Review

Balloon valvuloplasty surgery for the treatment of pulmonic stenosis in the dog: is there evidence for the prophylactic use of lidocaine to prevent the complications of ventricular arrhythmias?

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Abstract

The need for balloon valvuloplasty surgery for the treatment of pulmonic stenosis in dogs has become ever-increasing with the rise of popular brachycephalic dogs, such as pugs. The aims of this review are to detail the current best method for the treatment of pulmonic stenosis and to look at the role lidocaine has in the management of ventricular arrhythmias caused by the surgery. This review also evaluates, using the current literature, whether lidocaine could be potentially preventative rather than curative regarding the treatment of ventricular arrhythmias. Evidence from human studies show lidocaine has a preventative anti-arrhythmic role during pulmonary catheterisation. Evidence from a canine study shows that lidocaine is safe to administer prophylactically and has a preventative role in ventricular arrhythmias caused by gastric dilation and volvulus. This evidence is a basis for further research regarding whether prophylactic lidocaine can prevent ventricular arrhythmias in dogs undergoing balloon catheterisation.

Abbreviations

BV - Balloon valvuloplasty
ECG - Electrocardiogram
GDV - Gastric dilation and volvulus
PS - Pulmonic stenosis

Introduction

What is pulmonic stenosis? Balloon valvuloplasty (BV) has become the gold standard for the treatment of pulmonic stenosis in dogs.[1] Pulmonic stenosis (PS) is a congenital heart condition occurring in dogs and can be described as two variants: 'Type A' and 'Type B'. Type A causes a mild thickening of the pulmonary valve and fusion of the valve leaflets (flaps that act as one-way inlets for blood).[2] Type B causes moderate to severe thickening and hypoplasia of the valve leaflets as well as hypoplasia of the annulus (part of the fibrous skeleton of the heart).[2] Both types have reduced potential space for outflow of blood from the right ventricle, causing hypertrophy of the ventricle walls. Diagnosis and typing are undertaken using electrocardiography measuring the trans-pulmonic peak pressure gradients. The most severe stenosis has a gradient of more than 80 mmHg.[3] Clinically, this presents in severe patients as a heart murmur, exercise intolerance, ascites, and lethargy.[4] Importantly, the type of stenosis affects the success of BV surgery; patients with type A stenosis have a greater improvement of clinical signs after the surgery.[5] PS occurs in many breeds with overrepresentation in French bulldogs and English bulldogs. These breeds are becoming more popular, exacerbating the problem and as a result,

> *PS now accounts for around 32.1% of canine congenital heart disease.[6]*

How is balloon valvuloplasty carried out? BV is carried out under a general anaesthetic and is non-invasive.[7] The main surgical approaches are via an incision in the jugular vein or femoral vein. The jugular vein is preferred due to the increased size and ease of use in comparison to the femoral vein. A guidewire is passed through the vein followed by a vein dilator and introducer. Once the introducer is in place, the guidewire and dilator are removed. A balloon tip catheter is then passed into the introducer and the pressures in the right ventricle and pulmonary artery are measured so that the pressure gradient across the stenosis can be calculated. The catheter is moved through the right ventricle and into the pulmonary artery so that the balloon is in the position of stenosis at the pulmonary valve. The position is confirmed by angiography. Here the balloon is inflated rapidly, held for 6 seconds, then rapidly deflated. This rapid inflation forces open the closed stenosed valve leaflets and allows improved blood flow into the pulmonary artery (**Figure 1**).[7] The pressure gradient across the valve is then remeasured to check the gradient has reduced.

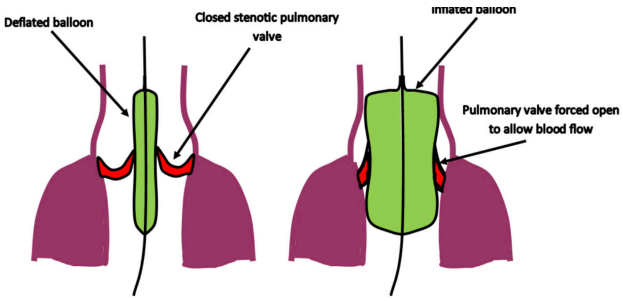

Figure 1: Balloon valvuloplasty. The left image shows the placement of the deflated balloon catheter into the pulmonary valve stenosis. The right image shows the inflation of the balloon, which stretches open the stenosis for improved blood flow out of the right ventricle. Adapted and republished, with permission, from resources at The Royal Children's Hospital, Melbourne, Australia. www.rch.org.au. Images subject to copyright.

