lindenthal (Beck 1992; Zeitler, 1997; Rieger and Schoop, 1999). The first experiments involving catheterization of the arterial and venous systems in dogs were performed in 1905 by Bleichröder.

The first reports on angiography in living human subjects were published in 1923 by Sicard, Forestier, Hirsch and Berberich. Angiography of the lower extremities was first performed in 1924 by Brooks in the US (Beck, 1992). This was followed by publication of a report on "arterial encephalography" in 1927 by Moniz and the first aortagraphy by Dos Santos in 1929 (Wilms and Baert, 1995; Rieger and Schoop, 1999).

Catheterization

The advent of catheterization was a major boost for angiography. The first percutaneous arterial catherization of the aorta was described by Pierce in 1949 (Beck, 1992). Another milestone in the de-

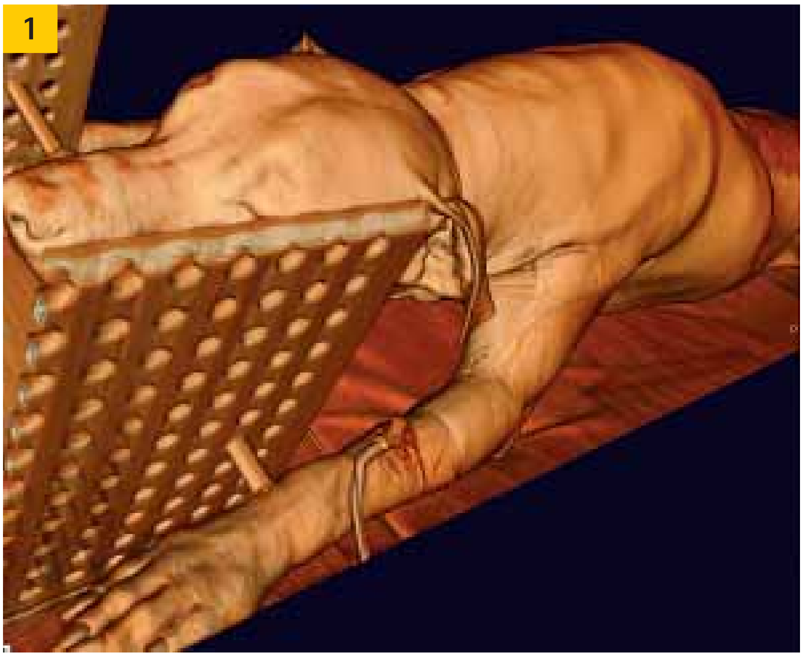


Fig. 1: Surface reconstruction via a surface shaded display (SSD) comprising calculated radiography fluctuation patterns. Even the venous catheter on the patient's leg is visible.

