Deciphering the mystery of the leaky pulmonary valve in a new era of interventional cardiology

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This editorial refers to 'Physiological consequences of percutaneous pulmonary valve implantation: the different behaviour of volume- and pressure-overloaded ventricles' by L. Coats et al., on page 1886

Deciphering the effect of pulmonary regurgitation on right ventricular (RV) function in patients after tetralogy of Fallot correction and deciding on timing for valve replacement seems like cracking the Da Vinci code. This question has become the Holy Grail of congenital cardiology in the 21st century. Every piece of information brings us closer to an answer based on sound scientific data therefore is of great importance. The study by Coats et al.,1 looking at the haemodynamic effect of percutaneous pulmonary valve implantation (PPVI) in patients with predominantly pulmonary regurgitation and RV volume overload, provides new insight into the physiological consequences of relieving chronic pulmonary regurgitation. The great advantage of this unique model is that it avoids the confounding effects of cardiopulmonary bypass and cardiac surgery. When prospectively studying their patients with detailed echocardiography, cardiac magnetic resonance imaging (MRI) and exercise testing, Coats et al. noted that 3 months after PPVI, RV end-diastolic volume decreased, and cardiac output at rest increased without a change in exercise capacity. Subjectively the patients felt better after the procedure, and New York Heart Association (NYHA) classification improved.

When deciding on when to intervene for pulmonary regurgitation, different parameters such as symptoms, RV dilatation, RV function, and exercise capacity are generally taken into account.2–6 The decision is still subject to debate and largely dependent on centre preference and subjective medical judgement. Some centres advocate waiting until the patients are symptomatic, but there is no agreement on how to define these symptoms. Using RV dysfunction as a criterion is even more problematic as no good quantitative techniques are available for assessing RV function in the context of volume overload. During recent years, a lot of attention was focused on defining a cut-off value for the degree of RV dilatation at which it was found that functional recovery was decreased after surgical intervention. A recent paper by Buechel et al.3 proposed a cut-off value for RV end-diastolic volume of 150 mL/m². Most patients in the study by Coats et al.1 have an RV end-diastolic volume below this threshold. Despite this, RV function did not really improve after valve implantation when evaluated using MRI and tissue Doppler parameters. The interventional patients differ from the published surgical patients as most surgical series predominantly include patients after transannular patch repair with important RV outflow tract dilatation which precludes them from PPVI. The patch as such increases the size of the RV cavity and, moreover, can sometimes aneurysmatically dilate. In previous studies, important RV outflow tract dilatation and dysfunction has been demonstrated to be an unfavourable risk factor.7 This difference in patient characteristics should be taken into account when interpreting the results. Despite this caveat, Coats et al.1 show that the degree of RV dilatation is probably not the only factor which should be taken into account when deciding on inserting a competent pulmonary valve.

A remarkable observation is that RV dysfunction does not seem to recover in this patient population with only a moderate degree of RV dilatation. This finding was based on different measurements: first there was no significant change in ejection fraction measured by MRI after PPVI. RV end-diastolic volume decreased but end-systolic volume did not change. Secondly, the echocardiographic parameters for RV systolic function, such as the load-independent isovolumetric acceleration and systolic annular velocities, were decreased compared with normal values and remained unchanged up to 3 months after the procedure. RV function does not seem to recover in this patient group, suggesting a detrimental effect of chronic volume loading on RV function, even when the ventricle is only moderately dilated. This is consistent with previously published surgical reports: Therrien et al.8 also did not observe a change in ejection fraction in an adult group after surgical valve insertion, suggesting that these patients were operated on too late. Vliegen et al.9 did not observe a change in RV ejection fraction after surgical valve replacement, but reported an improvement in 'corrected' ejection fraction which corrects for the effect of volume loading. It still is unclear what the real physiological meaning of this corrected ejection

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fraction is as it has not been validated with any other technique such as invasive RV pressure-volume loops. In the present study, it is of interest to note that, despite the increased preload, RV ejection fraction was not increased and even somewhat decreased before PPVI. This substantiates the authors’ idea that the RV is functioning on the decompensatory limb of the Starling curve. This study suggests that the patients were probably also referred too late for intervention to obtain a good RV functional recovery. It shows that parameters other than just RV size are to be taken into account when deciding when to intervene. This requires further exploration by comparing the effects of PPVI in patient groups who have been living with pulmonary regurgitation for different time periods. It might be that some late RV remodelling and recovery might still occur beyond 3 months of follow-up, so further data are still needed on late remodelling.

The persistent RV dysfunction can probably also explain the lack of change in exercise capacity despite the increased cardiac index at rest. The authors explain this by a reduced RV contractile reserve. This could potentially be studied by performing an exercise echocardiography or exercise MRI before and after PPVI. This study seems to contradict previous studies where a beneficial effect of pulmonary valve replacement on exercise capacity was demonstrated.\(^\text{9}\) This could be related to different factors such as a difference in time of initial repair, differences in timing of the valve repair (in Eyskens’ study the patients were much younger), and difference in time interval between the valve replacement and the repeat exercise study (1 year in Eyskens’ study). Therefore, further data are required.

Apart from the effect on RV function, pulmonary regurgitation also has an important effect on left ventricular (LV) performance. Recent studies demonstrated a close relationship between RV and LV dysfunction in patients with severe pulmonary regurgitation.\(^\text{10}\) Moreover, LV dysfunction seems a more important risk factor for unfavourable outcome compared with RV dysfunction. Two mechanisms play a role: first there is a decreased LV preload caused by a decreased effective pulmonary flow, and secondly an unfavourable RV-LV interaction caused by RV dilatation. Both cause diastolic LV dysfunction and have an additive effect. Looking at LV diastolic function and LV volume could therefore be an important factor in deciding on when to replace the pulmonary valve. Better insight is required in the mechanisms playing a role in the ventricular interaction. Probably the interventricular septum, which is an important interface between both ventricles, plays an important role. Bulging of the septum into the LV cavity and hypertrophy of the septum with reduced compliance could contribute to the effect of RV dilatation on LV function. In the present paper, the authors compare their data with data obtained in patients after percutaneous atrial septal defect (ASD) closure. This is also a model of RV volume load with the important difference that in these patients effective pulmonary flow is increased. Recent studies have demonstrated that ASD closure also results in improved LV performance by increasing LV preload.\(^\text{11-13}\) Probably the most important factor contributing to improved LV performance is the change in RV-LV interaction caused by a reduction in RV volume. In contrast to Fallot patients, RV function in ASD patients remains well preserved and returns to normal values after ASD closure. It is unclear why there is a difference between both types of volume load on the RV. In Fallot patients the volume load is imposed upon a hypertrophied RV myocardium which is probably also affected by the surgical intervention. This can result in fibrosis with decreased RV compliance. The hypertrophied RV myocardium seems to tolerate an additional volume load less well compared with normal RV myocardium. This difference possibly also explains why exercise capacity is observed to be improved in patients after ASD closure. In this patient group, RV contractile reserve is more likely to be preserved.

The study by Coats et al. demonstrates that looking for the Holy Grail of quantitative parameters which can guide us to decide on the optimal timing for valve replacement continues and, based on these data, it seems more and more likely that the decision will be based on looking at the combined effect of different parameters.

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