



## ORIGINAL PAPER

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# Complete Balanced Atrioventricular Septal Defect – Results of Bi-ventricular Surgical Correction

Michał Sobieraj<sup>1</sup>, Michał Szemień<sup>1</sup>, Marcin Bednarek<sup>1</sup>, Michał Wojtalik<sup>2</sup>,  
Wojciech Mrówczyński<sup>2</sup>

<sup>1</sup> Pediatric Cardiac Surgery Students' Interest Group, Poznan University of Medical Sciences, Poland

<sup>2</sup> Department of Pediatric Cardiac Surgery, Poznan University of Medical Sciences, Poland

### ABSTRACT

**Aim.** The aim of this study was to analyze the results of surgical treatment of balanced AVSD during 10-year period in a single center. The adequacy of atrioventricular valves reconstruction was scrutinized as well as risk factors for mortality, redo surgery, pulmonary hypertension incidence were assessed.

**Materials and method.** One hundred twenty one patients underwent surgical correction of AVSD between 2004 and 2013. All patients were operated by double patch technique with the apposition zone closure. Patients' median age was: 109 (86–151) days, body weight: 4.5 (4–5.5) kg. Down syndrome was present in 100 (82.6%) patients.

**Results.** Early mortality equaled 17.3% (21 patients) and late mortality was 1.7% (2 patients). Pulmonary hypertension (42.9%) and heart failure (33.3%) were the main causes. Cardiopulmonary bypass time ( $p < 0.0001$ ), aortic cross-clamping time ( $p = 0.003$ ), inotropic index value ( $p < 0.0001$ ), maximal mean pulmonary artery pressure ( $p = 0.008$ ) were significantly higher in the group of patients who died. Ten patients (8.3%) required early reoperation and nine (9%) required late reoperation. Early postoperative mitral valve regurgitation of III<sup>rd</sup> or higher degree was risk factor for early and late reoperations ( $p = 0.0002$ ). The probability of freedom from all reoperations at 6 months, 1 and 5 years was respectively: 0.83; 0.80 and 0.71.

**Conclusions.** Pulmonary hypertension and low cardiac output syndrome have significant influence on results of AVSD treatment. The predisposing risk factors are prolonged time of surgical procedure and presence of pneumonia. Mitral valve reconstruction quality has an influence for early and late results.

**Keywords:** AVSD, mitral valve regurgitation, redo surgery.

## Introduction

Atrioventricular septal defect (AVSD) is a complex cardiac malformation comprising entire spectrum of different defects: isolated cleft of anterior mitral valve leaflet, ostium primum atrial septal defect, ostium primum atrial septal defect with ventricular septal defect (VSD), transitional AVSD type, and finally a complete AVSD. The later can occur in more severe unbalanced form.

Anatomy and pathophysiology of the malformation causes 60–65% mortality rate in first year of life and over 90% in first two years. Thus, the only definitive treatment is a surgical correction with reconstruction of

atrioventricular valves – the most crucial part of surgical approach. Even though progress in cardiac surgery techniques improved outcomes of patients with AVSD including quality of life, still 15–20% patients require reoperation [1–3]. The most common indication for reoperation after initial repair is a regurgitation of atrioventricular valves, particularly mitral insufficiency which is the cause of reoperation in 70–90% [2, 4, 5].

Surgical correction of AVSD can be complicated by other different problems including: post-operative pulmonary hypertension (PH), low cardiac output syndrome (LCOS) and III<sup>o</sup> atrioventricular heart block.

## Aim

The aim of the study was to assess the results of surgical bi-ventricular correction of complete AVSD during 10-year period in a single unit. The risk factors of atrio-ventricular valves regurgitation, intraoperative mortality, pulmonary hypertension and other complications were studied.

## Materials and method

### Patients

One hundred twenty one patients underwent surgical correction of AVSD in the Department of Pediatric Cardiac Surgery in the University of Medical Sciences, Poznań, between 2004–2013. Patients with isolated cleft of anterior mitral valve leaflet, partial, transitional and unbalanced forms of AVSD were excluded. Medical records (surgical reports, case histories, local medical data base and local data from National Cardiac Surgery Register) were reviewed.

