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# Stent implantation into the interatrial septum in patients with univentricular heart and a secondary restriction of interatrial communication

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## Abstract

**Background:** Presence of a restrictive interatrial communication in patients with univentricular anatomy significantly affects surgical outcomes. In patients with univentricular hearts, wide open atrial communication leads to lower pulmonary artery pressure, which is one of the most important factors influencing the success of bidirectional Glenn and Fontan operations. In some patients, recurrence of restricted interatrial communication can be observed despite initially successful interventional or surgical creation of unrestrictive interatrial communication.

**Aim:** To evaluate efficacy of stent implantation into the interatrial septum in patients with univentricular heart and a secondary restriction of interatrial communication.

**Methods:** In 2006–2010, we created unrestrictive interatrial communication by stent implantation into the interatrial septum in 7 children with univentricular anatomy with systemic right ventricle (4 patients with hypoplastic left heart syndrome and 3 patients with mitral atresia). In all patients we diagnosed recurrent restriction of interatrial communication despite prior surgical or interventional creation of unrestrictive interatrial communication. Patient age at stent implantation was 3 to 30 months. Maximal systolic pressure gradient between the left and the right atrium was 6–29 mm Hg and left atrial pressure ranged from 20/17/19 mm Hg to 40/29/32 mm Hg. In all patients, we implanted a Palmaz-Genesis stent (length 18–29 mm) with subsequent balloon redilatation.

**Results:** In all 7 patients, we created unrestrictive interatrial communication with mean pressure gradient reduction from 13.14 mm Hg to 0.86 mm Hg ($p < 0.006$). Mean interatrial communication diameter increased from 4.14 mm to 10.57 mm ($p < 0.0001$).

**Conclusions:** Percutaneous stent implantation into the interatrial septum in children with univentricular heart and secondary restriction of interatrial communication is a safe and effective method.

**Key words:** restrictive interatrial communication, univentricular heart, stent, interventional treatment

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## INTRODUCTION

In recent years, we have witnessed an increase in the number of patients with congenital heart disease in whom complex anatomical and haemodynamic abnormalities preclude surgical correction of the defect with preservation of biventricular anatomy. These children are referred for palliative Fontan procedures, and the major factors determining success of this multi-stage surgical treatment include

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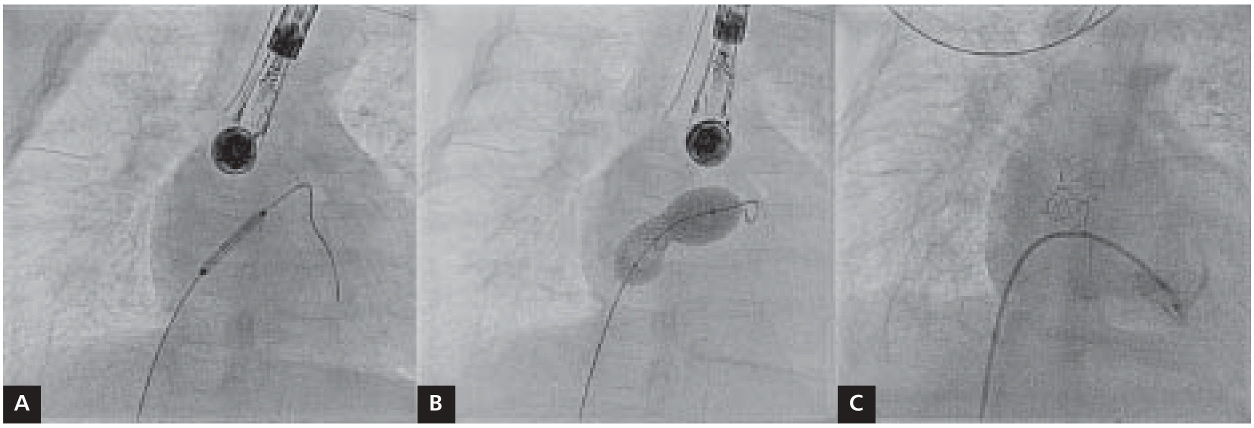


**Figure 1.** Angiographic images; **A.** Stent positioning at the level of the interatrial septum; **B.** Stent expansion; **C.** Fully expanded stent with adapted margins

well developed pulmonary vasculature and low pulmonary artery pressures. Thus, it is important to preserve unrestricted interatrial communication between subsequent surgical procedures. Development of interventional cardiology techniques and more frequent use of intravascular stents prompted attempts of interatrial septum stenting in these patients, particularly when conventional interventional techniques, such as Rashkind procedure and static balloon atrial septostomy, do not provide sustained haemodynamic effects. The purpose of this study was to evaluate efficacy and safety of stent implantation into the interatrial septum in patients with univentricular heart and a secondary restriction of interatrial communication despite previous atrioseptostomy or surgical resection of the interatrial septum.

