Repair of tetralogy of Fallot in infancy with a transventricular or a transatrial approach

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Abstract

Objective: The optimal time and approach of repair of tetralogy of Fallot (TOF) remain controversial. The purpose of this study was to evaluate the outcome following repair of TOF in infants with particular regard to the surgical approach used.

Patients: One hundred and sixty infants (mean age 195 ± 89 days, range 11–364 days) undergoing repair of a simple TOF were studied. Between 1974 and 2000, a transventricular approach (RV) was used in 91 and between 1988 and 2000, a transatrial (RA) approach in 69 infants. Ten of these infants (6.2%) had a previous palliative shunt (four in the RV versus six in the RA group). A transannular patch (TAP) was inserted in 96 (60%) infants (76 versus 20). Follow-up was complete (mean 14.5 ± 5.2 versus 6 ± 1 years).

Results: There were three operative deaths (1.9%), (two in RV versus one in RA group). A re-operation for right ventricular outflow tract obstruction (RVOTO) was performed in 19 patients (3 versus 16). Ten-year freedom from re-operation for RVOTO (± standard error of the mean) was 88 ± 4% (98 ± 2 versus 72 ± 6%, P < 0.0001). Within the RA group, 5-year freedom from re-operation for RVOTO for those who had a TAP was 79 ± 9% and it was 75 ± 4% for those having a simple repair. Six patients in the RV group required pulmonary valve replacement (PVR). Ten-year freedom from PVR was 98 ± 1% (97 ± 2 versus 100%, P = 0.3). There were two late deaths, one in each group. Ten-year survival was 97 ± 1%. One patient in the RV group developed late recurrent ventricular tachycardia requiring the implantation of a defibrillator. At most recent echocardiography, all but the patient who had the defibrillator had good right and left ventricular function.

Conclusions: Transventricular and transatrial repair of TOF in infancy, are associated with an acceptable operative risk, low incidence of late arrhythmias, good bi-ventricular function and excellent survival. In our experience, however, transatrial repair has a disturbing incidence of early and midterm residual or recurrent RVOTO, even when a TAP has been used. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Transatrial/transventricular repair; Tetralogy of Fallot; Infancy

1. Introduction

The optimal age and surgical approach of repair of tetralogy of Fallot (TOF) have been debated for several decades. Currently more centres favour primary elective repair in infancy [1–4]. The reasons for this are the low operative mortality observed in contemporaneous neonatal surgery, the appreciation of the benefits of early correction of hypoxaemia on the heart and other organs and the avoidance of a palliative procedure.

Traditionally, TOF was repaired through a right ventricu-lar (RV) incision providing an excellent exposure for closure of the ventricular septal defect (VSD) and relief of the right ventricular outflow tract obstruction (RVOTO) but there were concerns that the resultant scar may increase the incidence of ventricular arrhythmias and sudden death and impair the right ventricular function.

The right atrial approach (RA), first described by Hudspeth et al. [5] and Edmunds et al. [6], became popular in the eighties for its perceived advantage of avoiding the problems associated with the right ventricular incision [7,8]. Transatrial repair is now being increasingly advocated but its superiority over the transventricular repair in the infantile age group has not been documented.

Since 1974 we have favoured primary repair, rather than palliation in symptomatic infants requiring surgery, using only a RV approach. From 1988 we have also performed primary repair in asymptomatic infants using a RA or RV
approach depending on the preference of the operating surgeon. The evolution of our practice resulted in a progressively higher proportion of patients undergoing definitive repair of TOF in infancy, more than two thirds of them with a RA approach (Figs. 1 and 2).

We have previously reported on 89 infants undergoing repair of simple TOF by one surgeon (JLM) [9]. The purpose of this study was to describe our unit experience with the repair of simple TOF in the 1st year of life with particular emphasis on the surgical approach used.

2. Patients and methods

One hundred and sixty consecutive infants (90 male and 70 female) who underwent repair of a simple TOF (anatomically characterised by a dextraposed and overriding aorta, a ventricular septal defect and infundibular pulmonary stenosis) between October 1974 and September 2000 in Southampton, were studied. Their mean age (±standard deviation) was 195 ± 88.8 days, (range 11–365 days) and their mean body weight was 6.3 ± 1.6 kg (range 2.1–18 kg). Twelve additional infants who had repair of TOF complicated by lesions such as pulmonary atresia, atrioventricular septal defect and absent pulmonary valve syndrome do not form part of this study.

