



RESEARCH ARTICLE

RHYTHM AND CONDUCTION ABNORMALITIES AFTER SURGICAL CORRECTION
OF FALLOT'S TETRALOGY

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ABSTRACT

Objectives: Rhythm and conduction disturbances are common findings after surgical correction of Tetralogy of Fallot.

Methods: 71 Tetralogy of Fallot patients underwent surgical correction in Heart Institute, Cluj Napoca, Romania, between September 2001 and July 2006, without prior palliations. Employed surgical techniques were: transannular patch (n=46), infundibular patch (n=12), infundibular patch + pulmonary patch (n=5), transatrial + transpulmonary repair (n=8). The patients were divided into 2 groups, correction under 1 year of age and correction above 1 year of age, for comparative study of results. Among the 71 patients group, 58 were followed up at 43 months mean interval in group 1, and 48 months mean interval in group 2, by standard electrocardiography, 24 hours Holter monitoring and echocardiography.

Results: Major differences between the two groups were recorded: the QRS complex and Q-T corrected interval (QTc) duration were significantly different between the 2 groups, right bundle branch block with left anterior hemiblock was noticed especially in patients operated over 1 year of age, ventricular arrhythmias were present especially in the same group of patients operated over 1 year and did not appear in patients with combined (transatrial and transpulmonary) repair; furthermore, ventricular arrhythmias were especially present in patients with postoperative severe pulmonary regurgitation; the mean QRS duration was intensely significant correlated with the type of arrhythmia.

Conclusions: Rhythm and conduction disturbances are statistically significant correlated with the age at correction (the greater the age at operation, the bigger the risk for this type of complications), moreover being correlated with the surgical technique as well, and the postoperative pulmonary regurgitation is a key factor for rhythm disorders.

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INTRODUCTION

In the last four decades, congenital heart disease (CHD) mortality, in general, and Fallot's Tetralogy (TOF), has dramatically decreased (Teraiet al., 2002), due to improvements in surgical and medical treatment. The most important complications in TOF postoperative course are rhythm and conduction abnormalities. (Gatzouliset al., 2000; Fusteret al., 1980; Katzet al., 1982; Zhaoet al., 1985; Lilleheiet al., 1986; Morris and Menashe, 1991; Kaveyet al., 1982) There are, for example, Japanese studies, even a multicentric one, about postoperative arrhythmias in TOF. (Kobayashiet al., 1984; Niwaet al., 2002; Makotoet al., 2004)

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PATIENTS AND METHODS

77 patients were included in this study, who have undergone surgery at "N. Stăncioiu" Heart Institute, Cluj Napoca, Romania, between September 1st, 2001 and July 1st, 2006, all of them corrected per primam, with no prior palliations, with 2 deaths (mortality – 2,6%). Of these 77 patients, deaths were excluded, and operations at a higher age (14,18,21,32 years old), to avoid influence on results. Thus, we produced a homogenous lot of 71 patients (48 male and 23 female). This lot of 71 patients was divided in two groups, depending on age at surgery: group 1 of 25 patients operated before 1 year of age, and group 2 of 46 patients, operated after 1 year of age. These two lots were created since there are studies which show that arrhythmias are more frequent in older TOF patients. These 71 patients underwent the following surgical procedures:

transannular patch (46 patients, 17 in group 1, 29 in group 2), infundibular patch (12 patients, 2 in group 1 and 10 in group 2), combined patch (infundibular + pulmonary artery patch) (5 patients, 2 in group 1 and 3 in group 2), and combined correction through the pulmonary artery and the right atrium (8 patients, 4 in group 1 and 4 in group 2).

Of these 71 patients, 58 were followed-up over a period of: group 1 – 43,24 months +/- 14,28 and group 2 – 48,6 months +/-18,66. Among the 58 patients, 21 were in group 1 and 37 were in group 2. Of the initial 71 patients, 13 were not followed up (lost at follow up, institutionalized patients and 1 patient was excluded since he developed 3rd degree atrioventricular block, with no significant statistical results).

