Journal of Arrhythmia 29 (2013) 287–290

Contents lists available at ScienceDirect

Journal of Arrhythmia

journal homepage: www.elsevier.com/locate/joa

Case Report

Intravenous pacemaker lead implantation for a pediatric patient: A 16-year follow-up study

Susumu Nakamoto *, Kosuke Fujii, Takako Nishino, Takuma Satus, Tatsuya Ogawa, Toshio Kaneda, Toshihiko Saga

Department of Cardiovascular Surgery, Kinki University Faculty of Medicine, Osaka, Japan

ARTICLE INFO

Article history:
Received 17 December 2012
Received in revised form
1 February 2013
Accepted 12 February 2013
Available online 29 April 2013

Keywords:
Intravenous pacemaker lead implantation
Child
Screw-in lead

ABSTRACT

Intravenous pacemaker lead implantation for small children is not performed routinely. Here, we report the case of a pediatric patient who underwent endocardial lead implantation and follow-up for 16 years. The patient was a 4-year-old boy who underwent total correction of pulmonary atresia with ventricular septal defect following several palliative operations. After the patient underwent total correction, atrial flutter was noted. Atrial flutter was successfully terminated by overdrive pacing. However, atrial flutter occurred again immediately after overdrive pacing. To treat atrial flutter caused by sick sinus syndrome, a screw-in type lead was attached to the free wall of the right atrium and an excess loop was left to allow for the patient's growth. During the 16-year follow-up, no adverse effects were observed except for a gradual increase in pacing threshold. The selection of a small-sized endocardial lead and an appropriate entry vein, with meticulous management of the leads, makes implantation of an endocardial lead for small children easier and safer.

1. Introduction

Cardiac pacing using a myocardial lead is performed in small children to treat congenital complete atrioventricular block or bradycardia after cardiac surgery. Intravenous pacemaker lead implantation has advantages over a myocardial lead including lower frequency of exit block and better pacing threshold. However, intravenous pacemaker lead implantation has not been performed routinely in small children because this approach requires the consideration of growth of the child, an appropriate entry site to avoid venous obstruction, and careful selection of the lead. Here, we report the case of an intravenous pacemaker lead implantation in a 5-year-old patient who has been followed for 16 years after the procedure.

2. Case report

A 5-year-old boy was admitted for treatment of atrial flutter after correction of pulmonary atresia with ventricular septal defect. The patient had undergone total correction of cardiac disease at 4 years and 2 months of age after previous bilateral unifocalization for major aortopulmonary collateral arteries, Blalock–Taussig shunt creation, and Brock operation were performed. Atrial flutter occurred after total correction of cardiac defects in the patient at the age of 5 years. Atrial flutter was successfully terminated by overdrive pacing, but occurred again immediately. Recurrence of atrial flutter after overdrive pacing was considered to be caused by sick sinus syndrome. Use of a myocardial lead was initially considered to treat the sick sinus syndrome. However, it would have been difficult to attach a myocardial lead at the optimal location in the right atrium for AAI pacing, due to previous thoracotomies and cardiac surgery. A screw-in type pacemaker lead Medtronic 4568-53 cm (Medtronic Inc. Minneapolis, MN, USA) was inserted from a cephalic vein by cutdown and attached to the free wall of the right atrium. To allow for growth, an excess loop was left in the right atrium (Fig. 1). Medtronic THERA™ (Medtronic Inc.) was implanted under the major pectoral muscle. The patient's body weight, height, and surface area at the time of operation were 14.3 kg, 101 cm, and 0.63 m^2, respectively. After 16 years, the patient's body weight, height, and surface area were 47.2 kg, 169.0 cm, and 1.52 m^2, respectively. Because of body growth, the endocardial lead was stretched, causing a gradual increase in the radius of the endocardial loop. The round shape of the endocardial lead from the superior vena cava (SVC) to the left subclavian vein changed to a straight shape with the stretching. At the first pacemaker implantation, the voltage of the intrinsic P wave, pacing threshold, and lead impedance were 1.4–2.0 mV, 1 V at 0.4 ms, and 441 Ω,

* Correspondence to: Department of Cardiovascular Surgery, Kinki University Faculty of Medicine, 377-2 Ohno-higashi, Osakasayama, Osaka, 589-8511, Japan. Tel.: +81 72 366 0221; fax: +81 72 367 8657.
E-mail address: snakamot@med.kindai.ac.jp (S. Nakamoto).