Between 1974 and 2000, a transventricular approach was used in 91 infants (mean age 200.2 ± 90.7, 16–365 days and mean body weight 6.5 ± 1.6, 2.1–18 kg). From 1988 to 2000, a transatrial approach was employed in 69 infants (mean age 188.6 ± 86.1, 11–356 days and mean body weight 6.1 ± 1.5, 2.5–14 kg). Fifteen infants (nine in the RV group versus six in the RA group) were neonates (11–30 days old). Ten infants (6.2%) (four in the RV versus six

Fig. 1. The proportion of patients undergoing repair of tetralogy of Fallot during the 1st year of their life (grey columns) rose significantly over the years of the study period, from 26.8% (1975–1979) to 91% (1995–2000) (Chi square test for trend \( P < 0.0001 \)).

Fig. 2. The proportion of infants having a transatrial repair in the late eighties was 43%. By mid-nineties it rose up to 82% and more recently it declined to 74%.
arterial oxygen saturation was 86.3\%

During the study period, another 15 infants with TOF, some of them having, also, small left ventricles, anomalous origin of the left coronary arteries and/or multiple ventricular septal defects, underwent palliative shunts. Thirteen of these infants survived undergoing definitive repair after the 1st year of life and they were, thus, excluded from this study.

2.1. Diagnosis and pre-operative clinical features

Definitive diagnosis was, until around 1980, made by angiography. Thereafter a combination of echocardiography and angiography was employed.

One hundred and twenty-nine patients (81%) (84 in the RV versus 45 in the RA group, \(P < 0.0001\)) developed hypoxic spells at various intervals before their operation, 29 (18%) (seven versus 22, \(P < 0.0001\)) had no symptoms and one (1%) (RA group) was ventilator dependent since his birth. One hundred and nineteen patients (74%) (71 versus 46, \(P = 0.02\)) were on beta-blockers preoperatively. Mean arterial oxygen saturation was 86.3 ± 9.2%, range 31–100% (84.8 ± 10.5 versus 88.2 ± 7.2%, \(P = 0.1\)).

The operative procedure was elective in 71 (44%) (26 versus 45, \(P < 0.0001\)) and urgent or emergency in 89 (56%) patients (65 versus 24, \(P < 0.0001\)).

2.2. Surgical technique and operative data

Cardiopulmonary bypass with deep hypothermia and circulatory arrest, and surface or core cooling, were employed until the late eighties. Since then, repair of TOF under cardiopulmonary bypass alone became standard practice. Cold crystalloid cardioplegia (St Thomas’s solution) has been used since 1978 and, recently, cold blood cardioplegia.

Before 1988 only a transventricular approach was used. A transannular patch (TAP) was inserted if the diameter of the narrowest point of the right ventricular outflow tract, measured with Hegar dilators, was less than the minimum acceptable pulmonary valve ring diameter for the patient age and weight as suggested by Pacifico et al. [10]. In the event of uncertainty, use of a TAP was more likely if a bicuspid pulmonary valve was present. If a patch was necessary a longitudinal incision was made through the pulmonary valve ring and continued to the bifurcation of the pulmonary artery [11]. If an outflow patch was required a unicuspid from an antibiotic sterilised aortic homograft was used for preference prior to 1983. Since then homografts have been more difficult to obtain, and autologous pericardium has mostly been used.

Since 1988 a transventricular or a transatrial approach was used, depending on the operating surgeon’ preference, supplemented, if necessary, by pulmonary arteriotomy and pulmonary valvotomy. In the transatrial repair, if the insertion of a TAP was required, a minimal, 2–3 mm long, infundibulotomy was performed. In the transventricular repair, the extent of ventriculotomy was limited to about 1.5 cm and, if needed, a smaller TAP was inserted.

Currently, if from the preoperative investigations a TAP is thought not to be necessary, using criteria as previously defined [12] (PA/AA diameter > 0.5 on preoperative angiogram) a transatrial approach is used. If, however, the insertion of TAP is anticipated, repair through a transventricular repair through a small (1.5 cm) ventricular incision is preferred.