Ten patients underwent pulmonary artery banding before primary correction. Seven patients (5.79%) had coexisting malformations like pulmonary valve stenosis ( $n = 3$ ; 2.5%), tetralogy of Fallot ( $n = 1$ ; 0.8%), and coarctation of the aorta ( $n = 1$ ; 0.8%). Demographic data are shown in **Table 1**.

This observational study has been approved by the local Ethics Committee (resolution: 32/13 from 03.01.2013) and an individual patients' consent was waived.

**Table 1.** AVSD patients characteristics

Demographic variables	
N	121
Gender (female/male)	58 (47.9%) / 63 (52.1%)
Down's syndrome	100 (82.6%)
Age (days)	109 (86–151)
Body weight (kg)	4.5 (4–5.5)
Body surface area (m <sup>2</sup> )	0.26 (0.24–0.30)
Intraoperative variables	
CBP (min)	119 (103–138)
Ao-x-clamp (min)	74 (63–88)
Postoperative variables	
ICU time (days)	10 (6–20)
Mechanical ventilation (hours)	96 (32–266)
INO SCORE (mcg/kg/min)	15 (6.70–24.85)
Max. mPAP (mmHg)	49.2 ± 18.2

CBP – cardiopulmonary bypass time; Ao-x-clamp – aortic cross-clamp time; INO SCORE – inotropic index; ICU time – intensive care unit stay time; Max. mPAP – maximal mean pulmonary artery pressure

### Surgical technique

All patients were operated through the median sternotomy by applying two-patch technique [6, 7], with the use of aorto-bicaval cannulation for cardiopulmonary bypass in moderate hypothermia. Cardiopulmonary bypass time (CBP) and aortic cross clamping time (Ao-x-clamp) were recorded. Ventricular septal defect was closed with Gore-Tex patch attached to interventricular septum by a continuous suture. Then the division and reconstruction of atrioventricular valves was performed. The left-sided apposition zone of bridging leaflets was sutured with interrupted 6–0 polypropylene monofilament sutures. Autologous pericardium was applied for atrial septal defect closure. Regurgitation of reconstructed atrioventricular valves was tested saline injection into the ventricle and by the use of intraoperative transesophageal echocardiography.

### Post-operative care

All patients received standard intensive care unit treatment. When necessary pulmonary artery pressure was recorded by a catheter inserted through the infundibulum of the right ventricle. Pulmonary hypertension was treated by hyperventilation, nitric oxide inhalation, and phosphodiesterase V inhibitors administration via nasogastric tube (sildenafil). Pharmacological circulatory support was obtained by catecholamines and vasodilators: adrenaline, isoprenaline, dopamine, dobutamine and milrinone. The degree of catecholamine support was expressed by inotropic index [8, 9], defined as: INO-SCORE (mcg/kg/min) = DPA+DBX+100xISO+100xADR, (where: DPA = dopamine, DBX = dobutamine, ISO = isoprenaline, ADR = adrenaline). One patient required mechanical circulatory support – ECMO due to heart failure refractory to conventional treatment.

### Echocardiographic study

Transthoracic echocardiography was performed in all patients preoperatively, pos-operatively and during the follow-up. Left ventricular ejection fraction (LVEF), left ventricular shortening fraction (SF), common atrioventricular valve regurgitation (CAVI), mitral (MI) and tricuspid (TI) valve regurgitations were analyzed.

### Follow-up

Transthoracic echocardiography and medical examination were performed in all patients during the follow-up. Median observation time was 714 days (420–1002). Total follow-up was 143.5 patient-years.

## Statistical analysis

Normality of data distribution was tested by Kolmogorov-Smirnov test. Continuous variables were presented as mean and standard deviation or median and range according to the distribution normality. T-student and Mann-Whitney tests were used for intergroup independent comparisons. Fisher's exact test was employed for categorical variables comparisons. Kaplan-Meier method was applied to assess the probability of freedom from all reoperations and reoperations for significant mitral valve regurgitation, 95% confidence interval was calculated. *P*-value less than 0.05 was considered statistically significant.

## Results

### Mortality

Thirty-day mortality equaled 17.3% (21 patients). Nine patients died from pulmonary hypertension (42.9%), 7 from heart failure (33.3%), 2 from coexisting pulmonary hypertension and heart failure (9.5%). Multiple organ dysfunction syndrome was the cause of 3 deaths (14.3%). Late mortality (> 30 days) was 1.7% (2 deaths). Both patients died from coexisting pulmonary hypertension and heart failure.