What is the prevalence of ventricular arrhythmic complications during BV surgery and how are they currently treated? A common complication of BV surgery is the occurrence of a ventricular arrhythmia due to the endocardium of the right ventricular outflow tract being sensitive to irritation by the catheter as it passes through. Ventricular arrhythmias are monitored using an electrocardiogram (ECG) throughout the surgery. A retrospective study looking at the complications of anaesthesia in 39 dogs with severe PS undergoing BV surgery showed 54% suffered intraoperative ventricular arrhythmias.[8] Similarly, Viscacillas *et al.* (2015)[9] showed that when 46 dogs underwent BV surgery for severe PS, 87% suffered ventricular arrhythmias. In both of the retrospective studies mentioned, ventricular arrhythmias were corrected with a bolus of lidocaine. Lidocaine is an amide local anaesthetic commonly used as part of a perioperative analgesic plan, as it features a sedative effect without causing cardiovascular depression.[10] Additionally, lidocaine is an anti-arrhythmic that has long been used to treat ventricular arrhythmias in both human and veterinary medicine.[11,12] Lidocaine is a class Ib type antiarrhythmic drug and works by stabilising the membrane by blocking sodium ion channels. It therefore suppresses spontaneous depolarisation of the ventricles by a direct effect on the Purkinje fibres.[10] Currently in BV surgery in dogs, lidocaine is only ever administered should the anaesthetist detect a severe ventricular arrhythmia and treatment is usually successful. The average surgery time is 193.2 minutes and hospitalisation time is an average of 48 hours.[8] It is during this period that ventricular arrhythmias occur, are monitored, and are treated.

> *Consequentially, this is causing increased surgery and hospitalisation times and a method to prevent the ventricular arrhythmias would be advantageous.*

Methodology

A literature search was carried out using PubMed and Web of Science databases. All searches were carried out on 08/03/2021. Firstly, the PubMed search terms were: ((ventricular arrhythmia) OR (ventricular tachycardia)) AND ((lidocaine) OR (lignocaine)) AND ((prophylactic) OR (preventative) OR (CRI), where CRI=continuous rate infusion. This yielded 0 results. The search was widened by removing the focus on dogs only and by looking at catheterisation rather than specifically searching 'balloon valvuloplasty'. The term 'infarction' was excluded to narrow the search by removing arrhythmias caused by cardiac infarction which were deemed irrelevant. This yielded 9 papers, 3 of these were deemed relevant. Papers were ruled out due to irrelevance such as focusing on contrast media-induced arrhythmia or correction by laser ablation. The same search parameters were replicated in the Web of Science database as were used in PubMed. The search yielded 1 paper which overlapped with 1 of the 3 found in PubMed.

Lastly, the search was widened to look for any primary research involving the prevention of ventricular arrhythmias in dogs using lidocaine, regardless of the surgery undertaken or clinical condition. This yielded 3 papers, 1 of which was deemed relevant. Papers were ruled out due to their focus towards infarction-induced arrhythmia or the haemodynamic effects of lidocaine.

Discussion

The current evidence for the role of lidocaine to prevent ventricular arrhythmias The literature in human research regarding the preventative role of lidocaine to reduce ventricular arrhythmias during catheterisation is controversial. Sprung *et al.*[13] looked at whether lidocaine reduced the incidence of ventricular arrhythmias in patients undergoing pulmonary artery catheterisation for haemodynamic monitoring. The origin of the ventricular arrhythmias is thought to be due to the mechanical trauma of the endocardium when passing the balloon-tipped catheter through the right ventricle. This mechanical origin mirrors the cause of ventricular arrhythmias in dogs undergoing balloon valvuloplasty. The study randomly selected 31 patients from 67 to receive prophylactic lidocaine and the 36 other patients were given a placebo. The lidocaine group showed a significant improvement in the occurrence of ventricular arrhythmias compared to a placebo when catheterisation was under 20 minutes. However, no significant difference was observed when catheterisation was in place for over 20 minutes. Therefore, there is evidence of a preventative role in shorter catheterisations in humans, but this is considerably shorter than that of the time the balloon catheter is in place in dogs, as BV surgery averages 193.2 minutes in duration.[8] Another, limitation of this paper was that the patients had a systemic illness such as sepsis or respiratory failure, which may have influenced their likeliness to have ventricular arrhythmias. The efficacy of the lidocaine may then have been related to the primary illness, if the illness had a role in the cause or severity of the ventricular arrhythmias, rather than reducing the mechanical effects of the catheterisation.