Branch pulmonary arteries were assessed preoperatively with angiography supplemented more recently by echocardiography. If they were considered to be of adequate size a complete repair was planned, otherwise an aorto-pulmonary shunt followed by a later repair was performed. Hypoplastic pulmonary arteries remain a contra-indication for an early repair in our unit. The assessment of the adequacy of the size of branch pulmonary arteries was initially based on the judgement of the operating surgeon in the theatre. Subsequently the McGoon ratio and Nakata index were used [13,14].

Ventricular septal defects (VSD) were closed with a continuous polypropylene suture, using a Dacron, Goretex or bovine pericardial patch. Resection of infundibular muscle was carried out as required. Inter-atrial communications were routinely closed. All patients undergoing a transventricular repair had their right and left ventricular pressures measured prior to chest closure. This was not done routinely by all operating surgeons in the transatrial repair group.

2.3. Follow-up

After their discharge from the hospital the patients were followed-up at regular intervals by the paediatric cardiologists and echocardiography and 12-lead electrocardiograms (ECG) were routinely performed. Data was obtained through a detailed review of the hospital medical records. Additional information was sought from the referring physicians, family doctors and the patients’ families as appropriate. Mean follow-up was 10.8 ± 5.9 years, range 0–26.3 years, (14.5 ± 5.2 versus 6 ± 1 years, \(P < 0.0001\)). Follow-up information was complete within 12 months of the closing date of this study (3/10/2000).

2.4. Statistics

Continuous data was expressed as means (± standard deviation) and categorical data as percentages. Proportions were compared with Chi square or Fisher’s exact test and means with \(t\)-test. Freedom from time-related events (± standard error from the mean) was calculated with the Kaplan–Meier method and the resulting curves compared with log rank test. A \(P\) value of <0.05 was considered significant. Statistical Analyses were performed with the SPSS PC version 8 (SPSS Inc., Chicago, IL, 60611).
3. Results

3.1. Incidence of transannular patching

The mean diameter of the ascending aorta was 13.8 ± 2 mm, range 7–20 mm (13.9 ± 2 versus 12.8 ± 1.3) and the mean diameter of the pulmonary artery was 7.4 ± 1.6 mm, range 3–15 mm (7.4 ± 1.6 versus 7.6 ± 1.6). The pulmonary valve was bicuspid in 92 (58%) (54 versus 38), tricuspid in 66 (41%) (36 versus 30) and unicuspid in two (1%) patients (1 versus 1).

A TAP was inserted in 96 (60%) patients (76 versus 20, \( P < 0.0001 \)). These were unicuspid homograft in 36 (all in the RV group), bovine pericardium in 52 (33 versus 19), dura mater in seven (in the RV group) and a mini-gortex patch in one patient (RA group). Until 1988 the incidence of the use of a TAP was 78.1% (50 out of 64 patients) and since then it dropped to 47.9% (46 out of 96 patients) (\( P = 0.0003 \)).

Infants undergoing repair in the first or second trimester of life were somewhat more likely to have a transannular patch compared to older infants, but this may have been due to chance (all patients: \( P = 0.44 \), RV group: \( P = 0.10 \) and RA group: \( P = 0.76 \)).

Right and left ventricular pressures prior to sternal closure were measured in all patients in the RV group and in 41 patients in the RA group. The mean right to left ventricular pressure ratio (\( p_{RV/LV} \)) was 0.45 ± 0.14 (0.41 versus 0.55 ± 1.16, \( P < 0.0001 \)).

3.2. Operative mortality

There were three hospital deaths (two in the RV versus one in the RA group) giving an overall operative mortality of 1.9% (2.2 versus 1.4%).

An 8 months old male with Down syndrome died 4 days following an uneventful simple transventricular repair. While in the intensive care unit he became hypoxic and required high positive pressure ventilation. He subsequently developed bilateral pneumothoraces and respiratory distress syndrome. At post-mortem there was an unexplained generalised sloughing-off of the tracheo-bronchial mucosa.

A 1.5-month old male presented with central cyanosis and underwent an uncomplicated transventricular repair with a TAP. The following day he became hypotensive and developed low cardiac output unresponsive to vigorous resuscitative measures. At post-mortem a cause of death could not be established.