1880-4276/$ - see front matter © 2013 Japanese Heart Rhythm Society. Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.joa.2013.02.004

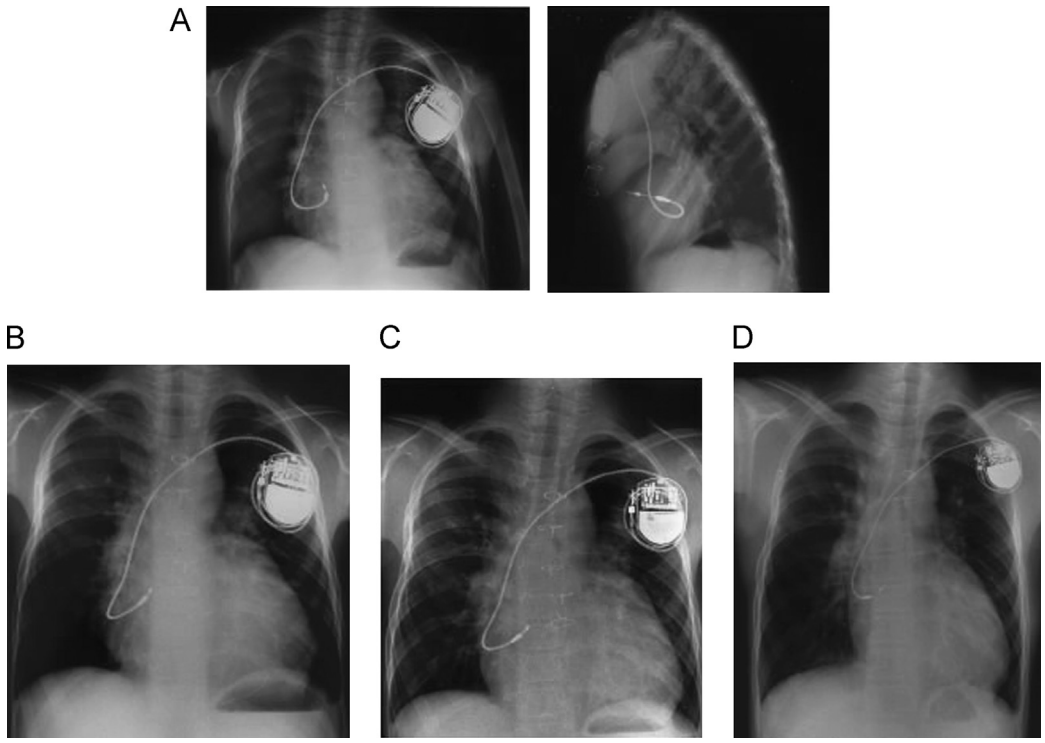

Fig. 1. (A) Upper chest radiography image immediately after implantation. The atrial lead is attached to the anterior wall of the right atrium. At implantation, the patient's body weight, height, and surface area were 14.3 kg, 101 cm, and 0.63 m^2, respectively. (B) Radiography image 2 years after implantation. (C) Radiography image 5 years after implantation. (D) Radiography image 16 years after implantation. At 16 years after implantation, the patient's body weight, height, and surface area were 47.2 kg, 169.0 cm, and 1.52 m^2, respectively. The original curled atrial lead was straightened following body growth.

