Permanent Cardiac Pacing in Pediatrics: Experience in Thailand

Jarupim Soongswang MD*,
Apichart Nana MD*, Duangmanee Laohaprasittiporn MD*,
Kritvikrom Durongpisitkul MD* Prakul Chanthong MD*,
Burin KhaoSa-Ard BEd**, Kesaree Punlee BSc**,
Charuwan Kangkakate MSc***, Suthipol Udompunturuk MSc***

** Division of Cardiology, Department of Pediatrics, ** Her Majesty Cardiac Center,*
**** Clinical Epidemiology Unit, Office of Research Promotion, Faculty of Medicine, Mahidol University*

Permanent cardiac pacing in pediatrics is uncommon. There has been limited data in Thailand. A retrospective study of cardiac data and pacing parameters during follow-up periods in patients who underwent permanent pacemaker implantation at the Department of Pediatrics, Siriraj Hospital, from January 1997 to December 2004 was conducted. There were 31 patients in total who have been followed-up for the median period of 34.4 (1.07-91.13) months. All patients had atrio-ventricular block prior to implantation. The etiology were; post cardiac surgery 38.7%, maternal autoimmune diseases 19.4%, post radiofrequency ablation 3.2%, and unknown 38.7%. Twenty three cases (74.2%) were implanted by epicardial approach, and 18(25.8% were implanted by endocardial approach. Modes of permanent pacemaker were VVIR 45.2%, VVI 35.5%, and DDD 19.4%. Age and body sized of the patients using epicardial approach were significantly lower than endocardial approach. Minor complications occurred in 3 cases (9.6%) i.e. 2 with surgical wound infection, 1 with post pericardiotomy syndrome. Minimum energy threshold, sensitivity, and impedance at implantation and during follow up periods were not different statistically. There was significantly less in minimum energy threshold of endocardial lead than epicardial lead. Epicardial lead failure was found in 3 cases (11.5%) at the median time of 8.9 (7.9-62) months post implantation, but was not significant different from endocardial leads. Survival of epicardial leads were 82% at 8 years.

Conclusion: *Permanent pacemaker implantation in pediatrics was rare (4.4 cases/year). It was feasible in almost all body size and a rather safe procedure. There was no significant change in pacing parameters at the medium term follow-up period for both epicardial and endocardial leads. Minimum energy threshold of epicardial lead was significantly higher than endocardial lead.*

Keywords: *Permanent pacemaker, Atrio-ventricular block*

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The development of pacemaker technology has reduced morbidity and mortality from atrio-ventricular block in children. Pediatric patients that require permanent pacemaker implantation are rare; accounting for about 1% of all patients with pacemaker(1). The major indications for this procedure are atrio-ventricular block post surgery for congenital HD; accounting rate around 1%, and congenital or autoimmune complete heart block; occurring rate of 1:20,000 live births(1,2). Most patients received epicardial lead pacing system because of the small body size and complex cardiac anatomy. These leads have a shorter longevity compared to endocardial leads due to increasing stimulation threshold over a period of time(1). Advances in pacemaker technology allow children to benefit from a variety of development, i.e., smaller pulse generator, steroid-eluting epicardial lead, and improved diagnos-

Correspondence to: Jarupim Soongswang, MD, Division of Cardiology, Department of Pediatrics, Faculty of Medicine, Mahidol University, 2 Prannok Rd, Bangkoknoi, Bangkok, Thailand, 10700. Tel: 02-419-7000 ext. 5672, Fax: 02-411-3010. E-mail: sijsw@mahidol.ac.th

tic and therapeutic pacemaker algorithms. Permanent cardiac pacing in children is always a challenge due to anatomical abnormality, difficulty in accessing to cardiac chambers, and small patients size. Most children with permanent pacemaker implantation require pacing throughout their lives. As a result, consideration for venous access and future pacing system replacement is important. In Thailand, there has been limited cardiac pacing data in children.

