An alternate technique to pacing in complex congenital heart disease: Assessment of the left thoracotomy approach

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BACKGROUND: Pacing in children with congenital heart disease often requires alternate approaches to standard transvenous pacing. The surgical approach used to implant the pacemaker leads has been shown to impact lead survival. There is a paucity of pediatric literature describing the experience using a left thoracotomy approach.

OBJECTIVES: To report on short- and mid-term experiences with pacemaker implant via the left thoracotomy approach in children with complex congenital heart disease.

METHODS AND RESULTS: Data were abstracted retrospectively from patients' hospital charts. To date, the left thoracotomy technique has been used in 11 patients with complex heart disease, with a median of three prior cardiac operations. The median patient age was five years (range of two months to 23 years of age). The pacing indications were acquired postoperative atrioventricular block (n=5), sinus node dysfunction (n=5) and long QT syndrome (n=1). There were no intraoperative complications or long-term complications from this approach. The pacing thresholds at implant and follow-up were acceptable in all patients. One patient died in follow-up for reasons unrelated to the pacemaker or arrhythmia.

CONCLUSIONS: The placement of epicardial pacemaker leads via the left thoracotomy approach is a safe and effective alternative to transvenous pacing in pediatric patients with complex congenital heart disease.

Key Words: *Arrhythmia; Congenital heart disease; Pacemakers; Pediatrics*

Une autre technique pour remplacer l'électrode en cas de cardiopathie congénitale complexe : L'évaluation de la thoracotomie gauche

HISTORIQUE : L'installation d'une électrode chez les enfants atteints d'une cardiopathie congénitale exige souvent d'autres démarches que la voie transveineuse classique. Il est démontré que la démarche chirurgicale utilisée pour implanter les électrodes du stimulateur influe sur la survie des électrodes. Peu de publications pédiatriques décrivent l'expérience d'une thoracotomie gauche.

OBJECTIFS : Rendre compte d'expériences à court et à moyen terme de l'implantation d'un stimulateur cardiaque par thoracotomie gauche chez des enfants atteints d'une cardiopathie congénitale complexe.

MÉTHODOLOGIE ET RÉSULTATS : Les données ont été tirées rétrospectivement des dossiers hospitaliers de patients. Jusqu'à présent, la thoracotomie gauche a été utilisée chez 11 patients atteints d'une cardiopathie complexe, affichant une médiane de trois interventions cardiaques antérieures. L'âge médian des patients était de cinq ans (fourchette de deux mois à 23 ans). Les indications d'électrode étaient obtenues après l'opération d'un bloc auriculoventriculaire (n=5), d'une dysfonction du bloc sinusal (n=5) et d'un syndrome du QT long (n=1). On n'a remarqué aucune complication intraopératoire et aucune complication à long terme par suite de cette démarche. Les seuils d'électrode au moment de l'implantation et pendant le suivi étaient acceptables chez tous les patients. Un patient est décédé pendant le suivi, pour des raisons n'ayant rien à voir avec le stimulateur cardiaque ou l'arythmie.

CONCLUSIONS : L'installation d'électrodes de stimulation par thoracotomie gauche représente une solution sûre et efficace par rapport à l'électrode transveineuse chez les patients pédiatriques atteints d'une cardiopathie congénitale complexe.

In recent years, due to technical advances in size and programmability, device therapy has assumed an important role in the care of patients with congenital heart disease (CHD) (1). Most children that require pacing can have their pacemakers inserted using transvenous techniques, which have been shown to be both reliable and durable (2-5). However, there are several impediments to pacing a young child or a patient with complex structural heart disease. These include restricted venous access due to lead size (6), pre-existing venous occlusion (6-8) and the need for life-long pacing. As well, there have been reports of paradoxical emboli in CHD with right to left shunt (9). Patients with Fontan physiology may be at risk for developing pulmonary emboli with transvenous leads secondary to low flow state (1,10). When indicated, these patients require permanent epicardial pacing. Advantages to epicardial pacing in patients with complex CHD include placement at the time of reparative or palliative surgery (10). An epicardial approach can be complicated in patients with previous sternotomies or thoracotomies, and there are several different surgical approaches to the implantation of epicardial pacemakers (11,12). The advantages and disadvantages of these different approaches have been well described in the adult literature; however, there are fewer numbers of similar studies in the pediatric literature (11,13). We describe our experience with pacing via a left thoracotomy approach (LTA) in patients with complex CHD. Although this approach appears to be an accepted clinical practice, there are few reports describing the technique and its outcomes.