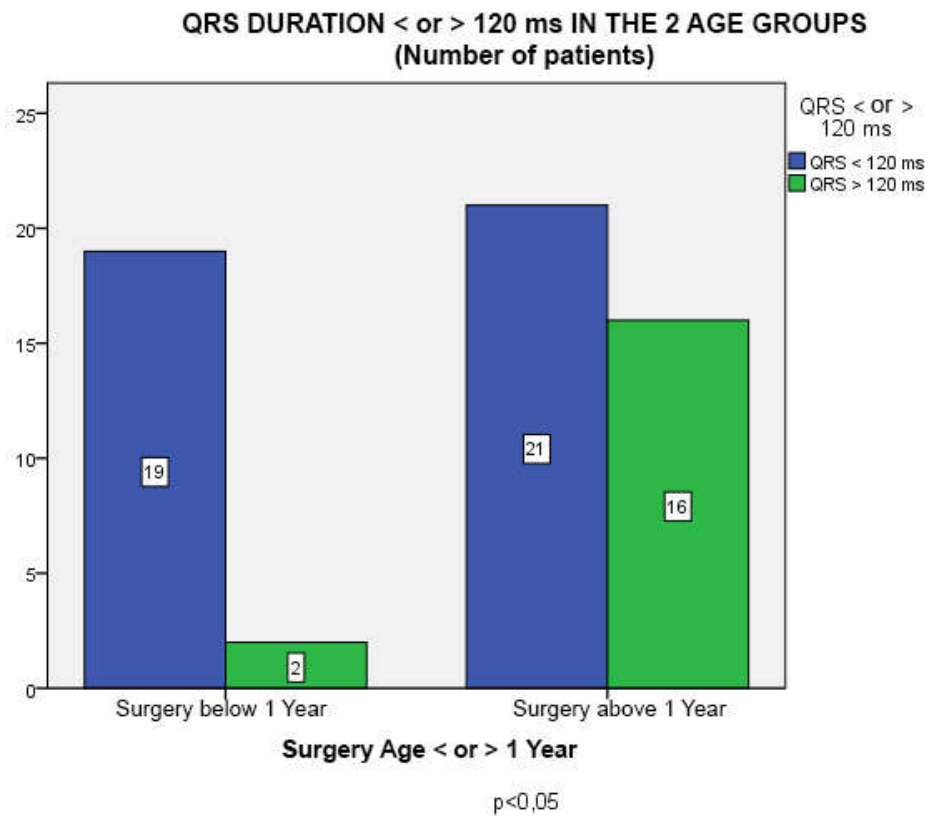


Figure 1. QRS duration below (<) or above (>) 120ms in the 2 age groups

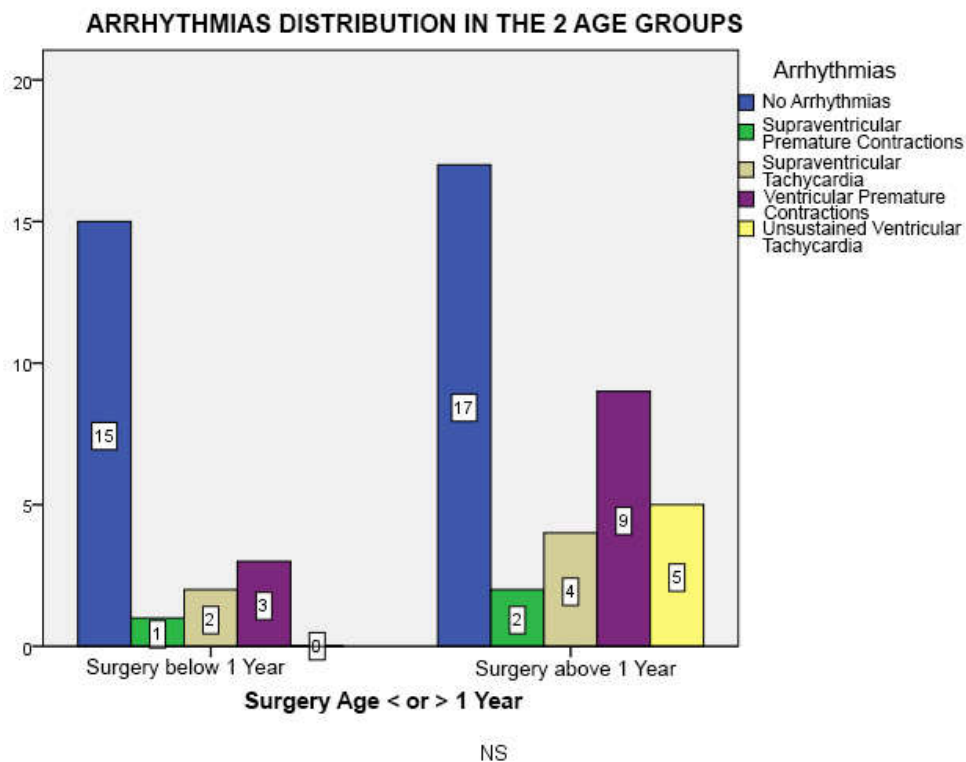