Material and Method

Retrospective review of medical records of every pediatric patient who had permanent pacemaker implantation and followed-up at Siriraj Hospital, Mahidol University, Bangkok, Thailand, from January 1997 to December 2004 was performed. Demographic data, pacing data at implantation and at each clinic visit (at 3 months, 6 months, and annually up to 5 years and the most recent follow-up), complications of implantation, history of leads failure, and end of generators (batteries) were analyzed. Minimum energy threshold (MET) of cardiac pacing leads was calculated according to the previous report[3] in order to standardize the measurement of stimulation thresholds.

$$\text{MET (microjoules)} = \frac{V^2 \text{ X pulse width (ms) X } 106}{\text{Impedance (Ohm) X } 1000 \text{ ms/s}}$$

V = Energy threshold (volt)

Statistical analysis

All values are presented as median (range). Non parametric test, i.e., Wilcoxon Signed Rank test was used to analyze the significant difference between the 2 groups at different follow-up periods. Mann-Whitney U test was used if the 2 groups were independent. Time to lead and battery change after the first implantation was analyzed by survival technique (Kaplan-Meier) and the 2 survival curves were tested for significance by Log-Rank test. A p-value < 0.05 is considered as significant difference.

Results

There were 31 pediatric patients (< 15 years old) underwent permanent pacemaker implantation from January 1997 to December 2004 (Figure 1). Boys accounted for 64.5%. All of them had atrio-ventricular block. Presenting symptoms were congestive heart failure (54.8%), near syncope and syncope (38.7%), and cardiogenic shock (6.5%). Fifty two percent had congenital heart diseases. Etiology of atrioventricular block were post cardiac operation 12 cases (38.7%), maternal autoimmune diseases 6 cases (19.4%), post radiofrequency ablation 1 case (3.2%) and unknown 12 cases (38.7%). Twenty three cases (74.2%) were implanted by epicardial approach and the rest were implanted by endocardial (transvenous) approach. Modes of permanent pacemaker function were VVI* in 11 cases (35.5%), VVIR* in 14 cases (45.2%), and DDD* in 6 cases (19.4%). There were 26 epicardial leads and 11 endocardial leads implanted. Age, weight, and length or height of patients who have had epicardial leads implanted were significantly lower than the ones who had endocardial leads implanted ($p < 0.001$). Complications occurred in 3 cases; 2 cases with infected surgical wound, and 1 case with post pericardiotomy syndrome. Minimum energy threshold (MET) of both epicardial and endocardial leads at implantation and follow-up periods as well as sensitivity and impedance were shown in Figure. 2 and Table 3, respectively. There were 6 cases who had sinus rhythm resumed at the median time of 2.5 (0.3-12.0) months (Table 2). In these cases, the QRS duration on electrocardiogram prior to implantation, causes of heart block, and cardiac surgery, did not affect in the recovery of atrio-ventricular conduction ($p = 0.648$, $p = 0.199$, and $p = 0.522$, respectively). Epicardial lead failure was found in 3 patients at the median time of 8.9 (7.8-62) months post permanent pacemaker implantation. Eight year survival rate of epicardial lead was 82% (Figure 3) which was not significantly different from endocardial lead.

*According to the North America Society of Electrophysiology (NASPE) and the British Pacing and Electrophysiology Group (BPEG): 4 letters represent chamber paced, chamber sensed, mode of response, and programmable/rate.

Discussion

Cardiac pacing is a crucial intervention to maintain adequate hemodynamic status and resulted in good quality of life. The patients who are benefit form this procedure are patients with atrioventricular block, sick sinus syndrome, and some patients with hypertrophic cardiomyopathy, left ventricular dysfunction, and with vasovagal syncope. The most important part of permanent pacing is the appropriate time to implant, mode of pacing and setting parameters for each individual patient.

The number of patients requiring permanent cardiac pacing was about 0.8% of new cardiac patients in Siriraj Pediatric Cardiology Unit. Every patient had indication of atrio-ventricular block, and the main cause