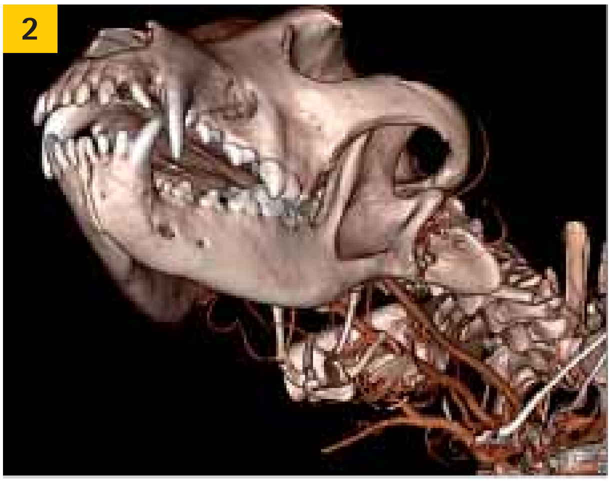


Fig. 2: Neck angiography

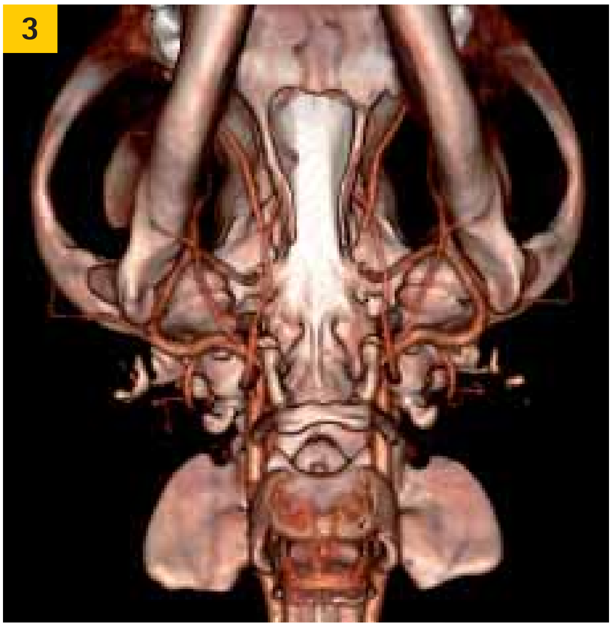


Fig. 3: Mandibular joint angiography

velopment of catheter techniques was the advent of percutaneous catheterization according to Seldinger, which was first described in 1953 and remains the standard angiography method to this day (Lehmann and Jaschke, 1993; Wilms and Baert, 1995; Hagen, 1997)

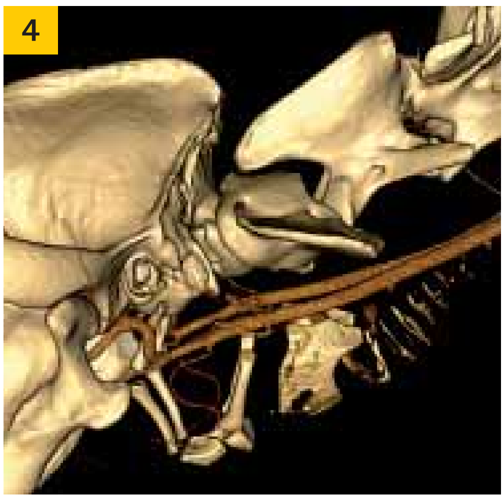
Contrast medium

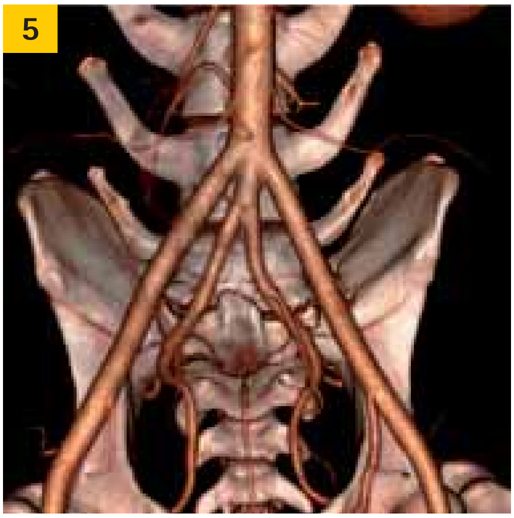
One of the main issues since the advent of CT angiography has been the selection of and search for a suitable contrast medium (Barke, 1970; Torvika and Walday, 1995). The introduction of iodized contrast medium allowed for a substantial reduction of complications arising from CT angiography (Grainінger, 1982; Peters and Zeitler, 1991; Schill, 1991; Dawson, 1992; Krause, 1994). Most of today's vascular contrast agents are non-ionic, low-osmolar substances, with iodine content ranging from 250-370 mg I/ml (Bouard et al, 1996; Busch et al, 1999; Brillet et al, 2001), that have allowed for substantial reductions in the side effect rate (Manninen et al, 1999; Speck, 1999; Meyer, 2003). These substances are injected using high-pressure injectors that allow for consistent flow quality and the requisite high flow rates (Belli, 1997).