Prolonged cardiopulmonary bypass time, prolonged aortic cross-clamping time, higher inotropic index and higher maximal mean pulmonary artery pressure were influencing negatively the survival with statistical significance (**Table 2**). Demographic data had no statis-

tically significant impact on the survival. There were no statistically significant differences in: pre-operative left ventricle ejection fraction, left ventricle fractional shortening, mechanical ventilation time and presence of common atrioventricular valve regurgitation (III-rd degree or higher) in patients who died and patients who survived. There were no early and late deaths in 10 patients who underwent pulmonary artery banding before total correction in comparison to children without banding (early mortality 0% vs. 18.9%) but this difference was not significant (*p* = 0.207).

### Reoperations

Ten patients required early reoperation ( $\leq 30$  days). Nine (9%) patients out of 100 who survived early postoperative time required late reoperation (>30 days). Four patients required second redo surgery. One patient underwent third reoperation. Causes of reoperations and re-interventions are listed in **Table 3**. The usual redo strategy for mitral valve regurgitation was repeated mitral valve reconstruction.

The median time of early reoperation equaled 14 days (7–24). The median time of late redo surgery was 205 days (52–950). The probability of freedom from all reoperations at 6 months, 1 and 5 years was respectively: 0.83 (0.75–0.92; 95%CI); 0.80 (0.70–0.90; 95%CI) and 0.71 (0.56–0.90; 95%CI) (**Figure 1**). **Figure 2** shows freedom from the first reoperation due to the significant mitral valve regurgitation with the probability of 0.87 (0.80–0.96; 95%CI); 0.85 (0.77–0.95;

**Table 2.** Mortality risk factors in patients undergoing AVSD correction

Variables	Survival	Death	<i>p</i> -value
Intraoperative variables			
CBP (min)	113 (101–130)	144 (129–179)	< 0.0001
Ao-x-clamp (min)	71 (62–85)	91 (76–103)	0.0003
Postoperative variables			
INO SCORE (mcg/kg/min)	12.9 (6.0–19.1)	58.5 (19.3–87.5)	< 0.0001
Max. mPAP (mmHg)	44.8 ± 17.4	61.0 ± 16.4	0.008
Mechanical ventilation (hours)	84 (32–244)	174 (19–573)	0.203
Demographic variables			
Age (days)	108 (87–153)	113 (69–172)	0.424
Body weight (kg)	4.55 (4–5.9)	4.15 (3.8–5)	0.207
Body surface area (m <sup>2</sup> )	0.27 (0.24–0.31)	0.26 (0.24–0.28)	0.132
Down's syndrome	84.7%	69.6%	0.129
Preoperative echocardiographic data			
CAVVI ≥ III-rd degree	32.3%	45.4%	0.320
LVEF (%)	78 (71–84)	78 (73–81)	0.812
SF (%)	43 (38–50)	43 (38–46.8)	0.951

CBP – cardiopulmonary bypass time; Ao-x-clamp – aortic cross-clamp time; INO SCORE – inotropic index; Max. mPAP – maximal mean pulmonary artery pressure; CAVVI – common atrioventricular valve regurgitation; LVEF – left ventricular ejection fraction; SF – left ventricular shortening fraction

**Table 3.** Reoperations in patients undergoing AVSD correction

Early reoperations	
MI	4
MI+TI	1
VSD	1
Pacemaker implantation	4
Late reoperations and interventions	
MI	6
MI+TI	2
Wound revision	1
Pleural effusion drainage	1
Pericardial effusion drainage	1
Pacemaker implantation	3

MI – mitral valve regurgitation; TI – tricuspid valve regurgitation; VSD – ventricular septal defect

95%CI) and 0.77 (0.61–0.97; 95%CI) at 6 months, 1 and 5 years respectively.