Figure 2. Arrhythmias distribution in the 2 age groups

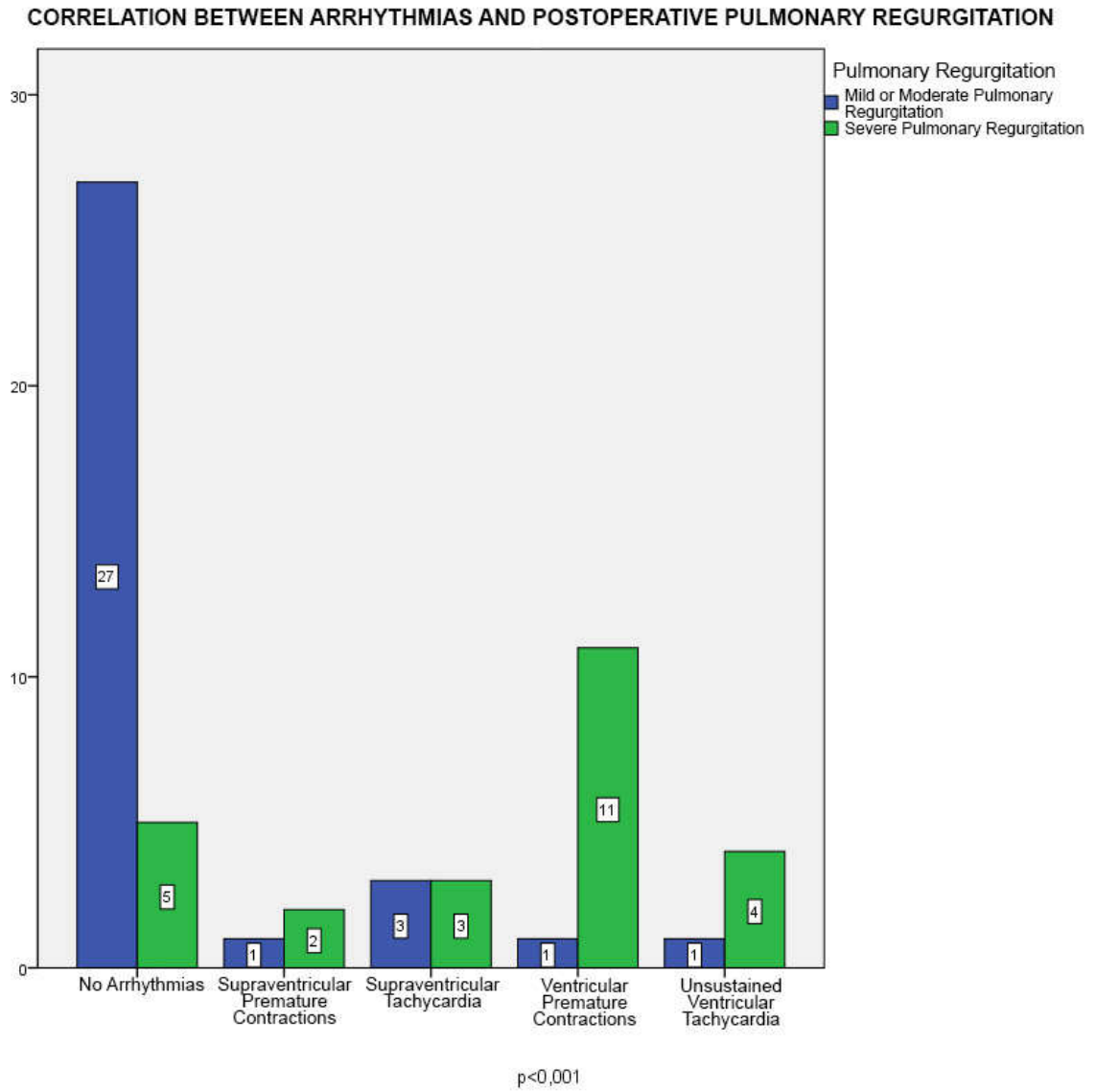


Figure3. Correlation between arrhythmias and postoperative pulmonary regurgitation