## METHODS

### *Patients*

In 2006–2010, we performed 7 procedures of percutaneous dilation of restrictive interatrial communication with a Palmaz-Genesis stent implantation into the interatrial septum. All patients had univentricular anatomy with systemic right ventricle. In 4 children with hypoplastic left heart syndrome (HLHS), a secondary restriction of interatrial communication occurred despite previous successful surgical creation of unrestricted interatrial communication, and in 3 children with mitral valve atresia, restriction developed despite performance of Rashkind procedure or static balloon atrial septostomy. Patient age at stent implantation was 3 to 30 months. Maximal systolic pressure gradient between the left and the right atrium was 6–29 mm Hg and left atrial pressure ranged from 20/17/19 mm Hg to 40/29/32 mm Hg.

### *Procedure*

All interventional procedures were performed in general anaesthesia with endotracheal intubation. Stent positioning and expansion were monitored with fluoroscopy (using a single plane digital angiography unit) and transoesophageal echocardiography (mini-TEE probe) (Fig. 1). Femoral vein was cannulated with a short 6 F sheath, and 100 U/kg of heparin was administered. Low-molecular-weight heparin (100 U/kg of Fragmin) was given 4 h after the procedure, along with 3 mg/kg of acetylsalicylic acid orally. Antiplatelet treatment was continued until stent removal during the next stage of surgical treatment.

### *Equipment*

We used Palmaz-Genesis stents (Cordis, Johnson and Johnson) pre-mounted on a balloon catheter (length 18–29 mm). After deployment, stents were additionally dilated with high-pressure balloons. Distal stent margins were adapted using low-pressure balloons to obtain adequate dilatation and prevent stent migration. In one patient, when the diameter of the interatrial communication evaluated by TEE was 6 mm, and a stent with the nominal diameter of 8 mm was available, the stent was manually mounted on a 12 mm balloon catheter and dilated to 16 mm after deployment.

## RESULTS

In 7 patients with a stent implanted into the interatrial septum, mean left atrial pressure was reduced from 24.85 mm Hg to 14.86 mm Hg ($p < 0.004$), and mean interatrial pressure gradient was reduced from 13.14 mm Hg to 0.86 mm Hg ($p < 0.006$). Mean interatrial communication diameter increased from 4.14 mm to 10.57 mm ($p < 0.0001$; Table 1, Figs. 2, 3).

In one patient, during expansion of a 8 × 29 mm Palmaz-Genesis stent manually mounted on a low-pressure TYSHAK 12 × 30 mm balloon (Numed), the balloon was damaged, resulting in incomplete stent expansion. The stent was completely expanded using a high-pressure balloon, and after a stable position of the stent within the interatrial sep-

**Table 1.** Characteristics of patients with a secondary restriction of interatrial communication

| No. | Diagnosis | Age [months] | Stent size [mm] | IAC pressure gradient before Rx [mm Hg] | IAC diameter before Rx [mm] | LA pressure before Rx [mm Hg] | IAC pressure gradient after Rx [mm Hg] | IAC diameter after Rx [mm] | LA pressure after Rx [mm Hg] | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | HLHS after Stage I | 7 | 7 × 18 | 11 | 3 | 25/22/23 | 1 | 12 | 18/15/16 | Stent expanded to 12 mm during Stage I and to 14 mm during Stage II after 6 months |
| 2 | MV Atr. + DORV after PAB | 4 | 7 × 18 | 29 | 2 | 40/29/32 | 2 | 7 | 20/14/15 | After 2 Rashkind procedures |
| 3 | HLHS after Stage II | 30 | 8 × 29 | 6 | 6 | 20/17/19 | 0 | 15 | 13/12/13 | Stent expanded with a 16 × 30 mm balloon |
| 4 | HLHS after Stage I | 8 | 7 × 18 | 11 | 4 | 24/20/22 | 0 | 10 | 17/13/14 | Stent expanded with a 10 × 30 mm balloon |
| 5 | MV Atr. + VSD after PAB | 3 | 7 × 18 | 17 | 3 | 40/25/32 | 0 | 10 | 16/10/13 | After 2 static balloon atrial septostomies; stent expanded with a 12 × 20 mm balloon |
| 6 | MV Atr. + DORV + PS | 5 | 8 × 24 | 12 | 4 | 27/23/26 | 2 | 8 | 19/16/17 | After Rashkind procedure |
| 7 | HLHS after Stage II | 26 | 10 × 25 | 6 | 7 | 23/19/20 | 1 | 12 | 18/14/16 | Stent expanded with a 12 × 30 mm balloon |

