Non-invasive Cardiac Output Monitoring during Catheter Interventions in Patients with Cavo-pulmonary Circulations

Birmingham Children's Hospital

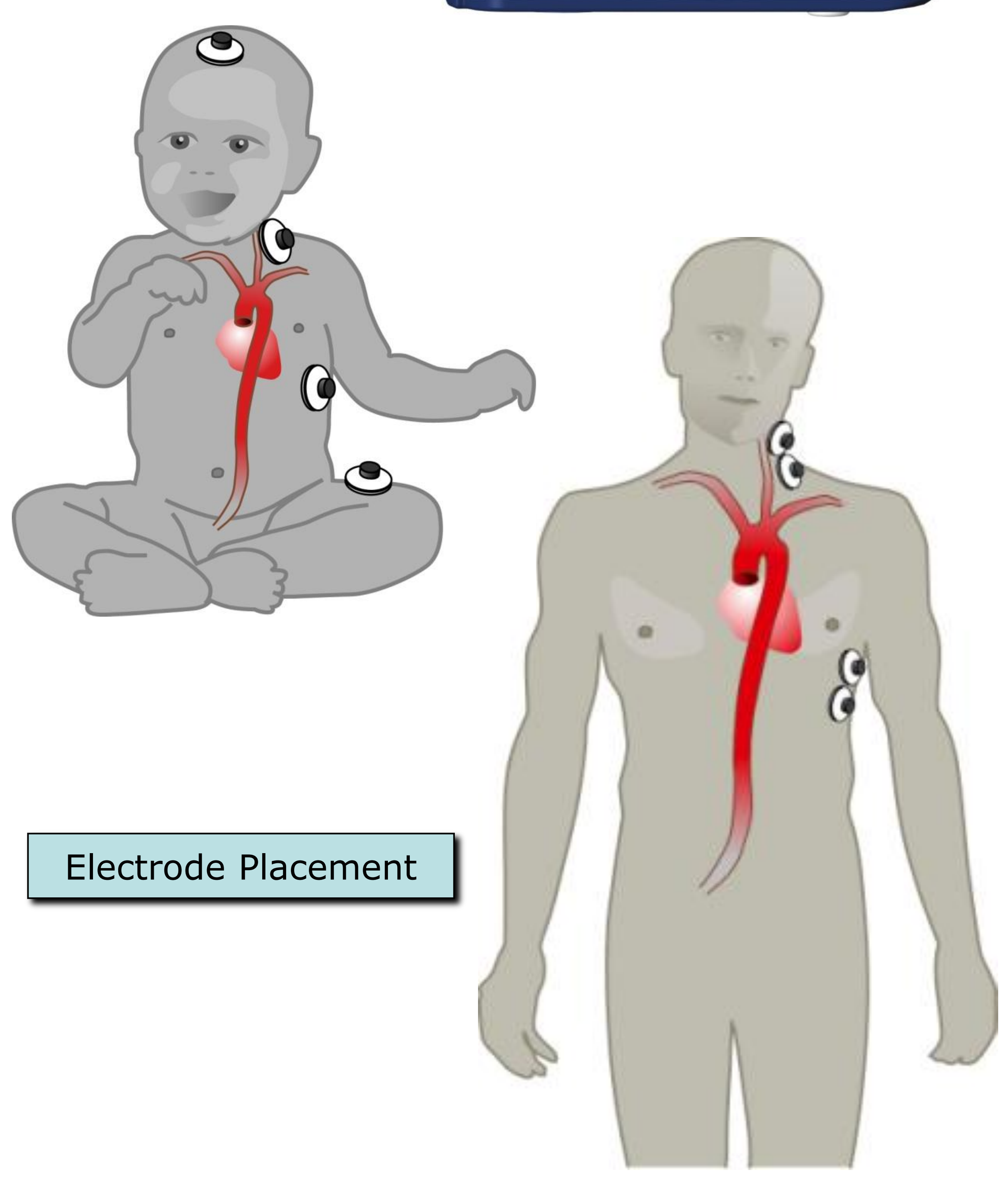
P.M.E. Noonan, S. Viswanathan, A. Chambers, J. Stickley, O. Stumper

The Heart Unit, Birmingham Children's Hospital - NHS Trust, Steelhouse Lane, Birmingham

Introduction

Electrical velocimetry (EV) uses changes in thoracic electrical bio-impedance to calculate cardiac output (CO) non-invasively. Recent studies have favourably compared EV to previously established invasive measurements of CO like thermodilution[1] and transoesophageal Doppler[2]. EV has also been shown to be comparable to CO measured using Fick principle in children with complex congenital heart disease[3].