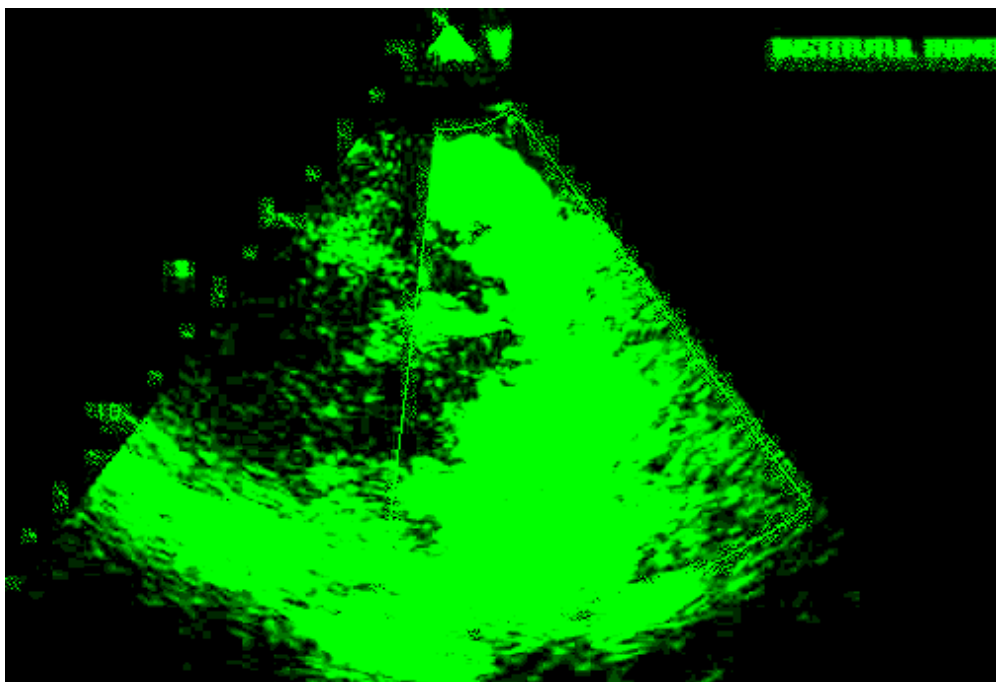


Figure 4. Severe postoperative pulmonary regurgitation

At follow-up, the 58 patients were studied by: standard EKG, Holter monitoring (3 channel EKG with CardioSpy software), and cardiac ultrasound. From the cardiac ultrasound, we extracted the degree of pulmonary regurgitation, this being the main physio-pathological element that determines all other changes that one can find on cardiac ultrasound (right ventricle dilatation, tricuspid regurgitation, and others). Alongside the analysis of rhythm and conduction abnormalities we also studied QRS complex and QTc interval (QT interval corrected with the cardiac frequency), given the fact that QRS duration is a risk factor for the development of rhythm abnormalities. The duration of the QRS complex is a risk factor above 180ms in European studies, and in the Japanese multicentric trial above 120ms. Since the follow up was done relatively close to the time of surgery, we considered as appropriate the 120ms value, for the reference duration of the QRS complex. For the QTc we chose 440ms as a reference value, which is the maximal normal value. For statistical analysis, we employed the IBM SPSS v.19 software. For means comparison, we used T-test for independent variables with the Monte Carlo test, for determining the p-value of statistical significance, and for correlations with surgical techniques, ultrasound values, and others, we employed cross-tables.

RESULTS

In the studied population, there were no late deaths. We have no data about the postoperative course of institutionalized patients and the ones lost at follow-up. Considering the prognostic significance of QRS and QTc durations, these intervals were studied comparatively in the 2 groups. The QRS duration was: Group 1 - 102ms \pm 15,06, Group 2 - 116ms \pm 20,48 ($p < 0,05$). QTc duration: Group 1 - 420ms \pm 32,3, Group 2 - 447ms \pm 23,2 ($p < 0,05$). We can observe a higher, statistically significant duration in QRS and QTc in group 2. Correlation of QRS complex duration with the body surface area shows an increase with growth ($p < 0,05$). When comparing QRS duration above and below 120ms between the two groups we observed a significant difference ($p < 0,05$) (QRS > 120ms: Group 1 - 9,5%, Group 2 - 43,2%) (**Figure 1**). The correlation of the duration of QTc interval above and below 440ms between the 2 groups was highly statistically significant ($p < 0,001$). So, the duration of QTc > 440ms: Group 1 - 19%, Group 2 - 73%. The duration of QTc also correlates with age (the higher the age, the wider the QTc interval - $p < 0,05$).

