TABLE 1. Size of the clips suitable for pulmonary lobectomies

Right side lobectomies		Left side lobectomies	
Upper lobectomy			
Truncus anterior	Large clips	Truncus anterior	Large clips
Ascending (posterior/anterior)	Medium-large clips	Ascending (posterior/anterior)	Medium-large clips
Middle lobectomy			
Single artery (46%)	Medium-large clips		
Double artery (51%)	Medium-large clips		
Lower lobectomy			
Apical segmental	Medium-large clips	Apical segmental	Medium-large clips
Basal trunk	Large clips	Basal trunk	Large clips

branch could even result in its avulsion.³ Another risk is the failing alignment of the two jaws of the stapler, leading to incorrect positioning of the staples. Primary mechanical malfunction is also possible,^{3,4} and the placement of the stapler by the assistant is not easy during robotically assisted lobectomy.⁵ Last but not least, staplers are expensive (endo-vascular stapler + 1 cartridge = 479 euros in our hospital) compared with the cost of the Hem-o-lok clips (6-clip blister pack = 46 euros), and the applicator is free and reusable.

Considering the use of Hem-o-lok clips in pulmonary surgery, we found some favorable conditions. First, the pressure of the pulmonary artery is lower than that of the systemic arteries and the dissection of the lobar branches usually allows the surgeon to achieve a vessel length sufficient to place 3 clips and maintain a 1- to 2-mm cuff of vessel, which is highly recommended. Moreover, it is important to select the appropriate size of the clips to be used;

the clips cannot be smaller than the vessel, but should not be larger.

In conclusion, our preliminary experience suggests the utility of Hem-o-lok clips in minimally invasive pulmonary lobectomies. Further larger studies about reliability, safety, and cost-effectiveness are warranted.

References

1. Ponsky L, Cherullo E, Moinezhadeh A, Desai M, Kaouk J, et al. The Hem-o-lok clip is safe for laparoscopic nephrectomy: a multi-institutional review. *Urology*. 2008; 71:593-6.
2. Szwerc MF, Landreneau RJ, Santos RS, Keenan RJ, Murray GF. Minithoracotomy combined with mechanically stapled bronchial and vascular ligation for anatomical lung resection. *Ann Thorac Surg*. 2004;77:1904-9; discussion 1909-10.
3. Craig SR, Walker WS. Potential complications of vascular stapling in thoracoscopic pulmonary resection. *Ann Thorac Surg*. 1995;59:736-7; discussion 737-8.
4. Yim AP, Ho JK. Malfunctioning of vascular staple cutter during thoracoscopic lobectomy. *J Thorac Cardiovasc Surg*. 1995;109:1252.
5. Melfi FM, Mussi A. Robotically assisted lobectomy: learning curve and complications. *Thorac Surg Clin*. 2008;18:289-95.

The option of taking down the Fontan circulation: The Melbourne experience

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In recent years, dramatic early failure of the Fontan circulation has become exceedingly rare,¹ although there are occasional deaths in patients with large ongoing chest drain losses. Fontan takedown to a prior palliative state has been described to allow successful survival of these patients, but only limited information exists on the early and long-term results of this rescue procedure.²

CLINICAL SUMMARY

Between January 1980 and December 2007, 413 patients underwent a Fontan procedure at the Royal Children's Hospital, Melbourne. During this period, 14