respectively. The pacing threshold gradually increased and the voltage of the intrinsic P wave decreased during the follow-up period. At the last generator exchange, the voltage of the intrinsic P wave, pacing threshold, and lead impedance were 0.6 mV, 7.0 V at 0.5 ms, and 562 Ω, respectively (Table 1). At the last pacemaker clinic, the pacing mode, voltage of intrinsic P wave, generator output, and lead impedance were AAI, 1.3–1.4 mV, 7.5 V at 1.0 ms, and 575 Ω, respectively. Venous occlusion at the implantation side is one of the disadvantages of transvenous implantation in children. Because we had not previously inserted a new lead from the subclavian vein, we had not checked whether the patient's left subclavian vein, brachiocephalic vein, or superior vena cava were occluded using a venogram or venous echo. However, dilatation of superficial veins on the anterior chest as collateral circulations for the occluded veins has not been observed. Moreover, the patient has never experienced swelling or pain in the upper extremities due to venous occlusions. During the follow-up period, no adverse phenomena, such as exit block, sensing failure, or lead floating, were observed except for a gradual increase in pacing threshold. However, the cause of the increasing capture threshold seems to be an inflammatory reaction at the electrode-myocardial interface. Increasing pacing threshold is not a phenomenon exclusive to small children, but is also observed in adult patients.

Table 1
Pacemaker follow-up data.

Date	Intrinsic P wave (mV)	Pacing threshold	Lead impedance (ohm)
06.06.1995	1.4–2.0	1 V (0.4 ms)	441
02.07.2000	1.0–1.4	1.5 V (0.4 ms)/0.09 ms (2.5 V)	486
05.14.2002	1.4–2.0	1.25 V (1.0 ms)/0.15 ms (2.5 V)	490
05.18.2008	1.3–1.4	6.6 V (0.5 ms)	575
01.28.2012	0.6	7.0 V (0.5 ms)	562

3. Discussion

The advantages of intravenous pacemaker lead implantation are: access to pacing sites that myocardial leads cannot be attached to, such as the intra-arterial septum; lower frequency of exit block [1]; better pacing threshold at the atrium and ventricle; and better sensing capability of intrinsic P waves [2], compared with myocardial leads. However, this approach for small children requires the consideration of growth, an appropriate entry site to avoid venous obstruction, and selection of a lead that is unlikely to detach during growth. Furman and Young [3] reported using an excess loop of endocardial lead to allow for patient growth. Gheissari et al. [4] reported that an excess loop of 10 mm per year was needed to allow for patient growth. Because it seems unlikely that 2 endocardial leads can be inserted into the vein without venous occlusion, many authors consider that atrioventicular synchronous pacing for small children is not useful in the treatment of atrioventicular block. Thus, in almost all reports on transvenous pacemaker lead implantations, the authors describe single chamber pacemaker implantation for VVI pacing. To perform atrial pacing as in our patient, the estimated length of excess loop left in the right atrium to allow for patient growth must not exceed the length for right ventricular apical pacing. Thus, the length of excess loop that should be left in the right atrium is as long as the length for right ventricular pacing. However, all of the excess loop estimated for right ventricular pacing cannot always be left in the right atrium. To resolve this problem, Strojanov et al. [5] suggested that the part of the lead that could not be left in the right atrium can be left in the pacemaker pocket, and that the lead should be fixed to the

Table 2
Summary of papers on intravenous pacemaker lead implantation for small children.

Authors	Entry vein Method	Mode	Age	BH (cm)	BW (kg)
Furman and Young [3]			1 month		
Holmes et al. [6]	Subclavian vein Puncture		18 months	75	8.6
Gillette et al. [2]	Subclavian vein Puncture	DDD/ VVI	< 4 years		< 15
Till et al. [7]		VVI DDD	Newborn 3 years		2.8 12.8
Guerola et al. [8]	Subclavian vein Puncture	DDD	Newborn		1.2
Sachweh et al. [9]	Cephalic vein Cutdown		1.3 years		8.5
Strojanov et al. [10]	Cephalic vein Cutdown				2.45
Kammraad et al. [11]	Subclavian vein Puncture	VVI	2 days		2.3

subcutaneous tissue with a slowly absorbable ligature with the expectation of spontaneous lead migration as the child grows.

In this case, the excess loop in the atrium initially stretched and the round shape of the endocardial lead from the SVC to the left subclavian vein changed to a straight shape following growth. The adhesion of the endocardial lead to the junction between the SVC and the innominate vein has often been observed when endocardial extractions are performed. Thus, tension on the endocardial lead will not be passed directly to the excess loop in the right atrium and the course of the lead will change from round to straight.