The conduction disorders observed in the whole 58 patient group were: incomplete right bundle branch block - 20,7%, right bundle branch block - 50% and right bundle branch block with left anterior hemiblock - 17,2%. 12,1% of the patients didn't present any conduction disorders. When distributing conduction disorders between the two groups, there were differences in patients with no conduction disorders (23,8% - Group 1, 5,4% - Group 2) and in patients with right bundle branch block with left anterior hemiblock (4,8% - Group 1, 24,3% - Group 2). The rhythm disorders found in the 58 patient group were as follows: premature supraventricular contractions - 5,2%, supraventricular tachycardia - 10,3%, premature ventricular contractions - 20,7% and unsustained ventricular tachycardia - 8,6%. When distributing conduction disorders between the two groups, there were differences in patients with premature ventricular contractions (Group 1 - 14,3%, Group 2 - 24,3%), unsustained ventricular tachycardia (Group 1 - 0%, Group 2 - 13,5%) and in patients with no rhythm disorders (Group 1 - 71,4%, Group 2 - 45,9%) (**Figure 2**). The ischemic

changes observed on the Holter interrogation were present in 13,8% of the 58 patients, with no differences between the two groups. We also studied the correlation between the rhythm abnormalities and the 4 types of surgery. We could observe that ventricular rhythm disorders appear in surgical techniques which employ a ventriculotomy and don't appear in the combined correction through the right atrium and pulmonary artery. The distribution of ischemic modifications does not differ between the four groups of surgery, but these modifications don't appear in patients with combined atrial and pulmonary correction. The duration of QRS complex below or above 120ms or QTc interval below or above 440ms did not correlate with the type of surgery, but we could observe that there are more patients from the ventriculotomy group with QRS > 120ms and with QTc > 440ms. When correlating rhythm disorders with the degree of pulmonary regurgitation, we found significant statistical correlation ($p < 0,001$) (**Figure 3**). Ventricular rhythm disorders are more frequent in patients with "free" pulmonary regurgitation (**Figure 4**), while patients without rhythm disorders have (84,4%) minor or mild pulmonary regurgitation (**Figure 5**) at follow-up. The mean duration of QRS complex is highly correlated ($p < 0,001$) with the type of rhythm and conduction disorders (**Fig. 6**), meaning that it has a higher value for ventricular rhythm disorders and for right bundle branch block with left anterior hemiblock.