A 3 months old female with acyanotic form of TOF (large VSD and left to right shunt) was ventilator dependent since her birth and died 8 days following a simple transatrial repair from cardio-respiratory failure.

3.3. Operative morbidity

In addition to those who died, a total of 31 (20%) patients (17 versus 14) experienced significant early postoperative complications.

In the RV group these were cardiorespiratory failure requiring prolonged ventilation or inotropic support (4), chest infection (4), intravascular haemolysis (1), transient seizures (1), renal failure (1), cardiac arrest (1), transient complete heart block (1), coagulase negative staphylococcal septicaemia (1), mediastinal bleeding requiring re-opening (2) and pericardial effusion treated with open drainage (1).

Complications in the RA group were cardiac dysfunction due to residual RVOT or distal pulmonary artery obstruction requiring early re-operation (4), respiratory failure (2), renal failure (2), diaphragmatic paralysis (2), ventricular fibrillation (1), second degree heart block (1), mediastinal bleeding requiring re-opening (3), pericardial effusion managed with open drainage (2), septicaemia (1), pulmonary hypertensive crisis (1) and convulsions (1).

3.4. Re-operations and/or re-interventions

Thirty-four patients (21%) (13 in the RV versus 21 in the RA group) underwent further re-operations and/or catheter re-interventions with one death (RA group).

In the RV group five patients underwent only a re-operation, five had a re-operation and a catheter re-intervention and three had only a catheter re-intervention (Table 1).

In the RA group 19 patients had only re-operations, one

<table>
<thead>
<tr>
<th>Re-operation</th>
<th>No. of patients</th>
<th>Catheter re-intervention</th>
<th>No. of patients</th>
</tr>
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<tbody>
<tr>
<td>PVR</td>
<td>6</td>
<td>Balloon dilatation of hypoplastic LPA and/or RPA</td>
<td>4</td>
</tr>
<tr>
<td>Patch enlargement of the PAs</td>
<td>2</td>
<td>Balloon dilatation of RVOT</td>
<td>2</td>
</tr>
<tr>
<td>Relief of RVOTO</td>
<td>1</td>
<td>Balloon dilatation and stenting of RPA</td>
<td>1</td>
</tr>
<tr>
<td>Insertion of pericardial cusps into PV and patch enlargement of the PAs</td>
<td>1</td>
<td>Stenting of RPA and LPA</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>Total</strong></td>
<td><strong>8</strong></td>
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\(^{a}\) PVR, pulmonary valve replacement; PA, pulmonary artery; RVOTO, right ventricular outflow tract obstruction; PV, pulmonary valve; RPA, right pulmonary artery; and LPA, left pulmonary artery.
had two re-operations and a catheter re-intervention, and two had only a catheter re-intervention (Table 2).

Overall 20-year freedom from any re-operation or re-intervention was 76.4 ± 4%. In the patients in whom a TAP was inserted 20-year freedom from re-operation or re-intervention was 80 ± 5% and it was 74 ± 6% in those undergoing a simple repair (P = 0.2).

In the RV group 10 and 20-year freedom from any re-operation or re-intervention was 92 ± 3 and 87 ± 4% and in the RA group 5 and 10-year freedom from any re-operation or re-intervention was 67 ± 6 and 65 ± 6% (P < 0.0001).

3.5. Re-operations for ventricular septal defect

One patient in the RA group underwent one early and three late re-operations to close a residual large VSD.

3.6. Re-operations or re-interventions for RVOTO

Nineteen patients (3 versus 16) required re-operations or re-interventions to relieve residual or recurrent RVOTO. Four of these patients (RA group) developed systemic or suprasystemic RV pressures early postoperatively and had a re-operation during the same hospital admission. The usual indication for late re-operation was a RV pressure more than 2/3 systemic measured at cardiac catheterisation with the patient anaesthetised.

Overall, 20-year freedom from re-operation or re-intervention for RVOTO was 86 ± 3%. For the patients receiving a TAP, 20-year freedom from re-operation or re-intervention for recurrent RVOTO was 91 ± 4 and for those undergoing a simple repair it was 79 ± 6% (P = 0.03).

In the RV group 10 and 20 year freedom from re-operation or re-intervention for RVOTO was 98 ± 2 and 96 ± 3% and in the RA group 5 and 10-year freedom was 75 ± 6 and 73 ± 6% (P < 0.0001) (Fig. 3).