EV is a non-invasive method that uses standard ECG surface electrodes placed on the patient. It measures the rate of change of thoracic bio-impedance which correlates to alignment of erythrocytes in the aorta during systole. Using the maximum rate of change of bio-impedance, the left ventricular ejection time and the patient's body mass, the stroke volume can be calculated. Other measures of contractility (Icon measurement, systolic time ratio (STR)) and fluid status (thoracic fluid index (TFI)) are also calculated. Measurements are continuous giving a real-time measurement of cardiac output .



Electrode Placement

Methods

We used an Icon® monitor (Osypka, Germany) to assess changes in CO during catheter interventions in ten patients with cavo-pulmonary connections. Nine patients had hypoplastic left heart syndrome post fenestrated Fontan and one had pulmonary atresia, intact ventricular septum and Glenn shunt (1.5 ventricle repair). Stroke volume (SV) was recorded during periods of stable heart rate before and after interventions and so was directly related to CO.

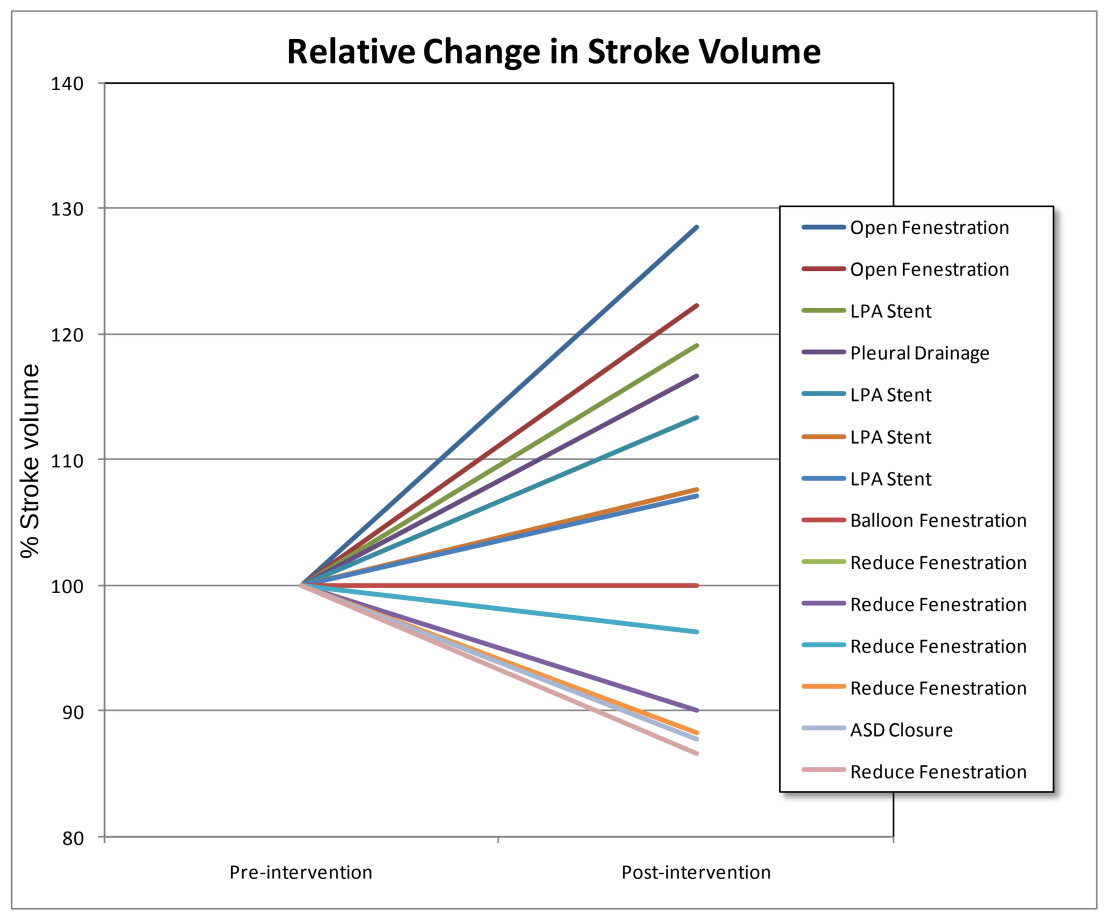
Ages ranged from 4.8-15.3 (median 6.1) years, weight was 15-63 (median 18.5) kg. All studies were carried out under GA and positive pressure ventilation.