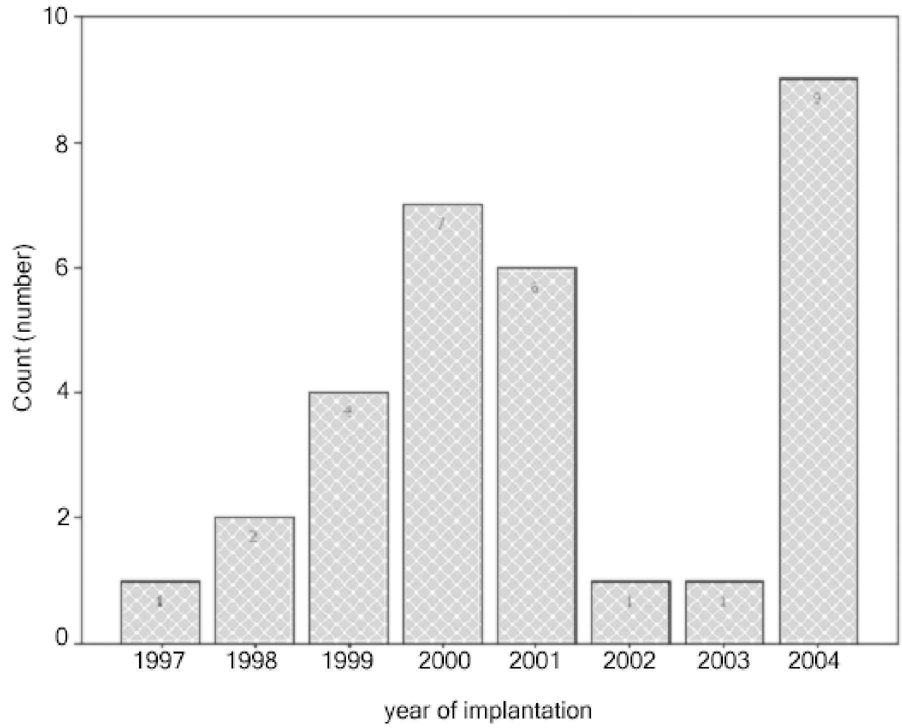

Fig. 1 Number of patients underwent permanent pacemaker implantation per year during 1997-2004

Table 1. Demographic data and pacing parameters at first implantation of pediatric patients

Parameter	Median (min-max)
Age at PPM* implantation (yr)	3.77 (0.00-18.00)
Age at PPM* epicardium route (yr)	2.42 (0.00-11.20)
Age at PPM* endocardium route (yr)	12.46 (.92-15.00)
Ventricular rate prior to implant (bpm)	51.00 (30-80)
Wt at first implantation of epicardium (kg)	11.00 (2.2-19)
Wt at first implantation of endocardium (kg)	33.25 (21-55)
Ht at first implantation of epicardium (cm)	80.50 (47-122)
Ht at first implantation of endocardium (cm)	140.50 (125-163)
Implantation	
Threshold of epicardial leads (volt)	1.00 (0.40-3.40)
Threshold of endocardial leads (volt)	0.50 (0.40-1.10)
Pulse width of epicardial leads (ms)	0.40 (0.12-1.20)
Pulse width of endocardial leads (ms)	0.45 (0.40-0.58)
Sensitivity of epicardial leads (mv)	10.80 (4.80-25.00)
Sensitivity of endocardial leads (mv)	9.70 (6.8-11.2)
Impedance of epicardial leads (Ohm)	494 (205-760)
Impedance of endocardial leads (Ohm)	537 (384-900)
Setting upper rate (bpm)	130 (120-170)
Duration follow up (months)	34.4 (1.07-91.13)

*PPM; permanent pacemaker

Table 2. Underlying heart rhythm at implantation and follow-up periods

Underlying	At implant No (%)	3 mo No (%)	6 mo No (%)	1 yr. No (%)	2 yr. No (%)	3 yr. No (%)	4 yr. No (%)	Most recent FU. No (%)
CHB*	24 (77.4)	17 (54.8)	16 (51.6)	12 (38.7)	12 (38.7)	8 (25.8)	7 (22.6)	23 (74.2)
Mobitz 2	7 (22.6)	1 (3.2)	2 (6.4)	1 (3.2)	-	1 (3.2)	1 (3.2)	1 (3.2)
Sinus rhythm	-	7 (22.6)	6 (19.4)	8 (25.8)	5 (16.1)	4 (12.9)	2 (6.4)	6 (19.4)