Patients with early ( $\leq 30$  days) III-rd or higher degree mitral valve regurgitation required significantly

more reoperations than other children (22% vs. 0%) ( $p = 0.0002$ ). Patients' age, body weight, body surface, cardiopulmonary bypass time, aortic cross-clamping time, inotropic index, maximal mean pulmonary artery

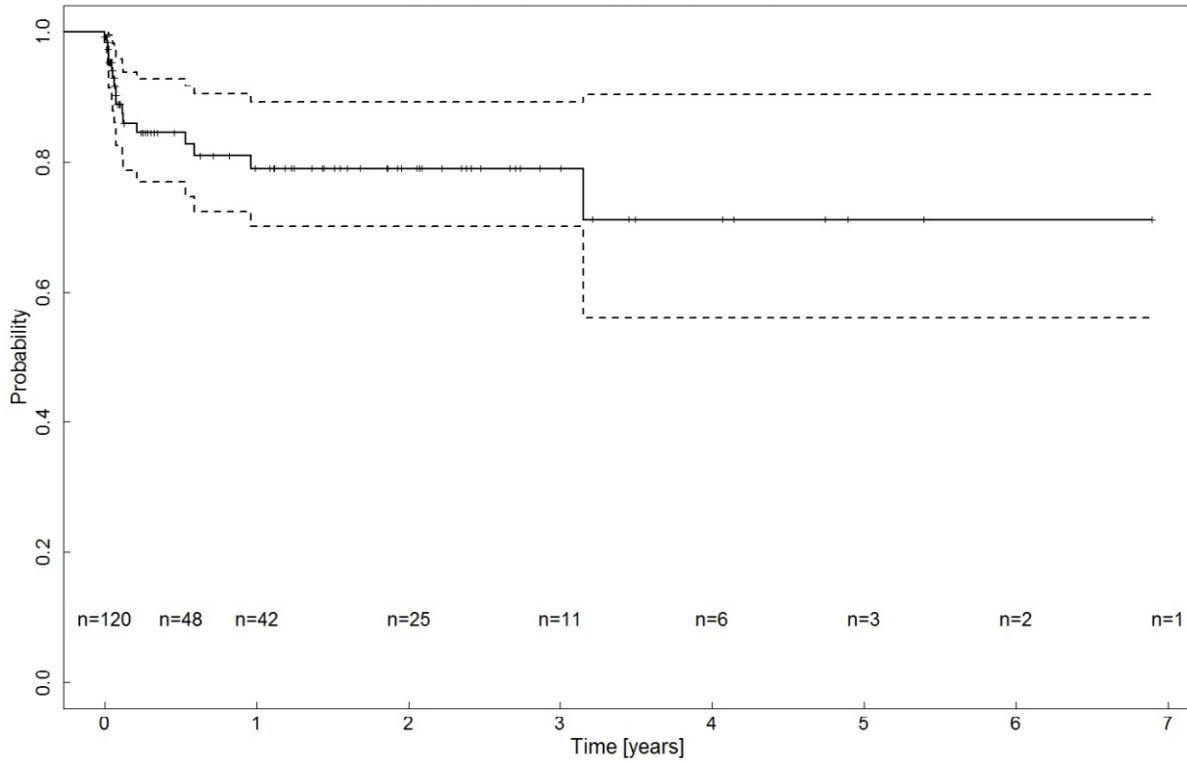


Figure 1. Freedom from the first reintervention

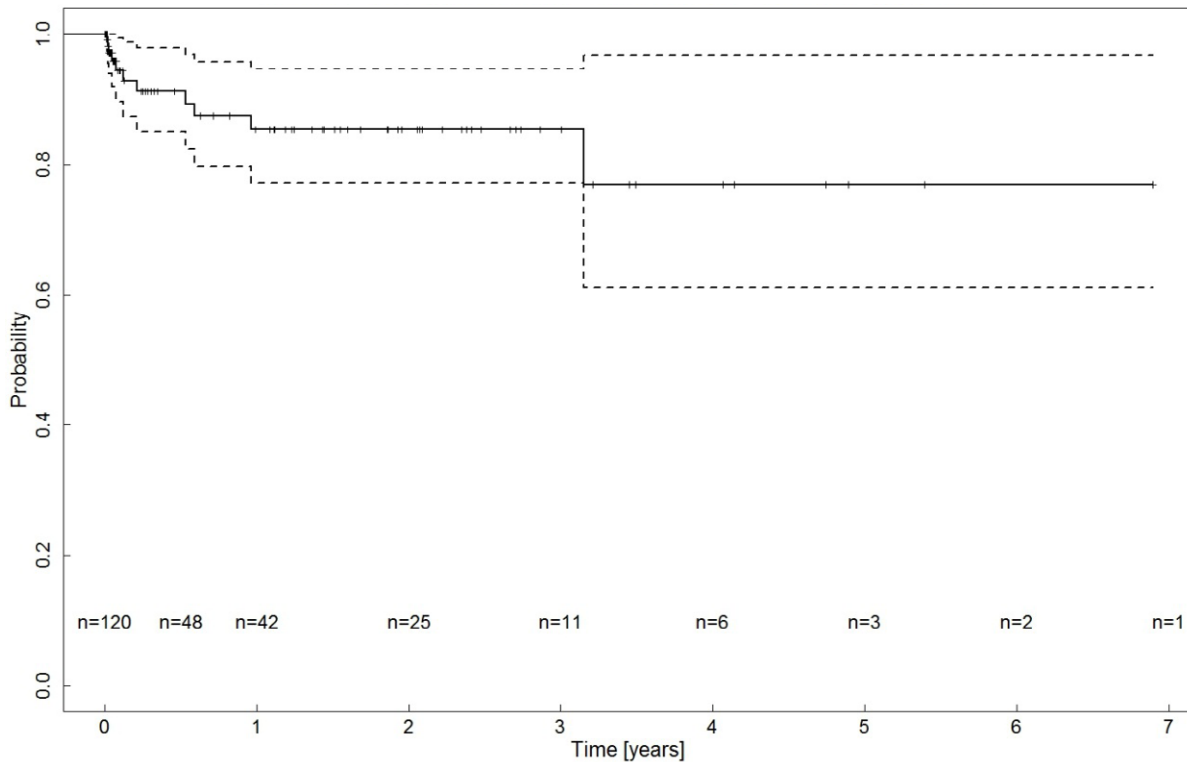


Figure 2. Freedom from the first reintervention due to mitral regurgitation

pressure, left ventricle ejection fraction, left ventricle fractional shortening were not significantly different in the groups of children requiring redo mitral valve surgery and in the group of patients without reoperation. Presence of preoperative III-rd or higher degree common atrioventricular valve regurgitation was not significantly more frequent in patients undergoing redo surgery (Table 4).

Patients who underwent pulmonary banding as a first stage of treatment did not require early neither late reoperations in comparison to the rest of the cohort (0% vs. 17.12%). However, this comparison was not statistically significant ( $p = 0.360$ ).

### Atrioventricular valve function

Ninety five (78.5%) patients had pre-operative common atrioventricular valve regurgitation, forty patients (34.8%) had III-rd or higher degree incompetence. In the first post-operative echocardiographic study 45 patients (44.5%) had III-rd or higher degree mitral valve regurgitation, whereas IV-th degree mitral valve regurgitation was present in 12 patients (12%) – 5 of them required early