TABLE 1. Patient characteristics

Diagnosis (predominant ventricular morphology)	Age at Fontan (y)	Type of Fontan	Timing of takedown (d)	Indication for takedown	Pulmonary artery pressure before takedown (mm Hg)	Ultimate palliation	Suspected reason for failure	Final outcome
AVSD (right)	1.8	Lateral tunnel (fenestrated)	0	Low output	11	Bilateral BCPS	Pulmonary venous obstruction	NYHA class III with severe atrioventricular valve regurgitation
PA-IVS (left)	3.4	Lateral tunnel (fenestrated)	0	Low output	20	BCPS with left BT shunt	Systemic- pulmonary collaterals	NYHA class I after successful re-do Fontan at 11 y
DORV (right)	19.7	Lateral tunnel (fenestrated)	0	Low output	30	BCPS	Elevated pulmonary vascular resistance	NYHA class I
TA (left)	4.4	Extracardiac conduit	0	Low output	Unknown	BCPS	thrombosis	NYHA class I after successful re-do Fontan at 2 y
PA-IVS (left)	3.4	Atriopulmonary	1	Low output	20	Central shunt	Elevated pulmonary vascular resistance	Hospital mortality
DILV-TGA (left)	6.8	Atriopulmonary	2	Low output	17	Aortopulmonary window	Systolic dysfunction	Hospital mortality
Primum ASD, left isomerism (left)	4.4	Lateral tunnel	2	Low output	25	BCPS (Kawashima)	Systolic dysfunction	NYHA class I
DILV-TGA (left)	4.9	Lateral tunnel (fenestrated)	13	Low output	Unknown	BCPS	Thrombosis	NYHA class III after successful BT shunt at 5 y
HLHS (right)	6.0	Extracardiac conduit (fenestrated)	67	Effusion	Unknown	BCPS	Diastolic dysfunction	Hospital mortality
TA (left)	5.0	Extracardiac conduit (fenestrated)	73	Effusion	17	Bilateral BCPS	Chylothorax	Hospital mortality
HLHS (right)	3.1	Extracardiac conduit	93	Effusion	16	BCPS	Pulmonary venous obstruction	NYHA class II
HLHS (right)	15.1	Extracardiac conduit (fenestrated)	163	Effusion	24	BCPS	Systemic- pulmonary collaterals	NYHA class II after successful coil embolization of collaterals
DORV (right)	4.0	Atriopulmonary	406	Effusion	Unknown	Aorta to left PA shunt	Chylothorax	Hospital mortality
AVSD (right)	6.3	Extracardiac conduit	458	Protein-losing enteropathy	18	BCPS with aorta to left PA shunt	Elevated central venous pressure	NYHA class I

NYHA, New York Heart Association; PA-IVS, pulmonary atresia with intact ventricular septum; DORV, double-outlet right ventricle; DILV-TGA, double-inlet left ventricle with transposition of the great arteries; AVSD, atrioventricular septal defect; HLHS, hypoplastic left heart syndrome; ASD, atrial septal defect; TA, tricuspid atresia; BCPS, bidirectional cavopulmonary shunt; BT, Blalock-Taussig; PA, pulmonary artery.

patients (3%) had their Fontan taken down to an intermediate palliative circulation (3/152 atriopulmonary connections, 6/105 lateral tunnels, and 5/156 of extracardiac conduits). The characteristics of these patients are pre-

sented in Table 1. The comparative characteristics of the overall cohort of patients who underwent a Fontan and patients who had their Fontan taken down are presented in Table 2.

TABLE 2. Comparative characteristics

	All Fontans (413 patients)	Takedown (14 patients)	P value
Age at Fontan (y), mean (SD)	6.2 (5.4)	6.3 (5.0)	.92
Male:female (%)	57.8%	64.3%	.63
Pre-Fontan PA pressure (mm Hg), mean (SD)	12.1 (3.3)	13.8 (3.0)	.02
Prior staging with BCPS, %	47.2%	57.1%	.59
Moderate or greater atrioventricular valve regurgitation, %	19.9%	35.7%	.17
Right ventricular dominance, %	50%	31.2%	.15

PA, Pulmonary artery; SD, standard deviation; BCPS, bidirectional cavopulmonary shunt.