*CHB; complete heart block

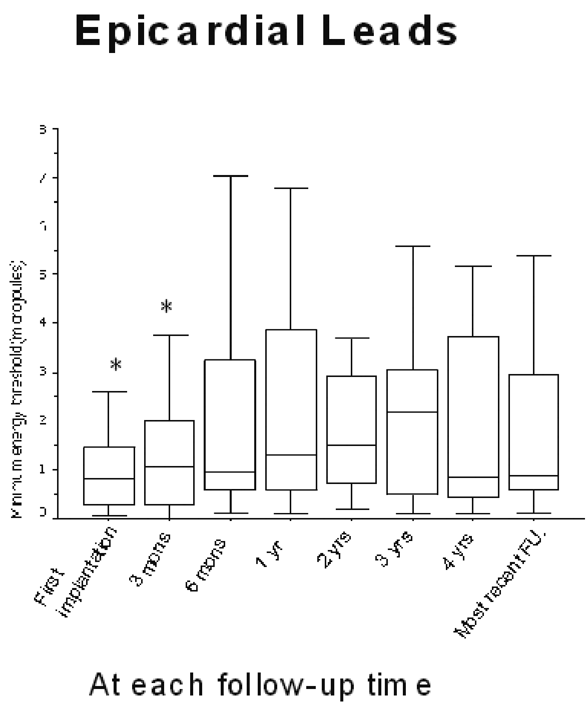

Fig. 2a Minimum energy threshold (MET) of epicardial leads at implantation and follow-up periods**;** * compare to each other; p value = 0.025

was post cardiac surgery. This was comparable to the other studies. Other indications for this procedure included sinus node dysfunction, after anti-arrhythmic drugs and reflex anoxic seizure[4,5]. Improved surgical techniques and better understanding of the anatomy of the cardiac conduction system have lowered the absolute risk of post surgical atrio-ventricular block to 1-2%[6]. Unknown etiology was high (38.7%) in this study which might be due to delayed presentation and diagnosis which could have resulted in the disappearance of the real culprit. About eighty percent of our patients had single chamber pacemaker (VVI or VVIR). It had been shown that it was unnecessary to establish atrial synchrony in young patients who had intrinsic normal ventricular function[7]. The majority of the patients in this study had epicardial leads (74.2%) which was also reported in other studies[5,8]. There were criteria to consider for endocardial lead, i.e., age 4 years or more, body weight $\geq$ 15 kg, no right to left intracardiac shunt, adequate superior vena cava to right atrium communication, and no simultaneous cardiac surgery[9]. Development of smaller transvenous (endocardial) lead

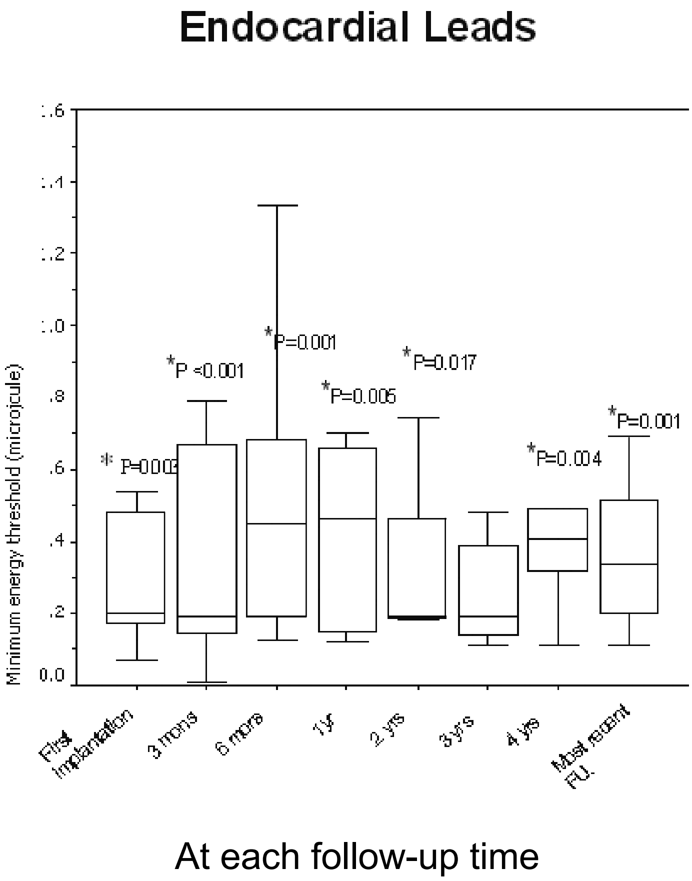

Fig. 2b Minimum energy threshold (MET) of endocardial leads at implantation and follow-up periods; there was no significant difference of MET at each follow-up period
*MET of endocardial leads significantly less than epicardial leads

