Editorial

Total anomalous pulmonary venous drainage repair: redefining the long-term expectations

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Total anomalous pulmonary venous drainage (TAPVD) is a rare congenital heart anomaly that comprises approximately 1.5% of all congenital heart disease (CHD) (1). This condition may exist in isolation or associated with other complex congenital defects including heterotaxy and a univentricular circulation. Since the first surgical attempt to correct TAPVD reported in 1951 (2), changes in perioperative management and surgical strategy has led to improved outcomes. The current operative mortality for isolated TAPVD repair is low (3,4). However, three issues remain in the management of TAPVD. Firstly, early mortality continues to be higher in neonatal patients (5,6). These patients often present in extremis and represent the most severe end of the disease spectrum. In contrast, TAPVD repair in infants can be performed with 0–5% mortality in the current era (3,6,7). Secondly, the development of postoperative pulmonary venous obstruction (PVO) occurs in approximately 10–20% of patients and is associated with a poor prognosis (8). The sutureless technique has been utilized during primary repair in an attempt to mitigate this complication (9). Finally, the management of TAPVD in the context of a univentricular circulation remains a challenge with high early and late mortality in this current era (10-12).

Excellent long-term survival has been described after isolated TAPVD repair (12). Patients are often asymptomatic and many have been discharged from long-term cardiology follow-up. This has led some authors to consider patients to be completely "cured" after surgery (13). Although these studies have demonstrated improvement in results in the current era and include large cohorts of patients, they lack follow-up beyond childhood. Therefore, survival into adulthood after TAPVD repair is unknown. There is current interest in the shifting demographic of patients with CHD. More than half of patients with CHD are now adults (14) and impose an increasing burden upon adult congenital specialists.

In this context, we read with interest a recent paper by St Louis *et al.* (15), which provides long-term population-based outcomes of TAPVD patients after repair. This study is unique as it combines a large surgical database (Paediatric Cardiac Care Consortium) with a national registry that records death and transplant events within the United States in order to determine follow-up into adulthood. Between 1982 and 2003, a total of 777 infants underwent TAPVD repair (median age of 21 days) and survived beyond the hospital stay. To the best of our knowledge, this study represents the longest follow-up of TAPVD patients (median of 18.4 years) with the largest number of patients followed-up into early adulthood.

The authors report an overall rate of death or transplantation after hospital discharge of 9.7%. The rate of death or transplantation was 5.5% and 31% for the simple and complex TAPVD groups, respectively. The simple TAPVD group was defined as TAPVD without other co-existing CHD (excluding patent ductus arteriosus and atrial

septal defect). All other patients with co-existing CHD were classified in the complex TAPVD group. The highest risk of mortality of transplantation was within the first 12 months after isolated TAPVD repair, whilst an ongoing low-grade attrition was noted for the complex cohort up to 4 years after repair. On multivariate analysis, the authors found complex TAPVD, mixed TAPVD and prolonged postoperative length of hospital stay to be associated with increased risk of death or transplantation. The authors report that in isolated TAPVD, long-term survival after 1 year of surgical repair matches that of the general population.

There are several limitations of the study. Firstly, the patients included were operated on 15 to 36 years ago and patterns of treatment and diagnosis have changed over time. This may be relevant to the complex TAPVD group, in particular the patients with a univentricular circulation. However, this issue is unavoidable in this study where the focus was on the long follow-up duration. Conversely, it is reassuring that hospital survivors after isolated TAPVD repair in this earlier era have achieved such excellent long-term survival and freedom from transplantation. Secondly, 1,334 patients were originally identified in the database, however, 277 (20%) were excluded from analysis for various reasons. It is unclear if these patients may have influenced the true long-term outcomes of this cohort.

Nevertheless, this is an important study as it provides a new insight into patients surviving to adulthood after TAPVD repair. Recent studies have questioned the assertions that patients with 'simple' CHD have a normal life expectancy (16). Hence it is a reassuring finding that repair of isolated TAPVD has an excellent long-term survival approaching that of the general population (15). This statement appears to be consistent for patients up to 30 years after initial repair. However, we are reminded that the majority of their cohort were of the age of 18 years at last follow-up (15). In our own experience of 214 infants and neonates with isolated TAPVD operated between 1973 and 2014, we similarly found most late deaths (80%) occurred within 1 year after repair (7). The majority of deaths within the first year after surgery were related to the development of postoperative PVO. Late outcomes were excellent with a 10-year freedom from mortality and reoperation of 88% and 90%, respectively. We did not observe a higher rate of mortality amongst patients with mixed TAPVD (17), however, our experience is small in comparison. Patients were followed-up for a mean of 13 years (range, 1 month to 42 years) after surgery and all were asymptomatic at last review (7).