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Kucharczuk et al (14) has reported three cases of epicardial atrial lead placement via an LTA in children with hypoplastic left heart syndrome with good pacing thresholds at implant and follow-up. We report our short- and mid-term experience with lead placement via the LTA in a cohort of children and young adults with complex CHD.

METHODS

For the purposes of the present review, all patients with CHD who had undergone the insertion of a cardiac pacemaker via the LTA at British Columbia's Children's Hospital were included. Data were abstracted retrospectively from the patients' hospital charts. The operative notes and pacemaker follow-ups were evaluated, and patients' clinical information was recorded.

Operative technique

In older children and young adults, split-tube ventilation or the use of a bronchial blocker was used to facilitate exposure. An epidural catheter can be used to improve postoperative pain control, especially in older children and young adults. Antibiotic prophylaxis consisted of intravenous cefazolin or vancomycin. The patient was placed in the right lateral decubitus position with a slight tilt posteriorly, and the left chest was prepped and draped in a sterile fashion. A standard left anterolateral thoracotomy incision was performed; alternatively, a lateral thoracotomy incision, sparing the serratus anterior and the latissimus dorsi, may be performed. The chest was entered through the fifth intercostal space if there was no prior thoracotomy, or a higher intercostal space if there was a prior thoracotomy incision. Adhesions between the lung and chest wall were taken down to expose the pericardium, with care being taken to protect the phrenic nerve. The pericardium was incised longitudinally, reflected on stay sutures, and adhesions between it and the ventricle were taken down. Working posteriorly inside the pericardium, the left pulmonary veins and their connection to the left atrium were gradually exposed. This area is usually adhesion-free, as previously described by Kucharczuk et al (14). The atrial leads can be placed on the junction between the pulmonary veins and the left atrium, the left atrium or the left atrial appendage. This area is quite deep. Following testing of the atrial leads, the ventricular leads were placed on the ventricular epicardium, which had been previously exposed. The leads were then tunnelled either to a left subcostal pocket or a left subpectoral pocket. Steroid-eluting bipolar epicardial leads were used (Medtronic model 4968, Medtronic Inc, USA). The pericardium was left open, a chest tube was placed, and the chest and pacemaker pocket were closed in a standard fashion. The patient was returned to the intensive care unit or step-down unit for monitoring. The chest tube was usually removed the following day. Antibiotic prophylaxis was continued for 24 h postoperatively.

RESULTS

Patients

The LTA was first used in March 2002 and has been employed in 11 patients since that time, out of a total of 44 device implants in the same time period. These 11 patients requiring epicardial pacemaker insertion at British Columbia's Children's Hospital form the basis of the present report (Table 1). The median patient age was five years (range two months to 23 years of age), and the median weight was 20 kg (range 4.2 kg to 62 kg). All of these patients had undergone at least one cardiac surgical procedure before their pacemaker insertion; the mean number of cardiac surgeries before pacemaker insertion was 2.8 (range one to four). Primary diagnoses are shown in Table 1. Indications for pacemaker insertion included acquired postoperative atrioventricular block (n=5), sinus node dysfunction (n=5) and congenital long QT syndrome (n=1). In eight of 11 patients, pacemaker insertion was the primary operative procedure during the patient's admission. In the remaining three patients, pacemaker insertion occurred following a surgical repair of their CHD during the same admission, but during a separate operation. Patients have been followed for a mean of 21.3 months (range of five to 39 months) following pacemaker insertion.