Within the RA group 5-year freedom from re-operation or re-intervention for RVOTO for the patients receiving a TAP was 79 ± 9% and it was 74 ± 7% for those undergoing a simple repair (P = 0.9) (Fig. 4).

3.7. Pulmonary valve replacement

Six patients, all of whom underwent a transventricular repair with a TAP, had replacement of a severely regurgitant pulmonary valve with an antibiotic sterilised aortic homograft. The usual indication in an asymptomatic patient was the presence of severe pulmonary regurgitation with progressing RV dilatation and/or ECG changes. In the presence of symptoms the threshold for pulmonary valve replacement (PVR) was lower.

Overall 20-year freedom from PVR was 97 ± 2%. Where a TAP was used this was 95 ± 3% and it was 100% amongst those having a simple repair (P = 0.2).

In the RV group, 10 and 20-year freedom from PVR was 97 ± 2 and 96 ± 2% but three patients required a PVR more than 20 years postoperatively. In the RA group no patient required a PVR (P = 0.3) (Fig. 5).

3.8. Late survival, arrhythmias and functional status

There were two late deaths one in each group. A female patient who had undergone primary simple repair of TOF at 6 months of age died 2 years later from leukaemia.

Another female patient had a modified Blalock-Taussig shunt on the 1st day of life and elective transatrial repair using a TAP 8 months later. Postoperatively she developed low cardiac output syndrome and had an early re-operation to reconstruct the left pulmonary artery (LPA) and fenestrate the VSD. She died 6 months later from congestive heart failure having first undergone LPA stenting and tricuspid valve annuloplasty.

Overall 5, 10 and 20-year survival, inclusive of operative mortality, was 97 ± 1% and it was, almost, identical in both groups (P = 0.94) (Fig. 6).

At echocardiographical investigations a RVOT gradient >40 mmHg was present in 17 patients (11%) (five in the RV versus 12 in the RA group, P = 0.03), moderate pulmonary
regurgitation in 62 (40%) (43 versus 19, $P = 0.007$), moderately severe right ventricular dilatation in 41 (27%) (29 versus 12, $P = 0.05$) and good right and left ventricular function in 154 late survivors (99%) (87 versus 67).

At latest 12-lead ECG, 144 patients (83 versus 61) had sinus rhythm with right bundle branch block pattern. Two (1 versus 1) had intermittent 1st-2nd degree heart block not requiring treatment, one (RV group) had occasional ventricular ectopics, one (RA group) had a permanent pacemaker and six patients (2 versus 4) had normal sinus rhythm. No patient had a QRS complex equal to or longer than 180 ms.

Holter, 24 h, ECGs were performed in 111 patients (72%)...
(58 versus 53). These confirmed the findings of the 12-lead ECG and showed that an additional patient (RV group) exhibited persistent recurrent tachycardia requiring anti-arrhythmic medications and the implantation of an automatic defibrillator. This was the only patient to develop significant arrhythmia in this series and did so 16 years after her original operation.

There has been no patient developing permanent neurological deficit.

At clinical evaluation all but the patient who had a defi-

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![Pulmonary valve replacement](image)

**Fig. 5.** In the RV group (continuous line) 10 and 20-year freedom from PVR was 97 ± 2 and 96 ± 2% but three patients required a PVR more than 20 years postoperatively. In the RA group (interrupted line) no patient required a PVR ($P = 0.3$).

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![Survival](image)

**Fig. 6.** Overall 5, 10 and 20-year survival, inclusive of operative mortality, was 97 ± 1% and it was, almost, identical in both groups ($P = 0.94$).
brillator were in NYHA functional class I, leading a normal or near normal lifestyle receiving no anti-arythmic medica-
tions.

4. Discussion

We, like a few other groups in the early 70s [15,16], have preferred definitive repair to palliation in symptomatic infants requiring surgery using a right ventricular approach. Since the late eighties we have performed increasingly definitive repair, also, in asymptomatic infants using transatrial or transventricular approach. At present, 90% of our patients with TOF have definitive repair in the 1st year of their life and more than two thirds of these cases are performed through a right atrial incision.