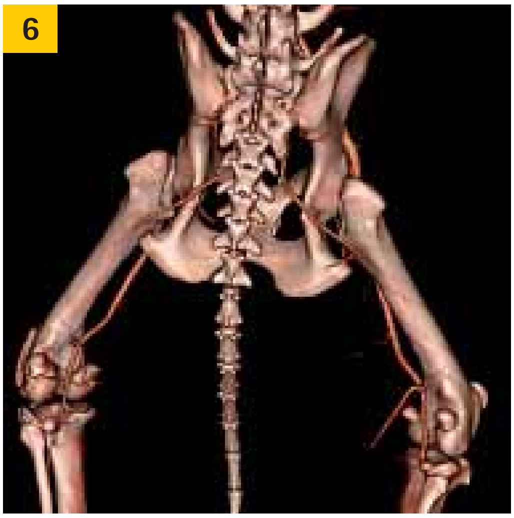
CT angiography in human medicine

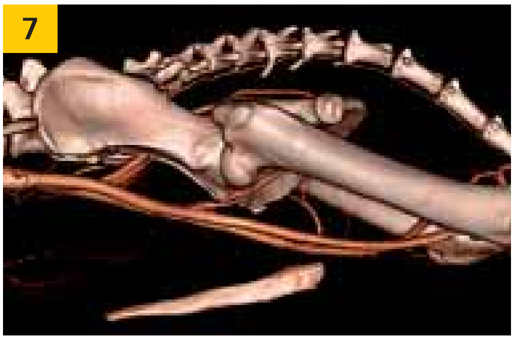
CT angiography is a minimally invasive diagnostic technique that allows for high spatial and low temporal resolution, as well as (when combined with modern reconstruction methods) 3D imaging of the larger vessels (Herzog et al, 2001). Assessment of total calcification volume in coronary vessels is a key factor for the early detection of coronary heart disease since coronary calcification levels correlate directly with the rate of incidence of heart attacks, cardiac arrhythmia and other cardiac disorders (Herzog et al, 2001). CT angiography combined with software that calculates the calcium score for assessments of a patient's risk for heart attack by measuring the calcification volume of coronary vessels. In addition to determining total coronary calcification volume, assessments of individual calcification deposits play a key role in the early detection of risk for heart attacks (Hittmair et al, 1999). CT angiography can be used for this as well, since it allows for the imaging of individual calcification deposits that can

Fig. 4: Neck angiography showing the carotid artery, larynx, hyoid bone and individual tracheal rings









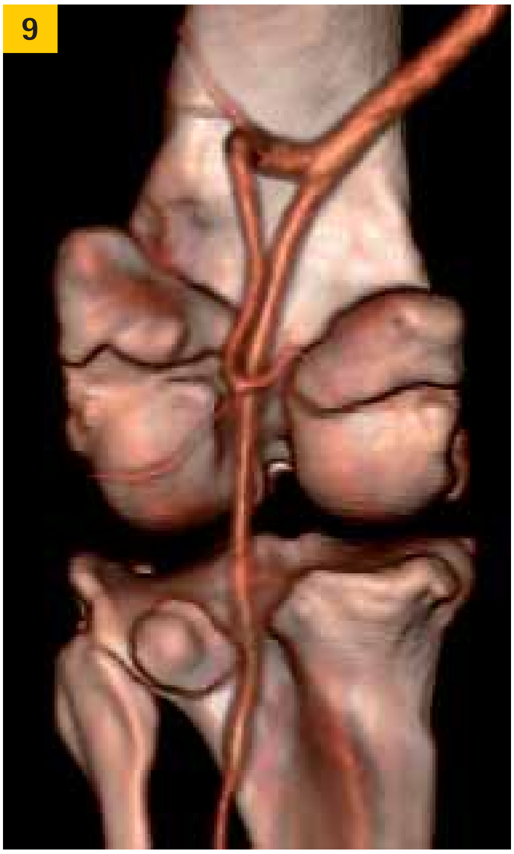


Fig. 5: Ventral pelvic angiography showing the abdominal aorta and origin of the external iliac, internal iliac and median sacral arteries