and pacemaker generator had make the implantation of endocardial leads in smaller patient successful without the increase in morbidity, e.g., vein thrombosis, lead dislocation, fracture and growth related problems[10,11]. However, there was no endocardial lead for neonate and infant [12].

This study showed that the minimum energy threshold of epicardial leads was significantly higher than endocardial leads, supported by the previous studies by Kerstjens-Fredrikse MWS[1] and Sachweh JS[5]. Fibrosis, tissue debris, or scar tissue especially in post cardiac surgery patients were part of the reasons. However, this study found that the time to end of battery life was not different between the epicardial and endocardial leads pacemaker system. The reason was that the energy depletion depended on many factors other than minimum energy threshold such as the percentage of pacing and sensing, the dual or single chamber system, the demanding heart rate, etc. Fracture or insulation break of epicardial lead was found in 3 cases (9.7%). This complication was reported in 4% in the study by Horenstein MS.[13]. Epicardal lead survival in this study was about 82% at 8 years which was comparable to the other studies[4]. Steroid eluting epicardial leads usage in our institution helped improve lead survival[14]. However, better surgical technique may overcome this problem.

Two cases (6.4%) developed superficial and deep surgical wound infection but did not require system removal. This was closed to the number reported by other study; 4.9% superficial wound infection, 2.4% deep surgical wound infection and 0.3% requiring system removal[10]. Post pericardiotomy syndrome was also found in 1 case (3.2%). There was a report of 2% in children who underwent endocardial and epicardial pacemaker implantation and later developed post peri-