There have been no prospective randomised studies comparing the available options for repair of TOF and units employing various treatment protocols have reported good early and late results [1–4,6–12,15–20]. Comparison of these reports can be difficult as they often describe various age groups with a wide spectrum of pathological lesions, treated with different surgical approaches over a long time period.

The operative mortality in this series was low and was unaffected by age and surgical approach. Similar early death rates have been described from other centres pursuing a policy of transventricular and/or transatrial repair in neonates and infants [1–4,7,8]. These data do not support previous publications suggesting a higher probability of death if surgery was undertaken in the first 3 months of life and attest to the safety of an early repair [19,20].

Whether younger age increases the need for use of a TAP is uncertain and the evidence conflicting [18,20]. In our study there was only a weak trend for increasing use of TAP in younger infants.

Also, a higher proportion of infants in the RV group compared to those in the RA group, had a TAP (83 versus 29%). This is explained by the evolution of our policy and it should not be attributed to the type of repair. A right ventricular approach was invariably used before 1988, when repair was performed only in symptomatic infants with more severe forms of RVOTO, and since then a RV repair was more likely if a TAP was needed. It would appear that the frequency of use of TAP is determined by the severity of the RVOTO and not the age or the surgical approach.

TAP provides effective relief of the outflow stenosis but subjects the infant to the adverse effects of acute and chronic pulmonary regurgitation. The mean p RV/LV value of 0.4 prior to sternal closure in the infants receiving a TAP was very satisfactory considering that they had the more severe right outflow tract stenosis. The 20-year freedom from a repeat procedure for RVOTO of 91% in the TAP group was significantly higher than the 79% of the patients having a simple repair. In return, the patients who received a TAP developed various degrees of pulmonary regurgitation and six had a valve replacement, whereas none of those having a simple repair required a PVR. It follows, therefore, that the avoidance of TAP reduces pulmonary regurgitation and the need for PVR but it raises the likelihood of re-intervention for RVOTO.

We found that relief of RVOTO, early and late postopera-
tively, was related to the surgical approach. Patients having transventricular repair had a significantly lower p RV/LV and they were less likely to have further procedures to relieve residual or recurrent RVOTO. It could be argued that that these differences were due to a higher TAP rate in the RV group. However, within the RA group, the 5-year freedom from re-intervention for RVOTO was unaffected by the use of TAP. The advantage of TAP in preventing the need for re-interventions for RVOTO in the entire series, was not observed in the transatrial repair group. The reasons for these findings are not clear. Some surgeons, in our unit, performed repair of TOF through a right atriotomy in all patients and it might be that some infants with severe infun-
dibular stenosis and small pulmonary annulus were not suitable for this approach. In response to these findings the unit policy is now to perform a transventricular repair in all cases requiring a TAP. This explains the recent decline in the proportion of patients undergoing a transatrial repair (Fig. 2).

The ventricular septal defects were closed successfully with a continuous suture technique in both types of repair, there being only one patient requiring further procedures for a recurring large central VSD. Castaneda, in his series of 41 infants, used interrupted pledgeted sutures and encountered only one late recurrent VSD, ascribing this result to the good tissue quality of the infantile interventricular septum [16].

The freedom from any type of re-operation was better in the RV group but this was mainly due to the higher re-
operation rate for RVOTO in the RA group.

There is no doubt that chronic regurgitation can lead to right ventricular dilatation and dysfunction and, probably, arrhythmias. Chronic pulmonary regurgitation was present in all patients who had a TAP, irrespective of the type of surgical approach used, but it was mostly well tolerated. In six patients it was severe enough to warrant pulmonary valve replacement, in three of them more than 20 years postoperatively. In agreement with others [21], we found that valve replacement reversed the process of the progres-
sive right ventricular dilatation and restored the impaired haemodynamics. One patient, though, did go on to develop persistent ventricular arrhythmias. Since late severe complications can occur many years after the repair, in particular in the patients having a TAP, life-long clinical and echocar-
diographical follow-up is strongly recommended. It is very important to replace the pulmonary valve before irreversible right ventricular damage or arrhythmias occurs.