Four patients underwent stenting for left pulmonary artery (LPA) stenosis. Six patients had partial or complete closure of Fontan fenestrations or ASD with right to left shunting. Four of these had partial occlusion of their Fontan fenestration using an Intrasept 0115S device (Cardia, MN). Another had reduction of a previous stent fenestration and the sixth had complete closure of an ASD with an Amplatzer Septal Occluder (AGA, MN). Three patients had procedures to increase their fenestration with two having a fenestration stent and the third was ballooned. One of the patients having stent fenestration had bilateral pleural drains inserted as part of the same procedure.

Results

All four patients who underwent stenting of LPA stenosis had an observed increase in SV and therefore CO post stent deployment. Increases in stroke volume ranged from 7 to 19% with a mean increase of 11.8%. All six patients who had partial or complete closure of an obligate right to left atrial shunt showed a decreased stroke volume post occlusion. Reduction in stroke volume ranged from 4% to 15% with a mean decrease of 11%. Creation of Fontan stent fenestration resulted in a marked increase in stroke volume (22% and 29% increase) in these two patients. There was no observed difference in SV in the patient who only had balloon dilation of fenestration. Insertion of pleural drains and removal of large pleural effusions showed a clear increase in SV and CO (16%).

		Stroke Volume (ml)		
Case	Intervention	Pre-intervention	Post-Intervention	% change
1	LPA stent	21	25	19%
2	LPA stent	15	17	13%
	Partial occlusion fenestration	17	15	-12%
3	Reduce stent fenestration	13.5	13	-4%
	Stent LPA	13	14	8%
4	Balloon fenestration	14	14	0%
	Stent LPA	14	15	7%
5	Partial occlusion fenestration	67	58	-13%
6	Partial occlusion fenestration	27	24	-15%
7	Partial occlusion fenestration	20	18	-10%
8	Close ASD	57	50	-12%
9	Pleural drainage	12	14	16%
	Open fenestration	14	18	29%
10	Open fenestration	18	22	22%



Change in pre/post-intervention stroke volume

Discussion

Changes in cardiac output have been previously reported with relation to manipulation of Fontan fenestrations[4]. The increased stroke volume seen in patients undergoing stent fenestration is likely to be related to an increased ventricular pre-load. Conversely the observed reduced stroke volume in patients with partial or complete closure of atrial R-L shunts is likely to be related to a reduced pre-load.

The changes seen in patients with cavo pulmonary connections undergoing LPA stenting have not been previously observed or reported. The most likely explanation for this finding is a reduction in afterload for the systemic ventricle in the context of a circulation in series. This would be supported by the wave-reflection theory. Further detailed studies are currently being undertaken. The observation clearly supports aggressive treatment of observed LPA stenoses after Fontan palliation.

Conclusion

Icon® is a novel monitoring technique ideally suited for use during interventional catheter procedures. Initial experience in patients with Glenn shunt and Fontan circulations is promising and provides new insights into the pathophysiology of the circulation in series.

References

1. Zoremba N; Bickenbach J; Krauss B; Rossaint R; Kuhlen R; Schalte G. Comparison of electrical velocimetry and thermodilution techniques for the measurement of cardiac output. Acta Anaesthesiologica Scandinavica, November 2007, 51/10(1314-9)
2. Schmidt C; Theilmeier G; Van Aken H; Korsmeier P; Wirtz SP; Berendes E; Hoffmeier A; Meissner A. Comparison of electrical velocimetry and transoesophageal Doppler echocardiography for measuring stroke volume and cardiac output. British Journal of Anaesthesia, 2005, 95(603-10)
3. Norozi K; Beck C; Osthaus WA; Wille I; Wessel A; Bertram H. Electrical velocimetry for measuring cardiac output in children with congenital heart disease. British Journal of Anaesthesia, 2008, 100 (88-94)
4. Ziyad M. Hijazi, MD; John T. Fahey, MD; Charles S. Kleinman, MD; Gary S. Kopf, MD; and William E. Hellenbrand MD. Hemodynamic Evaluation Before and After Closure of Fenestrated Fontan. An Acute Study of Changes in Oxygen Delivery. Circulation 1992;86;196-202