Fig. 6: Dorsal pelvic angiography showing the same elements as in fig. 5

Fig. 7: Lateral view of figs. 5 and 6 with the penile bone

Fig. 8: Lateral knee angiography showing the origin of the external iliac, middle caudal femoral, and popliteal arteries

Fig. 9: Caudal knee angiography showing the external iliac artery, the popliteal artery, the descending genicular artery, and the arteria saphena

Fig. 10: Left shoulder at the thoracic aperture. Transition from the subclavical artery to the axillary artery; origin of the external and lateral thoracic arteries. The origin of the caudal circumflex humeral artery at the axillary artery can be seen at the neck of the humerus.

provoke a stenosis. Plaque (non-calcified cholesterol containing coronary deposits) can also provoke a heart attack since it can likewise provoke a stenosis. Plaque deposits, which accumulate in the vessel lining, can provoke a life threatening vascular occlusion if all or part of a deposit breaks loose from the lining. CT angiography is the first method to allow for non-invasive early detection and reliable diagnosis of soft plaque (Hahn et al, 2001). The efficacy of other types of preventive diagnosis is also enhanced by high-end CT owing to the high resolution it provides of the most minute vascular changes.

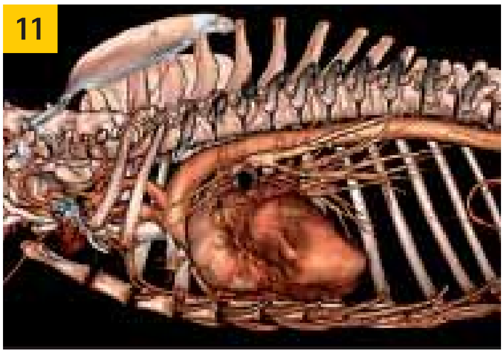


Fig. 11: View of the thorax and right kidney

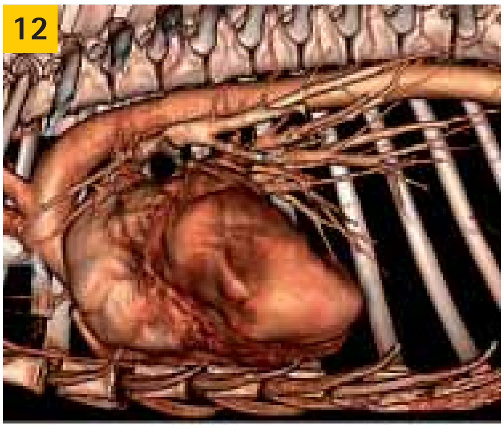


Fig. 12: Heart with aorta and pulmonary arteries

Fig. 13: Thoracic and abdominal aortas, with the origin of the intercostal dorsal, costoabdominal dorsal, lumbar, coelic, mesenteric caudal, phrenic caudal and left renal arteries

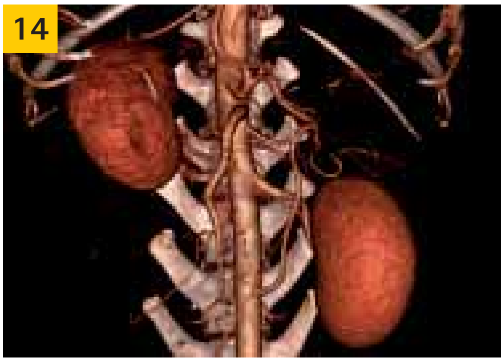


Fig. 14: Ventral view of the abdominal aorta with both kidneys, as well as the origin of the coelic artery, the caudal mesenteric artery, and the left and right renal arteries