Ventricular arrhythmias and sudden late deaths were prominent features in studies reporting on tetralogy repair in older children [22]. A QRS complex duration of more than 180 ms on 12 lead ECG has been shown to predict the
occurrence of late ventricular arrhythmias and sudden death [23]. There were no such ECG findings in our study. The low incidence of arrhythmias (one patient in the RV group) and the lack of sudden deaths in this series are in keeping with previous studies reporting no late arrhythmias or sudden deaths following transatrial or transventricular repair of TOF in infancy [1,2]. This suggests that endomyocardial fibrosis due to chronic hypoxaemia, rather than the right ventricular scar, is to be blamed for the more frequent occurrence of arrhythmias and sudden deaths in the patients undergoing delayed repair.

Miura et al. [24] have reported that compared to the transventricular approach, transatrial repair results in a better late regional wall motion and global RV function in addition to other limitations, pointed out be Ungeleider [25], the mean age at repair in that study was 5.5 years. Its findings, therefore, could not be applied in infants. This and previous studies addressing the late outcome after infantile tetralogy repair do not demonstrate a significant impact of ventriculotomy on right ventricular function. Indeed, the prediction of late survival of 97% after both types of repair compares well with that observed in general healthy population.

5. Conclusions

Transventricular and transatrial repair of TOF in infancy, are associated with an acceptable operative risk, low incidence of late arrhythmias, good bi-ventricular function and excellent survival. In our experience, however, transatrial approach has a disturbing incidence of early and mid-term residual or recurrent RVOTO, even when a TAP has been used. The concerns of a possible right ventricular impairment and arrhythmias, due to ventriculotomy, should, perhaps, not discourage the Paediatric Cardiac Surgeons from using a transventricular repair if this would increase the likelihood of achieving a successful repair.

Acknowledgements

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References

Appendix A. Conference discussion

Dr A. Dodge-Khatami (Utrecht, Netherlands): We just had some data from Great Ormond Street in London accepted for publication, looking into the incidence of postoperative junctional ectopic tachycardia and nodal tachycardia, in particular, with regards to the surgical approach, transatrial or transpulmonary or transventricular. This study revealed, amongst others, an increased risk of JET, when transatrial relief of RVOTO was performed. Could you comment on the incidence of JET or another supraventricular tachycardia in your series and was there a relationship to the type of surgical approach which you used?

Mr Alexiou: This study was focused primarily on the late outcome following repair of tetralogy in infancy. From the available data it would appear that there was no significant difference in the incidence of early atrial arrhythmias between the groups. In most cases of transventricular repair a right atriotomy was also performed to look for and/or close a co-existing ASD. The effect of a right atrial incision would, therefore, be present in both groups. Now, junctional tachycardias occurred in about 20% of our patients. They were mostly transient and tended to go away with time. I believe that an experience similar to ours has been recently reported by from Boston Children Hospital.

Dr T. Tlaskal (Prague, Czech Republic): I would like to ask you, did you change your policy for elective surgery for tetralogy of Fallot according to your study based on your experience with the higher incidence of right ventricular outflow tract obstruction, and then, what is your preferred age for elective surgery in tetralogy of Fallot?

Mr Alexiou: I am sorry, I didn’t hear the second part of your question regarding the age.

Dr Tlaskal: At what age would you prefer to indicate asymptomatic tetralogy of Fallot for repair?

Mr Alexiou: Yes, these observations have affected our policy. Over the study period, a type of repair was selected according to the preference of the operating surgeon and some surgeons used a transatrial approach in almost all infants. Currently, if a transannular patch is required, repair through a right ventriculotomy is preferred.

We would normally correct asymptomatic Fallot at about 6 months of life when the body weight is higher and the tissues are better formed. However, we do primary definitive repair at younger infants and neonates if they present with severe symptoms requiring surgery.

Dr A. Corno (Lausanne, Switzerland): I also have a question regarding the increased incidence of right ventricular outflow tract obstruction you observed with transatrial repair. Do you believe that this is due to the intrinsic anatomy of tetralogy of Fallot or to the mismatch between your surgical technique and the anatomy? As a consequence, what is your suggestion for us since you changed the policy in your unit? Should everybody abandon completely the transatrial repair for tetralogy of Fallot or should we modify the technique if we want to still apply the transatrial approach?

Mr Alexiou: The reasons for the increased rate of reoperation for RVOT obstruction in the transatrial repair group in our series are not clear but most recurrences occurred in those surgical firms where a transatrial repair was exclusively used.