Shaw *et al*.[14] looked at whether lidocaine reduced the incidence of ventricular arrhythmias in patients receiving a Swan-Ganz pulmonary catheter, which also travels via the right ventricle. The results supported the work of Sprung *et al*., in that there was a significant reduction in the incidence of ventricular arrhythmias when prophylactic lidocaine was administered before catheterisation. Notably, no complications occurred in either study directly from the prophylactic lidocaine administration. Contrasting the evidence supporting the use of prophylactic lidocaine is the work of Salmenpera *et al*.[15]; in a double-blind comparison of prophylactic lidocaine versus saline in 107 patients, there was not a significant reduction in the occurrence of ventricular arrhythmias. However, those with catheterisation times of less than 20 minutes did have a reduced occurrence of ventricular arrhythmias, highlighting that time could be crucial in the efficacy of lidocaine and supporting Sprung *et al*.[13] where they concluded the same. It is also possible that the dosage rate of lidocaine past 20 minutes was not high enough to be at an antiarrhythmic concentration. Further concentration-dependent investigations would be valuable to address this limitation.

A study assessed whether prophylactic lidocaine in 83 dogs compared to 47 retrospective controls reduced the occurrence of ventricular arrhythmias in dogs presenting with gastric dilation and volvulus (GDV).[16] Ventricular premature complexes and ventricular tachycardia are severe complications of GDV. The dogs were treated on presentation with an intravenous lidocaine bolus followed by CRI of lidocaine and arrhythmias were monitored via ECG. The lidocaine treated group showed a 25% ($P<0.001$) reduction of ventricular arrhythmias compared to the control.

> *Therefore, lidocaine has strong evidence of being preventative for ventricular arrhythmias in dogs, though only where ventricular arrhythmias are caused secondarily due to GDV complications.*

Even though the cause of the ventricular arrhythmias is via a different mechanism to those seen in BV, lidocaine is known to treat arrhythmias by suppressing the depolarisation of the ventricles directly.[10] Therefore, the potential suppressive action may be independent of the initial cause by acting at the heart directly. Research needs to be undertaken to assess if this level of protection is present when the ventricular arrhythmias are caused by mechanical trauma.

It was concluded in this study that the prophylactic lidocaine given was not associated with any adverse effects in the dogs, though it is unclear how they distinguished the clinical signs of GDV from the side effects of lidocaine. Although, if the case, this further supports the safety of its use as a prophylactic drug in dogs. There was a significant reduction in hospitalisation time postoperatively from a median of 72 hours in the control group to 48 hours in dogs receiving lidocaine.[16] Although there was no statistical analysis of the correlation of ventricular arrhythmias and hospitalisation time, a reduction of both in the lidocaine group is a strong indicator of a relationship. The current average hospitalisation time for balloon valvuloplasty, where ventricular arrhythmias are treated at time of occurrence, is 48 hours in intensive care.[8] This is a long time in a critical state post-surgery, and it would be beneficial to research if the level of reduction of hospitalisation time seen in GDV cases could be mirrored in BV surgery with prophylactic lidocaine.

Conclusion

In summary, there is currently no primary literature evidencing the role of lidocaine to prophylactically reduce the complication of ventricular arrhythmias during BV surgery in dogs. Unfortunately, the current evidence is also limited in wider studies in dogs regarding lidocaine's preventative role. The human studies do show promising evidence, although controversial, for the preventative anti-arrhythmic role of lidocaine during pulmonary catheterisation and highlight a gap in the literature for its prophylactic use in BV surgery in dogs. Therefore, there is scope to suggest further study, with the prevention of ventricular arrhythmias already showing a positive effect in reducing hospitalisation times, as evidenced in the GDV study. Human patients are already receiving prophylactic lidocaine to reduce complications and improve welfare after pulmonary catheterisation, and with further research, there is the potential to do the same for canine patients.

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