DISCUSSION

This study compares the incidence of rhythm and conduction disorders according to the age at the time of surgery (below and above one-year old). Compared to the European literature, our results are similar, but the incidence is higher than in the studies conducted in Japan (Teraie *et al.*, 1968; Gatzoulis *et al.*, 2000; Fuster *et al.*, 1980; Katz *et al.*, 1982; Zhao *et al.*, 1985; Lillehei *et al.*, 1986; Morris and Menashe, 1991; Kavey *et al.*, 1982; Kobayashi *et al.*, 1984; Niwa *et al.*, 2002; Makoto Nakazawa *et al.*, 2004). Complete atrioventricular block occurred in only one case which was excluded from the study. We found 17,2% of the patients with right bundle branch block and left anterior hemiblock, which can theoretically evolve towards a complete atrioventricular block and sudden death (Gatzoulis *et al.*, 2000; Deanfield *et al.*, 1980). The usage of a transannular patch or an infundibular patch is a risk factor for postoperative arrhythmias in TOF (Gatzoulis *et al.*, 2000; Zhao *et al.*, 1985). Kirklin *et al.* stated that transannular patch is a risk factor for early mortality but not for late mortality (Kirklin *et al.*, 1989). Also, technical problems - "too wide" patch - can determine a "free" pulmonary regurgitation, which dilates the right ventricle, causing a tricuspid regurgitation, that gives birth to vicious circle (Dean and Lab, 1989; Zahka *et al.*, 1988; Therrien *et al.*, 2001; Rahman *et al.*, 2000; Satoh and Zipes, 1996), which leads to right atrial enlargement. These alterations are risk factors for both atrial and ventricular tachyarrhythmias (Marie *et al.*, 1992), and become clinically manifest in patients with wider QRS complex (Gatzoulis *et al.*, 2000; Niwa *et al.*, 2002; Garson *et al.*, 1979; Deanfield *et al.*, 1980) and an enlarged cardio-thoracic index (Gatzoulis *et al.*, 2000; Satoh and Zipes, 1996). The duration of QRS and QTc correlates with the body surface area and the surgery age. A QRS > 120ms and a QTc > 440ms appear more frequently in group 2 - patients older than 1 year at surgery. Conduction disorders, especially right bundle branch block with left anterior hemiblock, and ventricular rhythm disorders, appear in group 2, the one with an age over 1 year at the time of surgery.