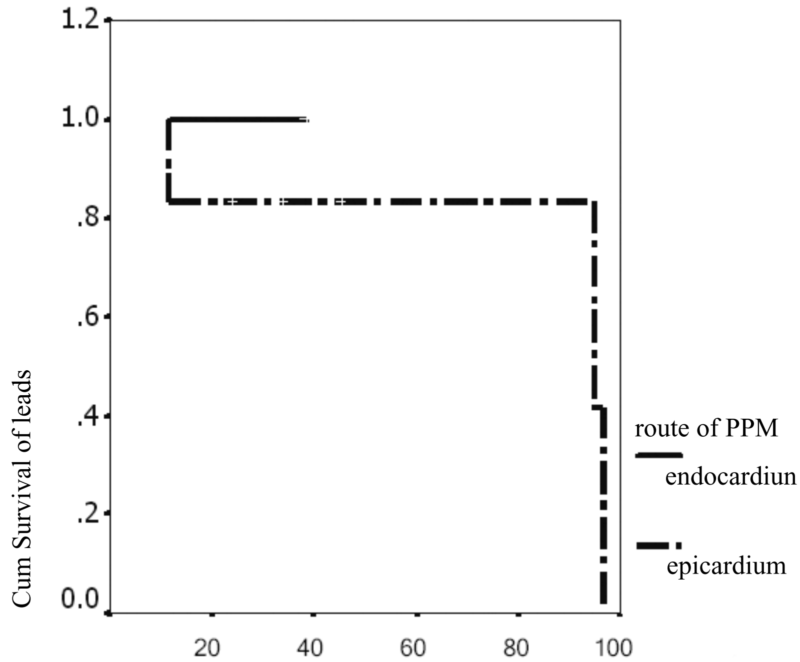

Fig. 3 Survival curve of epicardial and endocardial leads

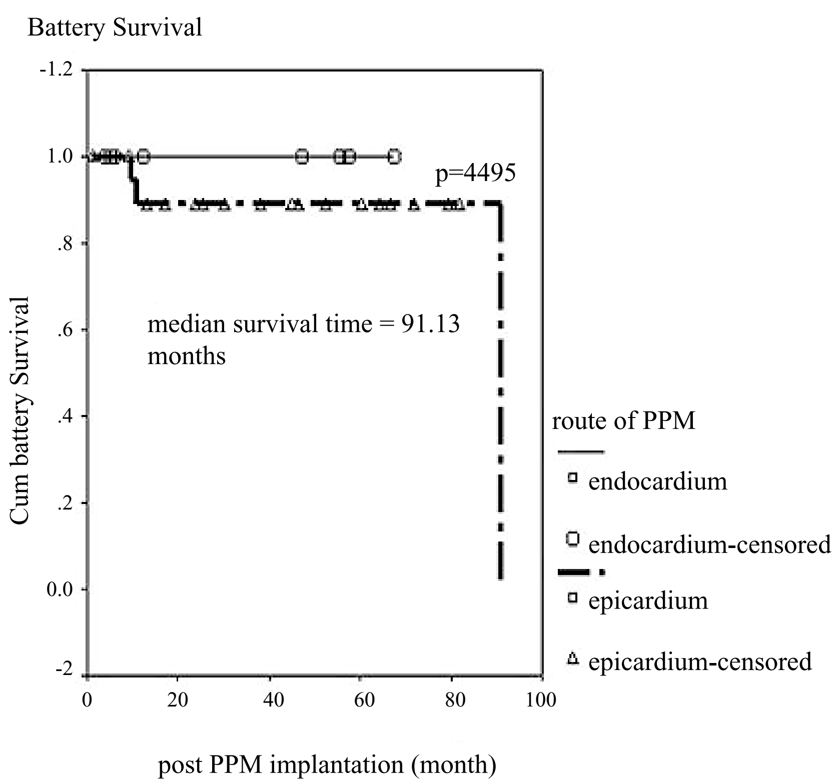

Fig. 4 Survival curve of generator's battery of permanent pacemaker

Table 3. Sensitivity and impedance of epicardial and endocardial leads at implantation and follow-up periods

Parameter	Implant	3 mo	6 mo	1 yr.	2 yr.	3 yr.	4 yr.	Mostrecent FU.	p value*
1. Epicardial									
1.1 Sensitivity (ventricle)	10.8 (4.8-2.5)	10.8 (5-15.8)	10.2 (5.0-15.8)	11.2 (4.0-15.8)	11.2 (3.8-22.0)	2.8 (1.2-5.6)	11.2 (5.0-22.4)	11.2 (3.3-13.0)	0.470
1.2 Impedance (atrium + ventricle)	520 (205›760)	424 (243-594)	443 (250-549)	407 (287-536)	407 (256-523)	427.5 (343-578)	443 (309-502)	442 (259-820)	0.296
2. Endocardial									
2.1 Sensitivity (ventricle)	9.7 (6.8-11.2)	10.5 (8-14.4)	11.2 (9.0-13.3)	11.2 (9.0-12.5)	-	2.8 (2.5-2.8)	13.2 (10.0-16.5)	11.2 (8.0-16.4)	0.225
2.2 Impedance (atrium + ventricle)	537 (384-900)	507 (410-1050)	590 (436-850)	570 (436-850)	526 (512-540)	511 (500-672)	618 (520-910)	509.5 (437-950)	0.260

* compare at implantation and at the most recent follow-up

cardiotomy syndrome[15]. Prophylactic lead placement had been shown to be successfully placed and retrieved in a subset of children who would have required pacing at a later date, e.g., surgical correction for corrected transposition of great arteries, modified Fontan operation, etc.[16] This study had 6 cases who had sinus rhythm resumed at the median post implantation time of 2.5 months. However, the atrio-ventricular conduction might not be as efficient as normal. Furthermore, they still needed cardiac pacing back up especially when there was an increase in sinus rate due to incomplete recovery of atrio-ventricular node function.

There has been a concern about left ventricular dysfunction resulted from chronic asynchronous contraction of both ventricles from right ventricular apex pacing[17]. Septal site of right ventricular pacing was demonstrated to have better left ventricular function[18]. Fortunately this problem did not occur within immediate or medium-term follow-up.