CT angiography in veterinary medicine

CT angiography plays a particularly important role for diagnostic imaging of intrahepatic portosystemic stent shunts (TIPS); the relevant techniques have been well described in the literature (Kneissl, 1997; Henninger, 2001: Henseler et al, 2001; Mahaffey, 2003; Zwingenberger and Schwarz, 2004; Winter et al, 2005; D'Anjou and Huneault, 2008). Methods for detecting coronary vessel malformation using CT angiography have also been satisfactorily described (Joly et al, 2008). Contrast medium investigations of the pancreas can reveal signs of malignancy (Iserit et al, 2007). Three-dimensional imaging of blood vessels and their paths is rarely used in veterinary medicine, and there are currently no indications for it. Imaging of coronary vessels in dogs and cats (unlike in humans) has no diagnostic relevance. However, spatial imaging of smaller arteries relative to the surrounding tissue may be useful for preoperative planning in veterinary settings, particularly for the extirpation of large tumors. Further research is needed in order to determine the extent to which intra- and extra-hepatic shunts can be imaged using CT angiography.

Case study

CT scanner

The investigation was performed using a Toshiba Medical Systems Aquilion 64 CT scanner. In 2004 Berlin's Charité hospital became the first European medical center to deploy this type of device. The Aquilion 64 – Toshiba Medical Systems' high-end scanner – acquires 64 simultaneous 0.5 mm slices, at a rotation time of 0.35 seconds, and isotropic voxel size of 0.35 mm.

The investigation

The patient was an eight year old, 61 pound (28 kilogram) neutered male pit bull mutt. The venous catheter was inserted in the left vena cephalica antebrachii. Using a Medrat contrast medium injector, 60 ml of iohexol (Accupaque 300mg I/ml) was injected at a rate of 2 ml/s. At the beginning of the scanning procedure, the flow of contrast agent through the descending aorta to the region of interest (ROI) (fourth thoracic rib) was monitored via bolus tracking. Once a sufficient volume of contrast medium had reached the ROI, the scanning procedure was initiated using 0.5 mm slices.

Results

Three-dimensional vascular imaging using the Aquilion 64 yielded outstanding results, particularly since smaller vessels could also be visualized optimally. The extent to which vessels in the liver and other organs can be visualized individually in order to detect pathological changes will require further investigation. The visualization of vessel paths in neoplasias, which provide surgeons with vital information, likewise requires further study. The presence of contrast medium in the parenchyma or musculature of organs such as the liver, heart and kidneys allows for quality imaging of these organs, whose surfaces can be visualized individually. However, this provides no indication as to the status of the organ. Organs such as the pancreas and renal cortex containing lesser amounts of contrast medium could not be visualized during the investigation. Thanks to the rapid investigation speed afforded by the Aquilion 64, it might be possible to perform CT scans on some polytraumatized patients without sedation, thus allowing for a quick assessment of internal and external injuries without substantial manipulation of the patients. Inasmuch as, for the foreseeable future, purchasing costs for high-end scanners compared to "slower" devices will outweigh their potential benefits for veterinary medicine, they will be used in human medicine only.

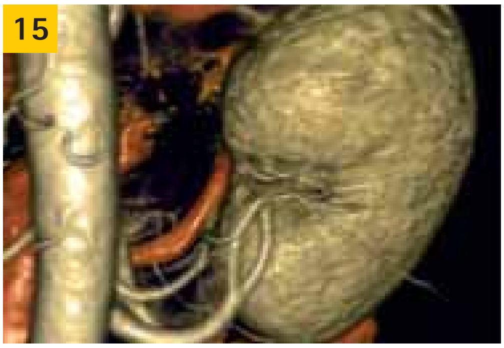


Fig. 15: Left kidney with the origin of the renal artery at the aorta and the two branches just before the renal hilus

Fig. 16: View of the abdominal cavity showing the following: right kidney, caudal pole of the left kidney, stomach half exposed, liver, loops of the small intestine, and pulmonary vessels

Fig. 17: View from the thorax (looking toward the abdomen) of the upper pulmonary arteries, lower stomach, kidneys, blood vessels and small intestine

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