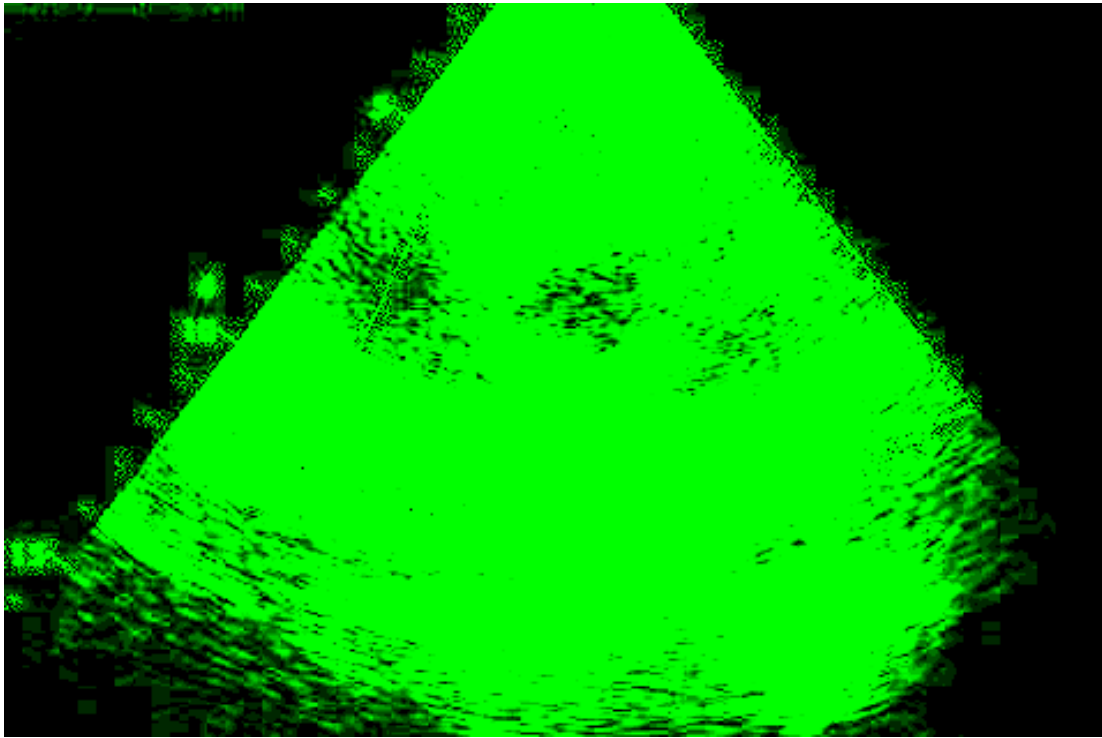


Figure 5. Moderate postoperative pulmonary regurgitation

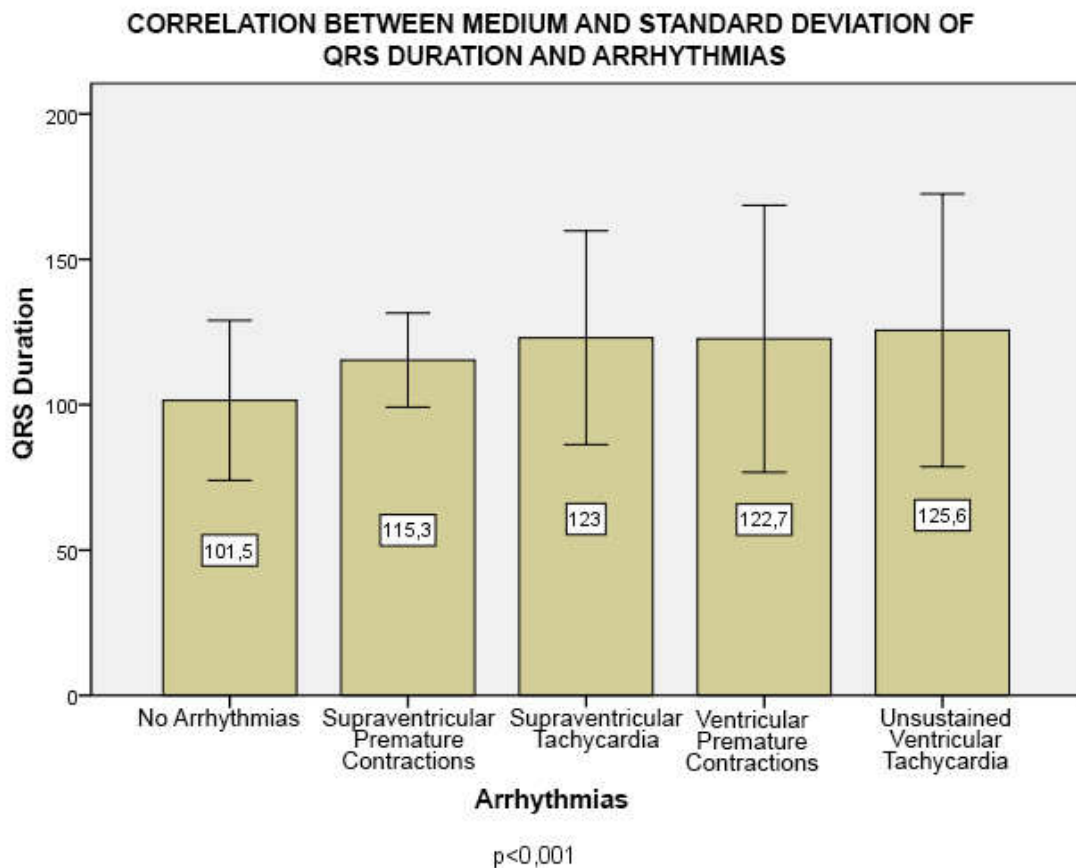


Figure 6. Correlation between medium and standard deviation of QRS duration and arrhythmias

The employed surgical technique is crucial, regarding the occurrence risk of both conduction and rhythm disorders. Considering that combined approach (through the right atrium and pulmonary artery) does neither require a ventriculotomy, nor employ the usage of a ventricular patch, this technique is advantageous, since in time, the ventricle does not develop scarring, which in its turn is a proven arrhythmogenic source.

The transannular patch technique also leads to pulmonary regurgitation, which is a trigger for beforementioned modifications. Also, the use of the combined approach (through the pulmonary artery and the right atrium) also leads to better right ventricle function in the postoperative period (25-29). The shorter duration of the QRS complex does not provide the substrate for the reentry mechanism of premature ventricular

contractions and ventricular tachycardia, which in time can become life threatening. The prognostic value for QRS complex (Gatzoulis *et al.*, 1995) proved of great value in our study, being intensely correlated with the type of rhythm disorders. Pulmonary regurgitation on ultrasound, appears, as expected, more frequently in patients with a transannular patch, and it can be avoided with careful calibration with Hegar dilators of the patch width, according to the normal value of the pulmonary annulus (available from nomograms, according to the body surface area).

Study limitations

Although our study group is homogenous, from a surgical standpoint, the follow-up was performed at a relatively short time after surgery, compared to other studies (European and Japanese) (Gatzoulis *et al.*, 2000; Makoto Nakazawa *et al.