RESULTS

In the initial period before 1990, 3 patients had their Fontan taken down to a systemic-pulmonary shunt. The remaining 11 patients had their Fontan taken down to a bidirectional cavopulmonary shunt (BCPS). Eight of the 14 patients (57%) had their Fontan circuit fenestrated. Before takedown, 1 patient with a lateral tunnel had a conversion to an extracardiac conduit, 1 patient underwent attempted creation of a 4-mm fenestration, 1 patient was supported on extracorporeal membrane oxygenation, and the remaining 2 patients underwent pleurodeses.

Hospital Mortality

There were 5 hospital deaths for an overall hospital mortality of 36%. All 3 patients with a takedown to a systemic-pulmonary shunt in the earlier era died within the first 2 postoperative days. Only 2 of the 11 patients (18%) with a takedown to a BCPS died. Takedown was performed in both patients because of persistent effusions, which persisted after the Fontan takedown. Hospital mortality was 60% (3/5 patients) when takedown was indicated for prolonged effusions, 25% (2/8 patients) for low-output syndrome, and 0% for pleural effusion (1 patient).

Follow-up

Complete follow-up was available in all 9 hospital survivors at a median duration of 9 years (2–11 years). There were no late deaths or cardiac transplantations. Two patients underwent an extracardiac fenestrated Fontan procedure 2 and 11 years after the takedown procedure, once reversible causes of failure were identified and treated. The first patient had thrombosis of his conduit and required pulmonary artery thrombectomy and reconstruction at the time of takedown. In the second patient, failure was attributed to the presence of systemic-pulmonary collaterals, which were embolized

percutaneously. Both patients were in New York Heart Association class I at last follow-up. The remaining 7 patients were left with a BCPS palliation and were in New York Heart Association class I (1), II (4), or III (2).

DISCUSSION

There are scant data on outcomes after Fontan takedown, and the indications for this rescue procedure remain obscure. The Boston team have reported their experience with 52 patients undergoing operations over a 27-year period. Their mortality decreased after 1990, a date that coincides with the introduction of fenestration and staging with BCPS. In our experience in the recent era, since we have started converting to a BCPS rather than a systemic-pulmonary shunt, we have not lost any patient undergoing operation for early hemodynamic instability. Only 2 of 5 patients who underwent operation for intractable effusions did not survive to discharge.

CONCLUSIONS

The number of patients presented in this article and by the Boston group remains small, making definitive conclusions difficult. One is left to subjective feelings to make decisions. Better indications for Fontan surgery have made takedown in this era rare, but prolonged effusions remain a recurrent issue. Early Fontan takedown for patients in low cardiac output is clearly an effective rescue measure. Fontan takedown performed later for prolonged large chest drain losses carries a higher mortality because it is usually performed when a patient's condition has considerably deteriorated; therefore, the ideal timing of takedown in this indication remains unclear. Because the mortality of those undergoing takedown is acceptable for this extreme situation and because surviving patients may expect durable survival, we suspect that takedown should be offered earlier rather than later. Late outcomes improved after reversible lesions were treated, and this report highlights once more that residual lesions should be aggressively sought. To prevent failure, we have already adopted a policy of systematic fenestration at the time of Fontan.³ Once the patency of the fenestration has been demonstrated, we believe that Fontan takedown should be offered for patients with prolonged effusions within 6 weeks, before their nutritional status deteriorates to the point where operative survival is impossible.

References

1. d'Udekem Y, Iyengar AJ, Cochrane AD, Grigg LE, Ramsay JM, Wheaton GR, et al. The Fontan procedure: contemporary techniques have improved long-term outcomes. *Circulation*. 2007;116(11 Suppl):I157-64.
2. Almond CS, Mayer JE Jr, Thiagarajan RR, Blume ED, del Nido PJ, McElhinney DB. Outcome after Fontan failure and takedown to an intermediate palliative circulation. *Ann Thorac Surg*. 2007;84:880-7.
3. Ruiz E, Guerrero R, d'Udekem Y, Brizard C. A technique of fenestration for extracardiac Fontan with long-term patency. *Eur J Cardiothorac Surg*. 2009;36:200-2.