The long-term survival and transplantation rate in patients with TAPVD and complex CHD, in particular those with a univentricular circulation, are largely unknown. This may be due to the small numbers of cases amongst most centres and the universally poor early and late outcomes associated with TAPVD repair in patients with a univentricular circulation (11,12,18). The study by St Louis *et al.* (15) attempts to shed light on this difficult subgroup of TAPVD patients with complex CHD. It appears that although this group (n=126) has a prolonged attrition of up to 4 years after surgery compared to isolated TAPVD patients, long-term transplant-free survival thereafter is excellent. The overall rate of death/transplant was 31% at follow-up. It is important to remember that even within this complex cohort there exists variation in severity. The single ventricle group had a significantly higher rate of death/transplant (51%) compared to the biventricular group (5.5%) of complex TAPVD patients. Duration of follow-up was also significantly shorter for the single ventricle group (median 14 years) compared to the biventricular group (median 19 years). It is therefore clear that patients with TAPVD and a univentricular circulation have much poorer outcomes, occurring over a shorter period of time after TAPVD repair. These findings are supported by Horer *et al.* (12) who reported on 193 patients (182 biventricular, 11 univentricular) who underwent TAPVD repair with a mean follow-up of 15 years. They reported poor long-term survival amongst patients with a univentricular circulation (50% of patients dying before 5 years of age) (12). The disparity in outcomes between patients with univentricular compared to biventricular circulation may be related to the more complex physiology and anatomy, concomitant palliative procedures or the increased risk of postoperative PVO (10,19,20). Furthermore, the univentricular circulation is particularly vulnerable to any degree of PVO which may predispose to early cardiac failure (15) or preclude completion of the Fontan circulation (12). Future research is required in patients with a univentricular circulation to determine the long-term outcomes into adulthood and the impact of TAPVD repair on the Fontan circulation.

The findings of St Louis *et al.* (15) allow clinicians to better counsel parents of children with TAPVD about the long-term expectations after surgery. In particular, children alive one year after isolated TAPVD repair can be assured of survival into early adulthood resembling that of the general population (15). However, the natural history of these patients and complications encountered

in adulthood is undefined. There is growing evidence that patients with "simple" CHD may have an increased morbidity in adulthood. Videbaek and colleagues reported increased rates of cardiac surgery, heart failure, endocarditis, pulmonary hypertension, arrhythmias and stroke when adult CHD patients were compared to the general population (16). It is unknown if TAPVD patients will encounter these complications with advancing years of adulthood. Furthermore, it appears that patients with repaired TAPVD, though asymptomatic, may not have normal cardiac function at late assessment. Marcondes *et al.* (21) performed echocardiography examinations on TAPVD patients, 11 years after repair, and compared them to normal controls and patients with repaired transposition of great arteries. In this interesting study, the authors found that patients with repaired TAPVD had left ventricular diastolic dysfunction compared to controls. This was postulated to be a result of the relative unloading of the left ventricle during early cardiac development (21). Though no clinical implications were identified by these findings, the authors still recommended more careful follow-up of these patients. Hence, more work is required in this area as the impact of subclinical cardiac impairment on long-term outcomes and how this may interact with acquired cardiac disease is unknown. We have previously described a hemodynamic index for risk stratification after neonatal TAPVD repair (22). Risk stratification after discharge for persistent pulmonary hypertension and PVO is not well defined. As we enter the genomic era of personalized medicine, we will most likely develop a better understanding of the underlying genomic basis for persistent pulmonary hypertension and recurrent PVO. Precise genomic assessment may dramatically improve risk stratification in patients with TAPVD. Finally, there is growing interest in the quality of life of adults with CHD (23). No specific study assessing the quality of life and comparing them to the general population has been conducted on repaired TAPVD patients in adulthood. As the population of TAPVD patients surviving to adulthood expands, future research into these areas will aid in redefining the long-term expectations after TAPVD repair.

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Footnote

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