*, 2004). An ongoing second longitudinal study will be ready next year, but the study results are related to the first ones, so far. The follow-up group was 13 cases smaller than the initial one, due to institutionalized patients and lost at follow-up patients, with no information, whatsoever. In these patients, there is risk of sudden death, and no correlations could be made with rhythm disorders, if they existed. In international studies, complete atrioventricular block and ventricular tachycardia are the most important risk factor for sudden death. In our study, the significance of complete block could not be studied, due to insufficient cases. Although the follow-up study was made rather earlier than other studies (Marie *et al.*, 1992) one can hypothesize that rhythm and conduction disorders in these patients will persist, with a risk of even further progression.

Conclusion

This study is the first in Romania to highlight the higher risk of postoperative arrhythmias in patients with corrective surgery for TOF at a higher age. Due to these well-known postoperative complications and for other reasons described by the international literature (ex: deficient psychological development in children with late surgical treatment) (Chira *et al.*, 2017), we have progressively lowered the timing for surgery in TOF patients. Compared to 20 years ago, nowadays, a significant percentage of TOF patients are operated at ages lower than 1 year, most of them by the age of 6 months. The prevalence of arrhythmias is higher in children with a higher age at the time of surgery, and with a wider QRS complex. Rhythm and conduction disorders appear in patients with late surgery, which usually require a transannular patch, with a higher risk of postoperative „free” pulmonary regurgitation, consequently increasing the risk of sudden death.

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Conflict of interest statement

Conflict of interest: none declared.

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