Conclusion

Cardiac pacing in pediatric is quite a safe procedure and feasible in all age group and in almost all patient sizes. There was no significant change in pacing parameter of epicardial and endocardial leads at medium-term follow-up period. Minimum energy threshold of epicardial leads was significantly higher than endocardial leads. Survival of epicardial leads were 82% at 8 years.

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การใช้เครื่องกระตุ้นการเต้นหัวใจแบบถาวรในเด็ก: ประสบการณ์ในประเทศไทย

จารุพิมพ์ สูงสว่าง, อภิชาติ นานา, ดวงมณี เลาหประสิทธิพร, กฤตย์วิกรม ดุรงค์พิศิษฏ์กุล, ประคัลภ์ จันทร์ทอง, บุรินทร์ ขาวสะอาด, เกษรี ปั้นลี้,จารุวรรณ คังคะเกตุ, สุทธิพล อุดมพันธุรักษ์

การใช้เครื่องกระตุ้นการเต้นหัวใจแบบถาวรในเด็กมีน้อยและมีข้อมูลจำกัดในประเทศไทย ได้ศึกษาย้อนหลังข้อมูลเกี่ยวกับการทำงานของเครื่องกระตุ้นการเต้นหัวใจของผู้ป่วยเด็กทุกรายที่มารับการดูแลรักษาที่หน่วยโรคหัวใจ ภาควิชากุมารเวชศาสตร์ รพ.ศิริราช ระหว่างมกราคม พ.ศ.2540 ถึงธันวาคม พ.ศ.2547 พบว่ามีผู้ป่วยทั้งหมด 31 ราย ระยะเวลาในการติดตาม 34.4 (1.07-91.13) เดือน ผู้ป่วยทุกรายมีปัญหา atrio-ventricular block ก่อนได้รับการใส่เครื่องกระตุ้นการเต้นหัวใจ โดยมีสาเหตุจากหลังผ่าตัดหัวใจ 38.7% มารดาเป็นโรคภูมิต้านทานตัวเอง 19.4% หลังการจี้ด้วยคลื่นวิทยุ 3.2% และไม่ทราบสาเหตุ 38.7% ผู้ป่วย 23 ราย (74.2%) ได้รับการใส่เครื่องกระตุ้นโดยใช้ epicardial lead ที่เหลือ 8 ราย ได้รับการใส่โดยใช้ endocardial lead โดยเลือกใส่ชนิดของ pacemaker เป็น VVIR 45.2%, VVI 35.5% และ DDD 19.4% พบว่าอายุและขนาดตัวเด็กที่ได้รับการใส่ epicardial leads น้อยกว่าชนิด endocardial lead อย่างมีนัยสำคัญทางสถิติ พบมีภาวะแทรกซ้อนชนิดไม่รุนแรง 3 ราย (9.6%) โดยเป็นการติดเชื้อที่แผล 2 ราย และ post pericardiotomy syndrome 1 ราย พบว่าพลังงานต่ำสุดที่ใช้ในการกระตุ้น (minimal energy threshold), sensitivity และ impedance ไม่มีความแตกต่างตั้งแต่เริ่มใส่ไปจนถึง การติดตามครั้งสุดท้าย แต่พลังงานต่ำสุดที่ใช้ในการกระตุ้นของ endocardial lead ต่ำกว่าอย่างมีนัยสำคัญทางสถิติ พบเหตุการณ์ที่ epicardial lead ใช้การต่อไม่ได้ (lead failure) ใน 3 ราย (11.5%) ที่เวลา 8.9 (7.9-62) เดือน หลังใส่ ซึ่งไม่แตกต่างจากกลุ่ม endocardial leads พบว่า 82% ของ epicardial lead ยังสามารถใช้งานอยู่ได้ที่ 8 ปี

สรุป: *การใส่เครื่องกระตุ้นหัวใจแบบถาวรในเด็กมีน้อยโดยเฉลี่ย 4.4 ราย/ปี ในรพ.ศิริราช สามารถทำได้ค่อนข้างปลอดภัยในผู้ป่วยเกือบทุกราย ไม่พบความแตกต่างของ pacing parameter ตั้งแต่ใส่ไปจนถึงการติดตามระยะกลาง แต่พลังงานต่ำสุดที่ใช้ในการกระตุ้นของ endocardial lead จะน้อยกว่า epicardial lead*