Procedure

The LTA was successful in all 11 patients. There were no intraoperative complications. The total operating room time is reported because 'skin to skin' time could not be obtained. The mean operating room time was 2 h and 38 min (range 1 h 15 min to 3 h 15 min). In patients in whom pacemaker placement was the primary operation of admission, the mean length of stay in hospital after pacemaker placement was 5.5 days (range three to eight days). In patients in whom pacemaker insertion was as a result of the primary operation, the mean length of stay was 15 days (range 11 to 21 days). Postoperative complications included fever (n=1), urinary tract infection (n=2), respiratory infection (n=1) and pneumothorax not requiring chest tube placement (n=2). There were no wound infections and no postoperative blood transfusions required.

Pacing thresholds

The pacing thresholds at implant and follow-up can be found in Table 2. The mean ventricular pacing threshold at implant was 0.63 μJ (range 0.07 μJ to 2.0 μJ), and the mean atrial pacing threshold at implant was 0.59 μJ (range 0.03 μJ to 1.28 μJ). The mean ventricular pacing threshold at follow-up was 1.04 μJ (range 0.25 μJ to 2.41 μJ) and the mean atrial pacing threshold at follow-up was 0.37 μJ (range 0.03 μJ to 0.79 μJ).

There was one death during the follow-up period in a patient with Shone's anomaly (Table 1, patient 2). This patient had undergone four prior procedures, including a previous coarctation repair via a thoracotomy, and eventually required a mechanical mitral valve. The patient had recurrent respiratory infections and elevated pulmonary vascular resistance, and died of respiratory failure. The death was not arrhythmic. With the exception of this patient, all of the other patients were doing well at follow-up and have had no device-related complications or recurrent arrhythmias.

DISCUSSION

The literature suggests that the surgical technique used for pacemaker lead implantation is one of the key factors that correlate with lead survival (1). Greater lead survival reduces the frequency of intervention and thus directly impacts on patient health and welfare, especially in those with complex CHD who will be exposed to multiple surgical interventions (15). Despite the importance of the surgical approach, this subject has not been fully explored in the pediatric pacing literature. The LTA is not a novel approach. Rather, it has become one of the viable alternates in this complex population. This approach is particularly beneficial in patients in whom a previous

TABLE 1
Patient information

Patient	Age at implant	Cardiac diagnoses	Cardiac surgical history	Prior cardiac procedures	Indication for pacing	Rhythm at implant time
1	5 years	TGA intact septum, SubPS	BT; Mustard, SubPS resection, MV repair; Redo mustard; LAV valve replacement	4	APB	Complete heart block, paroxysmal atrial fibrillation
2*	14 months	Shone's anomaly: CoA, MS, subaortic stenosis bicuspid aortic valve	CoA repair; Redo CoA repair; Resection supravalvular mitral ring; MV replacement	4	APB	Complete heart block, accelerated idioventricular rhythm
3	9 months	ToF	ToF repair	1	APB†	Sinus rhythm/accelerated junctional rhythm
4	10 years	PA, intact septum	BT; BDG; Fontan	3	SND†	Junctional bradycardia
5*	3 years	Hypoplastic left heart	Norwood, BT revision; BDG; Fontan	3	SND†	Atrial flutter
6	2 months	VSD	VSD repair	1	APB	Complete heart block with junctional escape
7	10 years	TA, VSD, subaortic stenosis	PA banding; BDG; Fontan	2	SND†	Sinus bradycardia with premature atrial beats
8*	23 years	TA, PS	RBT; LBT; Fontan; PA arterioplasty, Redo BT	4	SND, IART†	Sinus bradycardia
9*	5 years	Unbalanced AVSD, TGA, PA, AV valve incompetence	BT shunt; BDG; Fontan	3	APB†	Junctional bradycardia
10*	5 years	DILV	BDG; Fontan	3	SND†	Junctional bradycardia
11	4 years	ToF	ToF repair	1	Long QT†	Sinus rhythm, intermittent torsade de pointes

