

Clinical aspects of congenital anomalies in cats and dogs: double outlet ventricles

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With 2 tables.

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Abstract

Double outlet right ventricle (DORV) and double outlet left ventricle (DOLV) are congenital conditions where the great arteries (aorta and pulmonary trunk) both arise mostly or completely from the right or left ventricle. The limited body of evidence about this condition in cats and dogs suggests it is very rare. There does not seem to be a predisposition in certain breeds. The condition is diagnosed usually early and life and is usually medically treated. Despite surgery being a viable option in humans, it is rarely performed in animals. Unfortunately, there is still significant mortality regardless of treatment strategy. Additionally, a lot of animals are not treated at all. Further research is necessary to obtain more insights in the epidemiology of the condition and to assess the different treatment strategies. Retrospective studies should be considered, since prospective trials may be unfeasible due to the rarity of the condition. Subsequently, standard treatment protocols could be developed.

Keywords: Double out ventricle, Cats, Dogs, Anatomy

Introduction

Congenital heart anomalies have been well described in both cats and dogs (Hunt et al., 2006). Such anomalies occurring in both species include patent ductus arteriosus (Broaddus and Tillson, 2010; A Bascuñán et al., 2016), valve dysplasia (Amberger et al., 1989; Kuijpers and Szatmári, 2011) and double outlet ventricles (Chetboul et al. 2020). Double outlet right ventricle (DORV) and double outlet left ventricle (DOLV) are congenital conditions where the great arteries (aorta and pulmonary trunk) both arise mostly or completely from the right or left ventricle, respectively (Lee et al., 2010). In humans, DORV has been mentioned to make up 1-3% of all cases of congenital heart defects (Obler et al., 2008). These defects are almost always accompanied by a ventricular septal defect (VSD) (Takeuchi and Pedro J., 2000), which allows blood to flow between both ventricles and therefore enables blood crossing be-

tween the systemic and pulmonary circulation. Treatment of DORV often includes surgery (Wu et al., 2017). Like in humans, double outlet ventricles have also been observed in different animals, including dogs and cats (Chetboul et al. 2020). The literature of this condition in veterinary medicine is however very sparse. Therefore, there is still much to be learned about the epidemiology and treatment of these anomalies in companion animals, including cats and dogs. No review of the clinical aspects of this anatomical defect has currently been published. Therefore, this review aims to summarize the clinical aspects regarding canine and feline DORV and DOLV from the available literature. Additionally, proposals for future research are formulated.

Literature search and inclusion

To identify relevant literature in cats and dogs, the Medline database was searched using the “(double outlet ventricle) AND (dogs [MeSH Terms])” and “(double outlet ventricle) AND (cats, domestic [MeSH Terms])” search strings, yielding five and six results respectively. Three publications were included for the dogs. One publication was excluded because it concerned iatrogenic DOLV and another publication was excluded because it concerned a human patient. Two other relevant publications were identified through an internet search using the “double outlet ventricle dog”

string. For cats, four publications were included. One publication was excluded because it concerned double-chambered right ventricle and two were excluded because they could not be sourced. One additional publication was identified during an internet search using the “double outlet ventricle cat” string. Data extracted from the included publications is shown in table 1 and 2.

For both species, the literature identified consisted solely of case reports and case series. Eight cases of dogs with double outlet ventricles were identified (Vos et al., 1984; Bedolla-Alva et al., 2010; Lee et al., 2010; Koo et al., 2016; Chetboul et al., 2020). For cats, only three case reports were identified (Abduch et al., 2003; Hwang et al., 2016; Chetboul et al., 2020). Figure 1 shows a representative illustration of the double outlet right ventricles identified.

Animal characteristics

For both species, a wide variety of breeds were described to suffer from the condition. Dog breeds that were affected included, amongst others, a chihuahua (Bedolla-Alva et al., 2010), a Samoyed (Chetboul et al. 2020) and two poodles (Vos et al., 1984; Chetboul et al. 2020). The affected cats' breeds were a Persian (Abduch et al., 2003), a British shorthair (Hwang et al., 2016) and a Scottish fold (Chetboul et al., 2020). Based on this limited information, it could be hypothe-

sized that there is no strong predisposition for this condition in certain breeds. Likewise, there was an almost equal distribution between male and female animals, suggesting that sex does not strongly influence predisposition.

All animals were relatively young when diagnosed. The age at diagnosis for the dogs ranged from three months to two years. However, most of the animals were below one year of age. For cats, the age at diagnosis ranged from one to ten months. Based on these observations, it can be assumed that double outlet ventricles manifest with symptoms that occur early in life.

Based on the cases identified, it seems that in cats and dogs DORV is more common than DOLV. Only one dog with DOLV was described, while no cats were reported to suffer from DOLV. However, this will need to be confirmed by further research.