In 1977, Furman and Young [3] were the first to report on transvenous pacemaker lead implantation in 12 children and adolescents. The youngest patient was 1 month old. After their report, several other papers on endocardial pacemaker implantation in small children were published (Table 2) [2,3,6–11]. Gillette et al. [2] reported transvenous pacing from the subclavian vein via puncture. The criteria for transvenous pacemaker lead implantation were that the patient should be > 4 years of age with a body weight > 15 kg. Till et al. [7] reported that smaller pacemaker generator and transvenous lead established transvenous ventricular pacing (VVI) in a newborn infant of 2.8 kg and atrioventricular synchronized pacing (DDD) in children at the age of 3 years and 12.8 kg body weight. Guerola et al. [8] reported 7 cases of children who underwent dual-chamber pacemaker lead implantation with unipolar leads via subclavian vein puncture. The body weight at operation was < 4 kg and minimum body weight was 1.2 kg. There was a subclavian vein thrombosis in a 1.2 kg neonate and nearly all the patients required lead advancement prior to generator end-of-life. Sachweh et al. [9] and Strojanov et al. [10] reported transvenous pacemaker lead implantation via the cephalic vein by cutdown. Sachweh et al. [9] recommended that the transvenous lead should be inserted via puncture of the subclavian vein if the cephalic vein was too small in diameter or forward movement of the lead was impossible. Kammeraad et al. [11] reported endocardial lead implantation via subclavian vein puncture in infants who weighed < 10 kg (the minimum body weight was 2.3 kg).

Molina et al. [12] reported that the entry vein should be carefully selected according to patient age and that the size of the entry vein should also be checked using vascular echo due to variations in size. Furthermore, they reported that vein obstruction frequently occurs for large endocardial leads occupying more than half of the cross-sectional area of the entry vein. The entry vein should thus have a cross-sectional area of more than twice the sum of the cross-sectional areas of 2 leads if 2 leads for DDD pacing are chosen. Bar-Cohen et al. [13] recently assessed the rate of venous obstruction after pacemaker implantation for small children using a venogram and concluded that age, size, and lead factors alone do not predict venous obstruction. New leads could be placed by advancing a wire past the obstruction, thus bypassing the obstruction, or by advancing the new leads through tracts created by extracted leads. However, the presence of venous occlusion increases the procedural complexity in many of the cases. Therefore, we have to choose a larger vein and to select a smaller lead to decrease venous obstruction. We opted for a screw-type lead to prevent lead detachment, as Williams et al. [14] reported a case in which a tined lead became free-floating in the late phase. Advancements in technology facilitate the use of smaller diameter endocardial leads. According to the *2012–2013 Data Book Pacemaker & ICD/CRT* [15], the diameter of FINELINE™ II Storox (Boston Scientific, Natick, MA, USA) and Tendril™ (St. Jude Medical Inc., St. Paul, MN, USA) is less than 2 mm. Unfortunately, we have no experience of using Tendril for small children. FINELINE is a 1.7 mm, bipolar, screw-in pacing lead. This lead can be inserted into the vein using a 5 Fr sheath or directly by cutdown. This lead does not have a retractable screw-in system. A small amount of sugar covers the fixed helix for the first 5 min in the bloodstream. Thus, this lead must be attached to the right atrium or right ventricle before the sugar dissolves to prevent entanglement with the tricuspid valve apparatus. The body of the lead also has to be rotated to fix it to the myocardium, which is not very difficult; however, it is occasionally difficult to detach the lead from the myocardium to identify a better pacing and sensing site. Recently, the SelectSecure™ model 3839 lead (Medtronic Inc.) has become commercially available in Japan. The SelectSecure is a 4.1 Fr, steroid-eluting, bipolar, fixed-screw lumenless pacing lead. Its small size makes it beneficial for use in children. However, the delivery system, an 8.4 Fr steerable catheter requiring a 9 Fr introducer sheath, is not optimal for use in small children due to its size and its large radius of curvature. Lapage and Rhee [16] developed a 5 Fr checkFlo Performer™ Introducer set (Cook Medical Inc., Bloomington, IN, USA) to optimize delivery without the need for a large diameter introducer/sheath system. If we can use this delivery system, SelectSecure is then an attractive lead to use: the small outer diameter lead may prevent venous occlusion, the steroid-eluting lead may prevent increasing pacing threshold over time, and the lumenless lead may prevent lead fracture over time. During the 16-year follow-up period in our patient, no adverse phenomena, such as exit block, sensing failure, or free-floating of the lead, were observed, except for a gradual increase in pacing threshold. Intravenous pacemaker lead implantation has many advantages compared with a myocardial lead. It is important to avoid venous obstruction in the long term for good results after pacemaker lead implantation, especially in small children. A small-sized lead and an appropriate entry vein should be selected to avoid venous obstruction after lead implantation.