**Follow-up duration below mean; †Pacemaker implantation was primary operation of admission. APB Acquired postoperative heart block; AV Atrioventricular; AVSD Atrioventricular septal defect; BDG Bidirectional Glenn; BT Blalock-Taussig shunt; CoA Coarctation of the aorta; DILV Double inlet left ventricle; IART Intra-atrial re-entrant tachycardia; L Left; LAV Left atrioventricular; MS Mitral stenosis; MV Mitral valve; PA Pulmonary atresia; PS Pulmonary stenosis; R Right; SND Sinus node dysfunction; SubPS Subpulmonary stenosis; TA Tricuspid atresia; TGA Transposition of great arteries; ToF Tetralogy of Fallot; VSD Ventricular septal defect*

sternotomy introduces increased risk to the procedure, access to the atrium is difficult, or previous atrial surgery compromises the ability to pace and sense the atrium. These factors frequently coexist in pediatric patients with complex heart disease. Despite this, there are few reports of its overall effectiveness in the pediatric literature. In a retrospective cohort of 123 pediatric patients studied over the course of 17 years, Cohen et al (1) reported the results of 22 atrial and 38 ventricular leads placed via LTA. In this series, the thoracotomy approach was compared with lead placement using a sternotomy and subxiphoid approach. In comparison with the other approaches, the thoracotomy approach was not very successful in terms of long-term lead survival. Freedom from lead failure at one and 10 years for the thoracotomy approach was 94.1 % and 62.4%, respectively; for sternotomy, 93.9 % and 75.9%, respectively; and for subxiphoid, 100% and 100%, respectively. Although the absence of lead failure in the subxiphoid approach appears to be a deterrent from the thoracotomy approach, the authors comment that it is difficult to access the atrium from a subxiphoid approach, and indeed only four of 29 leads were atrial. Atrial pacing is essential in this group with sinus node dysfunction and atrial arrhythmias. Interestingly, unlike our patients, not all of the patients in that study had structurally abnormal hearts. Villain et al (16) reported success in terms of pacemaker survival in a cohort of 30 neonates and infants in whom the electrodes were implanted via a thoracotomy. In contrast with our report, that study looked at very young children, ranging in age from one day to 20 months, in whom anatomical barriers to a sternotomy may differ from our older, complex patients with multiple previous surgeries.

We have reported our experience with inserting epicardial pacing leads via the LTA in patients with complex CHD with minimal morbidity and no procedure- or device-related mortality. The postoperative course, pacing thresholds and rate of device and lead complications are comparable with other approaches. Given the minimal complications and good pacing thresholds achieved at implant and mid-term follow-up, we have found that it is a safe and efficacious surgical technique.

The retrospective nature of our study introduces some limitations. For example, we were not able to determine

TABLE 2
Ventricular and atrial pacing thresholds at implant and follow-up

Patient	Ventricular at implant (μJ)	Atrial at implant (μJ)	Ventricular at follow-up (μJ)	Atrial at follow-up (μJ)
1	0.45	1.23	0.51	0.03
2	0.86	0.63	0.32	0.51
3	0.27	0.45	0.41	0.31
4	0.35	0.17	1.73	0.36
5	0.91	1.28	2.41	0.56
6	0.21	0.17	0.30	0.16
7	0.13	0.86	2.17	0.57
8	2.00	0.03	2.34	0.79
9	1.50	0.49	0.25	0.23
10	0.15	0.11	0.66	0.21
11	0.07	1.04	0.35	0.78
Mean	0.63	0.59	1.04	0.37
Median	0.35	0.49	0.51	0.41
Range	0.07–2.0	0.03–1.28	0.25–2.41	0.03–0.79

accurate operative times. However, given that our patients had a number of previous procedures and may have had difficult dissection and vascular access, these times may be misleading. Furthermore, our sample size was small, which limits our ability to generalize the results. Moreover, our follow-up was relatively brief and generator changes have not occurred.

CONCLUSION

A growing number of children with complex congenital heart lesions are requiring pacemakers. We have found that for our group of patients in whom transvenous pacing was not feasible or practical, the placement of epicardial pacing leads using the LTA is a safe and viable alternative.

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