Concurrent defects

All animals that suffered from a double outlet ventricle had concurrent defects. In the identified case reports, all animals also had a VSD. This has also been described in humans (Wu et al., 2017) and allows blood to flow between the systemic and pulmonary circulation despite both great arteries originating from the same ventricle. It can be assumed that without a VSD, double outlet ventricle would almost be invariably lethal.

In some cases, the double outlet ventricle was assumed to be part of the tetralogy of Fallot (Vos et al., 1984; Bedolla-Alva et al., 2010). This means that additionally a pulmonary stenosis, overriding aorta, VSD and right ventricular hypertrophy were present. Other concurrent defects that were described included aortic stenosis (Chetboul et al. 2020) and patent ductus arteriosus (Chetboul et al. 2020).

Symptoms

Exercise intolerance was a symptom that occurred in nearly all cases that were described. This was frequently accompanied by cyanosis (of mucous membranes) and tachypnea. Other symptoms that were described included dyspnea (Lee et al., 2010), lethargy (Chetboul et al. 2020) and breathing difficulties (Bedolla-Alva et al., 2010). In selected cases, long-term effects such as growth retardation were described (Vos et al., 1984; Chetboul et al. 2020).

Diagnosis

In most cases, bloodwork and cardiac examinations, such as electrocardiography, were performed after the animals presented with symptoms. Afterwards, the final diagnosis was almost always made using echocardiography. In one instance, the diagnosis was only confirmed post-mortem (Vos et al., 1982). Other imaging techniques that were used in multiple instances were thoracic radiography

(Abduch et al., 2003; Hwang et al., 2016) and (cardiac gated) computed tomography (Koo et al., 2016; Chetboul et al., 2020).

No standard diagnostic guidelines have been developed for DORV or DOLV. This can probably be partly attributed towards the rarity of the anomaly. It is however clear that even without these guidelines, the diagnostic workflow was very similar between the different cases. Therefore, it may not be necessary to standardize the approach at this time. Further research could investigate whether there are strategies to discover a double outlet ventricle before it becomes symptomatic. This may in turn improve outcome when treatment can be initiated earlier.

Treatment and outcomes

In humans, double outlet ventricle is often amenable to surgery and treated this way (Wu et al., 2017). In the identified case reports, surgery was only attempted on one dog (Chetboul et al. 2020) and one cat (Abduch et al., 2003). Unfortunately, in both cases, the animal died during or very shortly after surgery. Additionally, one cat died during preparation for angiography (Vos et al., 1984). Due to the relative effectiveness of surgery in humans, further research should be conducted. Why surgery is not often conducted in veterinary patients and whether the poor outcomes currently described are representative.

Medical treatment was used in several cases (Abduch et al., 2003; Lee et al., 2010; Hwang et al., 2016; Chetboul et al. 2020). Drugs that were often prescribed included spironolactone and furosemide. Of the six animals that were medically treated, four were alive at the time of publication of the specific case report. It is clear that there was variation in the treatment schedules of the different animals. No standard treatment guidelines are currently available. Therefore, retrospective research should be performed to assess the efficacy and safety of the different medical treatment strategies. Based on these results, key opinion leaders should discuss to develop standardized treatment schedules, if appropriate. Prospective studies, such as dedicated clinical trials, may not be feasible due to the rarity of the condition.

Five of the dogs with a double outlet ventricle did not receive treatment. Only one of these animals survived. This could suggest that without treatment, the prognosis of the condition is relatively poor. In the case reports, little information was provided on why no surgical or medical treatment was initiated. Further research could investigate what the reasons for this are.

Conclusion

The small number of described cases and the lack of studies with a high

internal validity makes it difficult to make general conclusions. However, it seems that the condition is rare and that there are no breeds that have a specific predisposition. The anomaly is usually diagnosed early in life through the use of echocardiography. After being identified, different treatment strategies are used to mitigate double outlet ventricle, including surgery and medical treatment. A lot of animals are not treated, however. Unfortunately, regardless of the treatment strategy, this condition is very often fatal in cats and dogs.

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Conflict of interest

The author declares no conflict of interest.

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Table 1: Data extracted from the included papers about canine double outlet ventricle