Atr. — atresia; DORV — double outlet right ventricle; HLHS — hypoplastic left heart syndrome; IAC — interatrial communication; LA — left atrium; MV — mitral valve; PAB — pulmonary artery banding; PS — pulmonary stenosis; Rx — treatment; VSD — ventricular septal defect

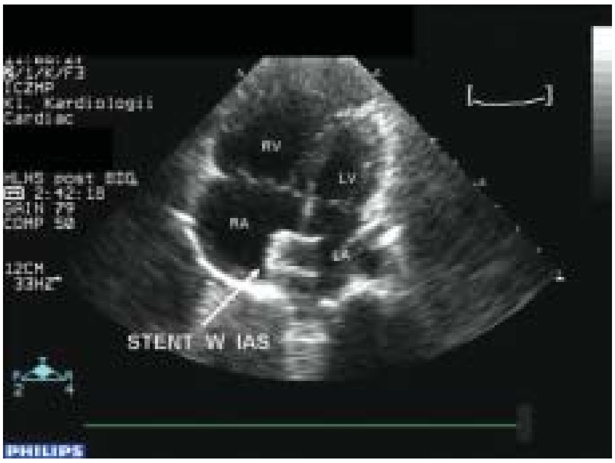


**Figure 2.** Transthoracic echocardiography, apical 4-chamber view, a patient with hypoplastic left heart syndrome after bidirectional Glenn procedure and stent implantation into the interatrial septum (IAS); LA — left atrium; LV — left ventricle; RA — right atrium; RV — right ventricle

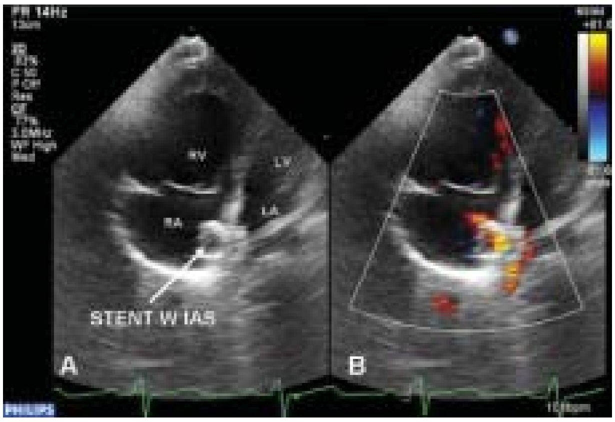


**Figure 3.** Transthoracic echocardiography, modified apical 4-chamber view. A stent can be seen within the interatrial septum (IAS); **A.** Two-dimensional image; **B.** Colour Doppler imaging of the flow through the implanted stent. For abbreviations see Figure 2

tum was secured, distal stent margins were additionally expanded using a 16 × 30 mm TYSHAK balloon catheter.

In 4 out of 7 patients, the stent was removed from the interatrial septum during the next stage of surgical treatment. A bidirectional Glenn procedure was performed in 3 patients, and a Fontan operation was performed in one patient. The time from the stent implantation to the surgical procedure ranged from 5 to 12 months (mean 7.7 months). The remaining 3 patients remain under ambulatory care awaiting for the next stage of surgical treatment (follow-up duration of 3, 6, and 38 months, respectively). No local and systemic complications were observed, and 24-h Holter monitoring revealed no arrhythmia or conduction disturbances.