reoperation. During the follow-up 8 patients who had significant mitral valve regurgitation required reoperation. In last control echocardiographic study 5 patients had III-rd degree mitral valve regurgitation but did not require reoperation at the end of observation. The IV-th degree mitral valve regurgitation was not noted at the follow-up conclusion.

### Post-operative complications

Fifty two patients (43%) had pulmonary hypertension in the immediate post-operative period. Thirty three patients (27.3%) required nitric oxide inhalation or phosphodiesterase inhibitor V treatment concomitant to hyperventilation. Pulmonary artery banding resulted in significantly less frequent incidence of pulmonary hypertension during the total AVSD correction (1% vs. 45.9%;  $p = 0.042$ ), only one patient who had pulmonary hypertension in this group required nitric oxide treatment.

Twenty one patients (17.4%) had pulmonary hypertensive crisis (PHC). Mortality rate, cardiopulmonary bypass time, mechanical ventilation time, intensive care unit stay time, inotropic index, maximum mean pulmonary artery pressure were significantly higher and incidence of pneumonia more frequent in patients with PHC than patients without it (Table 5). In contrary, the differences in demographic variables between these two groups were not statistically relevant.

Low cardiac output syndrome that required pharmacological support was present in 33 patients (27.27%). Cardiopulmonary bypass time, aortic cross-clamping time, mechanical ventilation time and inotropic index were significantly higher in patients with LCOS than patients without it (Table 6).