Reference	Age	Breed	Sex	Right/Left	Concurrent defects	Symptoms	Diagnosis	Treatment	Outcome
Bedolla-Alva et al., 2010	4 months	Chihuahua	Female	Right	Left ventricle hypoplasia Tetralogy of Fallot	Weakness Breathing difficulty Orthopnea Sneezing	Radiography Echocardiography	None	Fatal
Chetboul et al., 2020	17 months	Poodle	Male	Right	Ventricular septal defect	Exercise intolerance Intermittent tachypnea	Echocardiography Computed tomography (CT) angiography	Spirolonactone (0.5 mg/kg/day) Omega-3 fatty acids	Alive at 53 months
Chetboul et al., 2020	1.5 years	Yorkshire Terrier	Female	Right	Ventricular septal defect Subvalvular aortic stenosis Right and left ventricular hypertrophy	Chronic seizures Weakness Exercise intolerance Dyspnea Lethargy Cyanosis Tachypnea	Echocardiography	None	Fatal (Died 24 hours after diagnosis)
Chetboul et al., 2020	4 months	Samoyed	Male	Right	Ventricular septal defect Right ventricular hypertrophy Patent ductus arteriosus Mitral dysplasia	Exercise intolerance Lethargy Shortness of breath Mucous cyanosis Coughing Tachypnea Delayed growth	Echocardiography	Spirolonactone (1.2 mg/kg/day per os) Surgery	Fatal (Died during surgery due to ventricular fibrillation)
Chetboul et al., 2020	3 months	Shetland sheepdog	Female	Right	Subvalvular aortic stenosis Ventricular septal defect Pulmonary trunk hypoplasia Infundibular pulmonary stenosis Interventricular septum	Exercise intolerance Mucous cyanosis Delayed growth Tachypnea	Echocardiography	None	Fatal (Died two months after diagnosis)
Koo et al., 2015	2 years	Collie	Male	Right	Ventricular septal defect Right ventricular hypertrophy Complete transposition of the great arteries Pulmonic hypoplasia	Exercise intolerance Lingual cyanosis	Echocardiography Cardiac-gated computed tomography (CT)	None	Alive 3 months after diagnosis
Lee et al., 2010	8 months	Maltese	Female	Right	Ventricular septal defect	Dyspnea Exercise intolerance Tachycardia	Echocardiography	furosemide (1 mg/kg, BID) spironolactone (1 mg/kg) enalapril (0.5 mg/kg) sildenafil (1 mg/kg)	Alive
Vos et al., 1982	4 months	Toy poodle	Female	Left	Ventricular septal defect Pulmonic stenosis Tetralogy of Fallot (presumed)	Growth retardation Coughing Exercise intolerance Cyanosis	Post-mortem observation	None	Fatal (Died from cardiac arrest during preparation for angiogram)

Table 2: Data extracted from the included papers about feline double outlet ventricle.

Reference	Age	Breed	Sex	Right/Left	Concurrent defects	Symptoms	Diagnosis	Treatment	Outcome
Abduch et al., 2003	30 days (1st presentation) 5 months (2nd presentation) 2 years (3rd presentation)	Persian	Male	Right	Discordant atrioventricular connection Dextrocardia Subpulmonary stenosis Ventricular septal defect	1st presentation Dyspnea Fatigue Tachypnea Cyanosis (1st presentation) 2nd presentation Exercise intolerance Tachypnea Cyanosis Reduced growth 3rd presentation Dyspnea Cyanosis Fatigue 4th presentation Paralysis hindlimbs Loss pelvic neural reflexes Cyanosis Hypothermia hind foothpaths	Thoracic radiography Echocardiography	First presentation Propranolol (2.5 mg, orally twice daily) Second presentation Propranolol (5 mg orally, three times daily) Sodium-restricted diet Third presentation Propranolol (7.5 mg orally three times daily) Frusemide (2 mg/kg orally twice daily) Fourth presentation Thromboendarterectomy	Fatal (Died eight hours after surgery from cardiac arrest)
Chetboul et al., 2020	6 months	Domestic shorthair	Female	Right	Ventricular septal defect	Exercise intolerance Dyspnea	Echocardiography	Spirolactone (1 mg/kg/day)	Alive at age of 21 months
Hwang et al., 2016	10 months	Scottish Fold	Male	Right	Ventricular septal defect	Exercise intolerance	Thoracic radiography Echocardiography	Atenolol (6.26 mg/cat, SID)	Alive

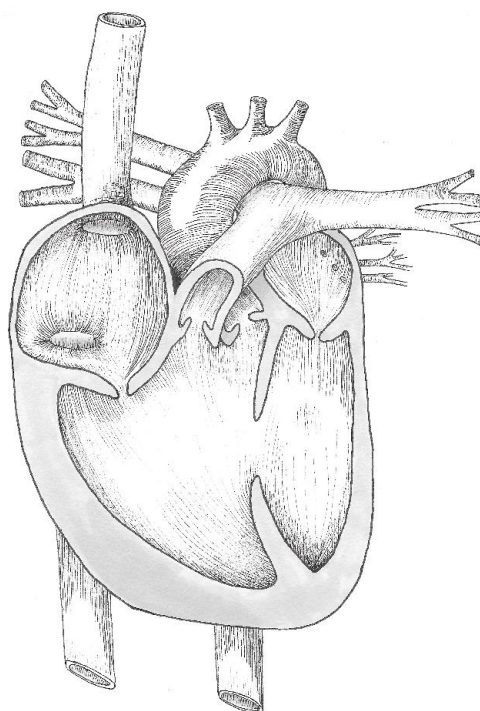


Figure (1): Illustration of a representative case of double outlet right ventricle with a ventricular septal defect based on the included case reports.