## DISCUSSION

In patients with univentricular anatomy, historical criteria predicting the success of Glenn and Fontan procedures based on adequate development of pulmonary vasculature and low pulmonary resistance are still valid [1, 2]. Thus, it is obvious that restrictive interatrial communication that increases left atrial and pulmonary pressures is a significant adverse factor determining surgical outcomes in these children [3]. In patients with HLHS or mitral valve atresia, left atrial outflow may be impaired already during fetal life, resulting in changes in small pulmonary arteries and rendering these patients poor candidates for any palliative treatment after birth. Attempts to dilate restrictive atrial communication are thus undertaken already during fetal life or immediately after birth [4]. Effective treatment in this period includes Rashkind procedure and static balloon atrial septostomy [5–7].

The situation is somewhat different when a secondary restriction of interatrial communication develops in a child with univentricular anatomy. In these cases, the interatrial septum is usually stiff and thickenes, and the final result of static balloon atrial septostomy is difficult to predict, with usually rapid recurrence of restriction [7–9]. In this patient group, stent implantation into the restrictive atrial septal defect is a necessary procedure before bidirectional Glenn or Fontan procedure.

Our technique of stent implantation into the interatrial septum was initially described by Gewillig et al. [10]. The reported outcomes are good and provide durable unrestricted interatrial communication [8–13]. To stabilise the stent and prevent its migration, the stent margins were additionally expanded to a diameter larger than that of the created interatrial communication [10].

With the development of hybrid treatment methods in recent years, an increasing number of children undergo stent implantation into the interatrial septum already in the neonatal period. In contrast to conventional balloon atrial septostomy, stent implantation requires long-term anti-aggregation treatment. In our patients, we used acetylsalicylic acid for this purpose.

## CONCLUSIONS

1. Percutaneous stent implantation into the interatrial septum in children with univentricular heart successfully abolishes a secondary restriction of interatrial communication, leading to durable left atrial decompression and reducing the need for additional surgical treatment between subsequent procedures to create the Fontan circulation.
2. The stent implanted into the interatrial septum can be easily removed during the next stage of surgical treatment.
3. No local and systemic procedure-related complications were observed during and immediately after stent implantation.

***Conflict of interest:*** *none declared*


### References

1. Glenn WW, Patino JF. Circulatory by-pass of the right heart. I. Preliminary observations on the direct delivery of vena caval blood into the pulmonary arterial circulation; azygos vein-pulmonary artery shunt. Yale J Biol Med, 1954; 27: 146–151.
2. Fontan F, Baudet E. Surgical repair of tricuspid atresia. Thorax, 1971; 26: 240–248.
3. Atz AM, Feinstein JA, Jonas RA, Perry, SB, Wessel DL. Preoperative management of pulmonary venous hypertension in hypoplastic left heart syndrome with restrictive atrial septal defect. Am J Cardiol. 1999; 83: 1224–1228.
4. Galantowicz M, Cheatham JP, Phillips A et al. Hybrid approach for hypoplastic left heart syndrome: intermediate results after the learning curve. Ann Thorac Surg, 2008; 85: 2063–2070.
5. Rao PS. Static balloon dilatation of the atrial septum. Pediatr Cardiol, 1996; 17: 349–350.
6. Webber SA, Culham JA, Sandor GC, Patterson MW. Balloon dilatation of restrictive interatrial communications in congenital heart disease. Br Heart J, 1991; 65: 346–348.
7. Moszura T, Dryżek P, Michalak K, Sysa A. Zabieg przezskórnej dekompresji lewego przedsionka u ważącego 1700 g noworodka ze skrajną stenozą mitralną — opis przypadku. Post Kardiol Interw, 2008; 3: 119–121.
8. Pedra CA, Pihkala J, Benson LN, Freedom RM, Nykanen D. Stent implantation to create interatrial communications in patients with complex congenital heart disease. Catheter Cardiovasc Interv, 1999; 47: 310–313.
9. Pedra CA, Neves JR, Pedra SR et al. New transcatheter techniques for creation or enlargement of atrial septal defects in infants with complex congenital heart disease. Catheter Cardiovasc Interv. 2007; 70: 731–739.
10. Gewillig M, Boshoff D, Mertens L. Creation with a stent of unrestrictive lasting atrial communication. Cardiol Young, 2001; 12: 408–411.
11. Stumper O, Gewillig M, Vettukattil J et al. Modified technique of stent fenestration of the atrial septum. Heart, 2003; 89: 1227–1230.
12. Moszura T, Mazurek-Kula A, Dryzek P et al. Interventions complementing surgery as part of multistage treatment for hypoplastic left heart syndrome: one center's experience. Pediatr Cardiol, 2009; 30: 106–113.
13. Moszura T, Mazurek-Kula A, Dryżek P, Moll JA, Moll JJ, Sysa A. Postępowanie interwencyjne u dzieci z zespołem niedorozwoju lewego serca i podwyższonym ciśnieniem płucnym — doświadczenia jednoośrodkowe. Pol Przegl Kardiol, 2008; 3: 202–206.