Among other post-operative complications pneumonia (48%), metabolic acidosis (15.7%), respiratory distress syndrome (5%) and sepsis (1.6%) were recognized.

**Table 4.** Reoperation risk factors in patients undergoing AVSD correction

Variables	Reoperation	No reoperation	p-value
Demographic variables			
Age (days)	105 (69–117)	112 (88–174)	0.133
Body weight (kg)	4.35 (3.9–5)	4.5 (4–5.9)	0.293
Body surface area (m <sup>2</sup> )	0.26 (0.23–0.28)	0.27 (0.24–0.31)	0.186
Intraoperative variables			
CBP (min)	139 (113–157)	118 (103–136)	0.223
Ao-x-clamp (min)	88 (67–96)	74 (63–88)	0.223
Postoperative variables			
INO SCORE (mcg/kg/min)	22 (6–32.3)	14.3 (6.53–23)	0.173
Max. mPAP (mmHg)	52.31 ± 14.9	43.62 ± 18.74	0.295
Preoperative echocardiographic data			
CAVVI ≥ III-rd degree	45.4%	34%	0.513
LVEF (%)	76 (67–85)	78 (72–83)	0.866
SF (%)	45 (35–51)	43 (38–48)	0.702

CBP – cardiopulmonary bypass time; Ao-x-clamp – aortic cross-clamp time; INO SCORE – inotropic index; Max. mPAP – maximal mean pulmonary artery pressure; CAVVI – common atrioventricular valve regurgitation; LVEF – left ventricular ejection fraction; SF – left ventricular shortening fraction

**Table 5.** Pulmonary hypertensive crisis risk factors in patients undergoing AVSD correction

Variables	PHC (100)	No PHC (21)	p-value
Intraoperative variables			
CBP (min)	115 (102–133)	130 (121–160)	0.015
Postoperative variables			
Mortality	12%	50%	0.0001
Mechanical ventilation (hours)	72 (27–168)	384 (221–585)	< 0.0001
ICU time (days)	9 (6–16)	24 (11–28)	0.002
INO SCORE (mcg/kg/min)	14.0 (6–20.7)	32.3 (15–98)	0.003
Max. mPAP (mmHg)	40.6 ± 9.6	65.9 ± 15.8	< 0.0001
Pneumonia	41%	81%	0.0013
Demographic variables			
Age (days)	110 (85–147)	106 (84–174)	0.719
Body weight (kg)	4.5 (4–5.9)	4.6 (3.9–5.5)	0.795
Body surface area (m <sup>2</sup> )	0.27 (0.24–0.31)	0.26 (0.24–0.29)	0.548
Gender (female/male)	50%/50%	38%/62%	0.348
Down's syndrome	83%	81%	0.760

CBP – cardiopulmonary bypass time; INO SCORE – inotropic index; ICU time – intensive care unit stay; Max. mPAP – maximal mean pulmonary artery pressure

**Table 6.** Low cardiac output syndrome in patients undergoing AVSD correction.

Variables	LCOS	No LCOS	p-value
CBP (min)	113 (101–130)	130 (117–164)	0.0002
Ao-x-clamp (min)	71 (62–86)	81 (68–93)	0.035
Mechanical ventilation (hours)	77.5 (29–217)	168 (72–439)	0.030
INO SCORE (mcg/kg/min)	12.9 (6–18.7)	30.2 (18.8–52.3)	0.0001

LCOS – low cardiac output syndrome; CBP – cardiopulmonary bypass time; Ao-x-clamp – aortic cross-clamp time; INO SCORE – inotropic index

## Discussion

This study analyzes the outcomes of complete AVSD correction in 121 patients in a single unit. All patients were operated with the double patch technique, which is commonly applied in many units [3, 5, 10–12]. The advantages of this method are: simpler partitioning and anchorage of bridging leaflets without a need for leaflet incision as well as potentially better protection of cardiac conduction system compared to single-patch and no patch technique. However, shorter cardiopulmonary bypass time and aortic cross-clamping time during single-patch and no-patch technique in comparison to double-patch approach can be an advantage of the formers [13]. The use of single patch/no-patch method is limited when additional intra-cardiac malformations like tetralogy of Fallot or double outlet right ventricle are present [13]. Moreover, the use of these techniques is connected with a frequent incidence of residual VSD and certain difficulties in attaching leaflets to Gore-Tech patch, which may result in dehiscence of sutured tissues, particularly in their mitral part [5, 14, 15].