With regard to our recommendations, as I have just presented, the current rate of transatrial repair of infantile TOF in our unit is 76%. So, we would not really recommend abandoning the transatrial approach. What we would perhaps suggest is that not all infants might be suitable for transatrial repair. Also, given the favorable early and late outcome observed with transventricular repair, if a transventricular repair is what it takes to achieve a complete repair you should just do it. This is what we recommend.

Dr H. Jalali (Brisbane, Australia): We presented a similar study last year to the Australian Society. We repaired Fallot under 6 months of age. We had no mortality and we had only 40% of transannular patch regardless of the technique, which was transatrial or transventricular. So I certainly would say that transventricular repair does not mean always a transannular patch. Can you tell us what was the rate of your transannular patches the past 5 years when a transventricular repair was used, eliminating all those old transannular patches people have done 10 or 15 years ago?

Mr Alexiou: The rate of patch for the transventricular repair is about 80% in the series. As I said, currently, those who need a transannular patch, they get a transventricular repair.

Dr Jalali: Right. You used transventricular repair whenever you think you are going to need a transannular patch.

Mr Alexiou: Exactly.

Dr Jalali: In some other units, some surgeons use transannular, transatrial and some other surgeons use transventricular, and in our unit it is the preference of the surgeons and 40% transannular patches regardless of whatever technique you have used. So I would say transventricular does not mean transannular patch. It is just a matter of the way you have set your mind to go.

Mr Alexiou: I appreciate there are different approaches in the surgical techniques applied in various units all over the world, which is why this topic is so controversial. We have a clear policy: if on preoperative angiogram the diameter of the pulmonary artery is less than half of that of the aorta, in our unit experience, this implies that a transannular patch is very likely to be needed. Our operative strategy on this occasion is to perform first a limited right ventriculotomy, to assess the annulus, and then extend the ventriculotomy up to the pulmonary artery as required.

Dr B. Asfour (Muenster, Germany): Do you assess the pulmonary valve annulus, intraoperatively, and what is the threshold for you to perform a transannular patch in terms of a Z value in both transventricular and transatrial approach, keeping in mind that a Z value of ~2 is still within the normal range?

Mr Alexiou: Yes, we follow the recommendations made by Pacifico, measuring the pulmonary valve annulus with Hagar dilators accepting up to two standard deviations of the recommended valve annulus size for the patient’s height and body weight.

Dr G. Sarris (Athens, Greece): I have three questions pertaining to the criteria of transannular patching. If transannular patching is deemed necessary, and I understand you consider this necessary if the pulmonary valve annulus is less than half the aortic diameter, do you then automatically go to a transventricular approach? An alternative would be to perform a transatrial-transpulmonary approach with enlargement of the annulus only as necessary, without resorting to a ventriculotomy. We will present this approach from our unit later this afternoon. Do you think that this approach might eliminate the problem of recurrent obstruction at the annular level? Finally, do you know whether it is the annulus that is the site where residual or recurrent obstruction occurs in your series?

Mr Alexiou: As I have previously mentioned, the decision to insert a transannular patch was based on the findings of the preoperative angiogram. Jim Monro, in the mid 1970 s, has described that a pulmonary artery size diameter less than half that of the aorta was as good in predicting the need for a transannular patch as was the intra-operative measurement of the pulmonary valve annulus with Hagar dilators. We hope that with our current policy, the occurrence of RVOT obstruction is going to be dramatically reduced. It is perhaps worth noting that consistent application of this approach in a particular surgical firm has resulted in only four patients having a re-operation for RVOTO obstruction over a 25 years.

Dr M. Murtra (Barcelona, Spain): I have noticed that one patient in the atrial approach group required tricuspid annuloplasty. That was the reason for the reoperation or was it associated also with repair of the outflow tract?

Mr Alexiou: This patient had persistent distal PA branch stenosis with suprasystolic right ventricular pressures.

Several attempts made to alleviate this, including patch-enlargement and balloononing, were unsuccessful and a PA stent didn’t work. She last presented with severe right ventricular failure, and had a further patch-enlargement of the distal PA branches, and tricuspid annuloplasty to reduce the tricuspid regurgitation. This was a very sad case, after the last procedure this patient died.