4. Conclusion

Implantation of an endocardial lead may be indicated for small children, particularly for the treatment of atrial arrhythmia or arrhythmia after cardiac surgery, if a small endocardial lead and an appropriate entry vein can be selected.

Conflict of interest

None of the authors have any conflict of interest to disclose.

References

[1] Hayes DL, Holmes Jr. DR, Maloney JD, et al. Permanent endocardial pacing in pediatric patients. J Thorac Cardiovasc Surg 1983;85:618–24.
[2] Gillette PC, Shannon C, Blair H, et al. Transvenous pacing in pediatric patients. Am Heart J 1983;105:843–7.
[3] Furman S, Young D. Cardiac pacing in children and adolescents. Am J Cardiol 1977;39:550–8.
[4] Gheissari A, Hordof AJ, Spotnitz HM. Transvenous pacemakers in children: relation of lead length to anticipated growth. Ann Thorac Surg 1991;52:118–21.
[5] Stojanov P, Velimirovic D, Hrnjak V, et al. Absorbable suture technique: solution to the growth problem in pediactric pacing with endocaridal leads. Pacing Clin Electrophysiol 1998;21:65–8.
[6] Holmes Jr. DR, Maloney JD, Feldt RH. The use of the percutaneous subclavian technique for permanent cardiac pacing in childhood. Mayo Clin Proc 1980;55:579–82.
[7] Till JA, Jones S, Rowland E, et al. Endocardial pacing in infants and children 15 kg or less in weight: medium-term follow-up. Pacing Clin Electrophysiol 1990;13:1385–92.
[8] Guerola M, Parrt B, Bofill J. Endocardial DDD pacing in new-born patients: 5-years follow-up [abstract]. Pace 1999;22:A148.
[9] Sachweh JS, Vazquez-Jimenez JF, Schondube FA, et al. Twenty years experience with pediatric pacing: epicardial and transvenous stimulation. Eur J Cardiothorac Surg 2000;17:455–61.
[10] Stojanov P, Velimirovic D, Zivkovic M, et al. Permanent endocardial pacing by cephalic vein access in new-borns and infants-surgical techniques. Cardiovasc Surg 2001;9:75–6.
[11] Kammeraad JA, Rosenthal E, Bostock J, et al. Endocardial pacemaker implantation in infants weighing $<$ or $=$ 10 kg. Pacing Clin Electrophysiol 2004;27:1466–74.
[12] Molina JE, Dunnigan AC, Crosson JE. Implantation of transvenous pacemakers in infants and small children. Ann Thorac Surg 1995;59:689–94.
[13] Bar-Cohen Y, Berul CI, Alexander ME, et al. Age, size, and lead factors alone do not predict venous obstruction in children and young adults with transvenous lead systems. J Cardiovasc Electrophysiol 2006;17:754–9.
[14] Williams WG, Izukawa T, Olley PM, et al. Permanent cardiac pacing in infants and children. Pacing Clin Electrophysiol 1978;1:439–47.
[15] Nitta T, Ishikawa T. 2012–2013 Data Book Pacemaker & ICD/CRT. Tokyo: CE Corporation; 2012.
[16] Lapage MJ, Rhee EK. Alternative delivery of a 4Fr lumenless pacing lead in children. Pacing Clin Electrophysiol 2008;31:543–7.