# Implantacja stentu do przegrody międzyprzedsionkowej u pacjentów z sercem jednokomorowym i wtórną restrykcją połączenia międzyprzedsionkowego

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## Streszczenie

**Wstęp:** Restrykcyjne połączenie międzyprzedsionkowe u pacjentów z czynnościowo pojedynczą komorą znacząco wpływa na wynik leczenia chirurgicznego. W tej grupie pacjentów szerokie połączenie międzyprzedsionkowe prowadzi do obniżenia ciśnienia w tętnicy płucnej, które jest jednym z najważniejszych czynników warunkujących pomyślny przebieg zabiegu dwukierunkowego zespolenia sposobem Glenna i operacji Fontana. U niektórych osób, mimo skutecznego, interwencyjnego (zabieg Rashkinda) lub operacyjnego wytworzenia swobodnej komunikacji międzyprzedsionkowej, występuje nawrót restrykcji na poziomie przegrody międzyprzedsionkowej.

**Cel:** Celem pracy była ocena skuteczności i bezpieczeństwa implantacji stentów do przegrody międzyprzedsionkowej u pacjentów z czynnościowo pojedynczą komorą, u których doszło do wtórnej restrykcji połączenia międzyprzedsionkowego.

**Metody:** W latach 2006–2010 wykonano 7 zabiegów przezskórnego poszerzenia połączenia międzyprzedsionkowego z implantacją stentów. Pod względem hemodynamicznym pacjenci reprezentowali serce czynnościowo jednokomorowe, z systemową komorą prawą (4 dzieci z zespołem niedorozwoju lewego serca, 3 pacjentów z atrezją zastawki dwudzielnej). U wszystkich chorych narastanie restrykcji obserwowano mimo wcześniejszego interwencyjnego lub operacyjnego wytworzenia swobodnego połączenia międzyprzedsionkowego. Wiek dzieci w czasie implantacji stentu wynosił 3–30 miesięcy, maksymalny gradient ciśnienia na poziomie restrykcyjnego połączenia — 6–29 mm Hg, a wartość ciśnienia w lewym przedsionku — od 20/17/19 mm Hg do 40/29/32 mm Hg. Wszystkim pacjentom implantowano stenty Palmaz-Genesis (długość 18–19 mm).

**Wyniki:** W grupie 7 pacjentów ze stentem implantowanym do przegrody międzyprzedsionkowej uzyskano obniżenie wartości gradientu lewo-prawego ze średnio 13,14 mm Hg do 0,86 mm Hg ($p < 0,006$). Uzyskano także poszerzenie średnicy połączenia międzyprzedsionkowego ze średnio 4,14 mm do 10,57 mm ($p < 0,0001$).

**Wnioski:** Przezskórna implantacja stentu do przegrody międzyprzedsionkowej u dzieci z hemodynamicznie wspólną komorą skutecznie eliminuje wtórną restrykcję połączenia międzyprzedsionkowego, pozwalając na dekompresję lewego przedsionka; zmniejsza również konieczność dodatkowego leczenia operacyjnego. Stent implantowany do przegrody międzyprzedsionkowej może być w prosty sposób usunięty podczas kolejnego etapu leczenia operacyjnego. U pacjentów z czynnościowo pojedynczą komorą i wtórną restrykcją połączenia międzyprzedsionkowego implantacja stentu stanowi skuteczną i bezpieczną metodę terapii.

**Słowa kluczowe:** restrykcyjne połączenie międzyprzedsionkowe, czynnościowo pojedyncza komora, stent, leczenie interwencyjne

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