Thirty-day mortality rate was 17.3%. Although this results are comparable to the rates from other reports

[2, 10, 16], it is possible to achieve mortality rates of 0–1.4% as reported by Bakhtiari [12] or Xie O [17]. In this study the main cause of early death was pulmonary hypertension (42.9%). This observation is in contrast to other reports where presence of pulmonary hypertension was not such a pronounced risk factor of early death. For example, Prifti [18] reports of only 12.5% deaths caused by pulmonary hypertension, whereas the study by Gunter [5] shows no early deaths related to this complication. Risk factors analysis shows that presence of pneumonia have significant influence on pulmonary hypertension and the PHC development [19]. Other risk factors predisposing to PHC included prolonged cardiopulmonary bypass time and high inotropic index value.

The most frequent cause of early death in patients undergoing surgical correction of AVSD is a heart failure. It contributes to more than 50% of early mortality [2, 3, 5, 16, 18]. In our study the heart failure was the cause of 33% deaths. Prolonged aortic cross-clamping time and prolonged cardiopulmonary bypass time were risk factors for low cardiac output syndrome. Consistent risk factors for in-hospital mortality were not defined so far. Prolonged cardiopulmonary bypass time, pro-

longed aortic cross-clamp time, pulmonary pressure value and inotropic index value were the risk factors for in-hospital mortality. This observation is corresponding to other reports [11, 18, 20]. However, some studies are opposite to it [2, 16].

The demographic variables were not risk factors for mortality in this study. Although this observation is similar to other studies [2, 3, 16, 18, 21], there are some contrary reports [3, 5]. There were no early or late deaths in patient group who underwent pulmonary artery banding. No statistically significant differences in mortality were recorded between group of patients with PAB and patients without it. It can be explained by small group of patients who underwent pulmonary artery banding before primary correction (10 patients with PAB vs 111 without it). Similar results is reported by Gunter's [5] study.

Ten patients from our cohort (8.3%) required early reoperations and 9 patients (9%) required late reoperations. This reoperations rate is similar to the results reported by others [3, 5, 16–18]. The probability of freedom from re-interventions at 6 months, 1 and 5 years were 0.83; 0.80 and 0.71 respectively and it is similar to other studies [2, 16, 20]. Mitral valve redo surgery was necessary in 13 patients (54.2% of 24 reoperations including second and third reoperation). Early mitral valve regurgitation had influence on early or late reoperations frequency which is comparable to other reports [3, 10, 18]. The demographic and preoperative echocardiography variables were not a risk factors for development of mitral valve regurgitation. However, some studies define patients age, body weight and the absence of Down's syndrome as risk factors for increased reoperation rate [2, 10, 16–18]. Hoohenkerk [3] and Prifti [18] reported pre-operative atrioventricular valve regurgitation as significant risk factors for the reoperation. Some authors indicate that the closure of the apposition zone can decrease the mitral valve reoperation rate [3, 18, 22]. However, this aspect was not scrutinized as the apposition zone was always sutured during each AVSD correction in this study.

#### Study limitations:

This study has the following limitations. It is a retrospective observational study comprising 10-year period. Cardiopulmonary bypass and cardio-protection techniques (introduction of blood cardioplegia) have evolved during that time. It could have affected the statistical analyses. The next limitation arises from the fact that the procedures were performed by different surgeons which certainly could have had influenced

the results. However, taking into account all consecutive interventions allows a global assessment of AVSD treatment results in a single unit.

## Conclusions

The early results of AVSD treatment are influenced by complications occurring in the early postoperative period including pulmonary hypertension and low cardiac output syndrome. The predisposing risk factors are prolonged cardiopulmonary bypass time, prolonged aortic cross-clamping time and presence of pneumonia.

Impaired atrioventricular valvular function still remains a significant problem. Mitral valve reconstruction quality has an influence for early and late results. Mitral valve regurgitation in the early post-operative period affects early and late reoperation rate.

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### Conflict of interest statement

The authors declare that there is no conflict of interest in the authorship or publication of contribution.

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**Correspondence address:**  
27/33 Szpitalna Str.  
60-572 Poznań, Poland  
phone: +48 61 8491277