

Cardiac Pacing in a Patient with Diaphragm Pacing for Congenital Central Hypoventilation Syndrome (Ondine's Curse)

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Cardiac Pacing in a Patient with Diaphragm Pacing for CCHS. Mechanical ventilation support and diaphragm pacing has improved the prognosis of patients with idiopathic congenital central hypoventilation syndrome (CCHS; Ondine's curse). However, severe bradyarrhythmias may occur. This report is about a patient who was supplied with a bilateral diaphragm pacing system at early childhood. At the age of 17 years, he experienced multiple syncopes due to sinus nodal arrest, which was successfully treated by the implantation of a dual chamber pacemaker. (*J Cardiovasc Electrophysiol*, Vol. 17, pp. 789-791, July 2006)

cardiac pacemaker, diaphragm pacemaker, electromagnetic interference, idiopathic congenital central hypoventilation syndrome, syncope

Introduction

Idiopathic congenital central hypoventilation syndrome (Ondine's curse) is a rare breathing disorder characterized by severe hypoventilation owing to a deficit in the ventilatory response to hypercapnia. It is associated with several other conditions, such as Hirschsprung disease, ophthalmological disorders, and tumors of the neural crest. In addition, bradyarrhythmias have been described.¹⁻³ In these patients, adequate oxygenation can be maintained by ventilation via a tracheostoma, by ventilation via a nasal or face mask, or by pacing the diaphragm via the phrenic nerve. In the case of bradyarrhythmias, phrenic pacing is thought to be an obstacle for cardiac pacing because of possible electromagnetic interference with the cardiac pacing system. The following case is a report on the simultaneous use of these pacing systems.

Case

We report a 17-year-old male with idiopathic congenital central hypoventilation syndrome. At the age of 16 months, a bilateral phrenic pacing system (Avery Laboratories, Commack, NY, USA) was implanted. Unipolar pacing electrodes were fixed to the phrenic nerve and tunneled to the receiver/stimulator unit in a subcutaneous abdominal pocket. The patient developed without mental or physical retardation, using diaphragm pacing continuously at nights and occasionally at daytime when he felt exhausted. Recently he experienced several syncopes. There was no evidence of a malfunction of the diaphragmatic pacemaker, neither could a neurological disorder apart from his breathing disturbance be found. However, Holter ECG showed

repeated sinus nodal arrests with pauses of up to 6 seconds followed by a junctional escape rhythm with 20–30 beats/min. Bradyarrhythmic episodes occurred in the early morning hours when the patient was awake. Hypoxia as a possible cause for the bradycardia was ruled out. Echocardiography disclosed no abnormalities.

Dual chamber pacemaker implantation (Fig. 1) was performed under conscious sedation with midazolam (cumulative 120 $\mu\text{g}/\text{kg}$ of body weight) and fentanyl (cumulative 0.7 $\mu\text{g}/\text{kg}$ of body weight) keeping him awake enough for spontaneous breathing. Bipolar pacemaker leads (atrial lead Medtronic 5076, ventricular lead Medtronic 4092 [Medtronic, Minneapolis, MN, USA]) were introduced via the cephalic vein and positioned to the right atrial appendage and the right ventricular apex. Cardiac signal amplitudes were between 7.0 and 8.0 mV for the atrial lead and between 20.0 and 22.0 mV for the ventricular lead, pacing thresholds were 0.2 V at 0.5 ms for the atrial lead and 0.5 at 0.5 ms for the ventricular lead, and pacing impedances were 710 Ω (atrial) and 603 Ω (ventricular).

The leads were connected to the pacemaker (Medtronic Kappa 901 DR) and diaphragm pacing was turned on. Pacing settings of the diaphragm pacemaker were as prior optimized for the patient with a respiratory rate of 11 per minute, an inspiration time of 1.75 seconds, and a pulse train of 25 pulses per inspiration (corresponding to a pulse interval of 73 msec). When switching the phrenic pacemaker to the maximal output that was tolerated by the patient, interference occurred at an atrial sensitivity of 0.5 mV and values that were more sensitive. Interference with the ventricular channel of the cardiac pacemaker was observed at a sensitivity of 4.0 mV and values that were more sensitive, respectively (Fig. 2a and b).

Testing for possible interference was repeated 6 hours, 3 days, and 3 months after the operation. The phrenic pacemaker interfered with the atrial lead at sensitivity levels of 0.25 mV and higher and with the ventricular lead at sensitivity levels of 2.8 mV and higher. Cardiac pacemaker sensitivity levels were programmed to 1.0 mV for the atrial channel and to 5.6 mV (8.0 mV at 3 months follow-up) for the ventricular channel, respectively.

Intrinsic cardiac signal amplitudes as measured by the cardiac pacemaker remained stable at 5.6–8.0 mV (atrium) and 22–32 mV (ventricle), pacing thresholds and pacing impedances remained stable as well.

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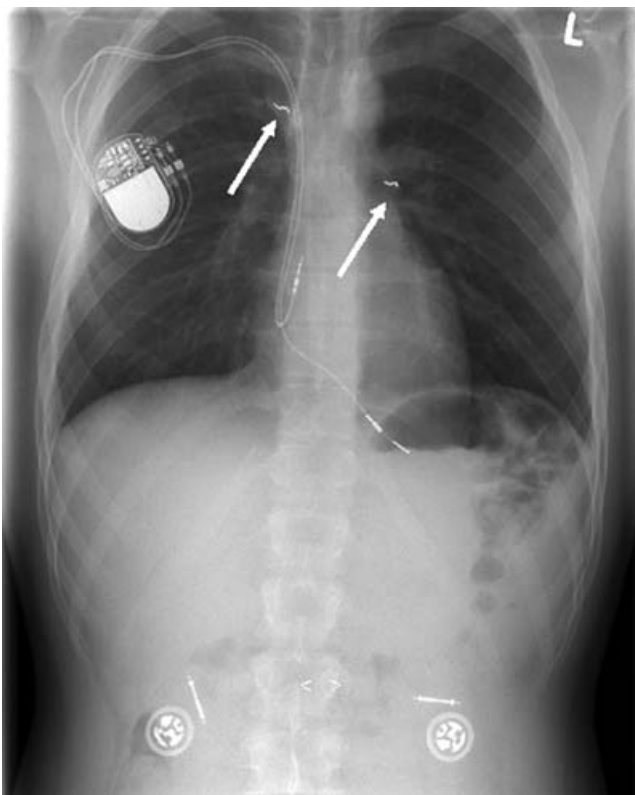


Figure 1. Chest X-ray of a 17-year-old boy with a bilateral unipolar diaphragm pacing system in which leads are connected to the phrenic nerves (arrows) and a concomitantly implanted dual-chamber cardiac pacing system.

During a follow-up of 3 months no syncopes occurred, and repeated Holter ECG showed no interference of the phrenic pacemaker with the cardiac pacemaker and vice versa.

Discussion

In patients with Ondine's curse bradyarrhythmias have been described.^{1,2} It is unclear whether they are based on an isolated sinus or atrioventricular node dysfunction or whether they are the result of a disturbance in autonomic regulation mechanisms.^{3,4} Rarity of the Ondine's curse (prevalence 1 in 180,000 births)⁵ makes it difficult to ascertain whether bradyarrhythmias are causally linked to it or whether they are merely coincidental. Nevertheless, it is conceivable that these patients have an increased risk for the development of bradyarrhythmias. As diaphragm pacing is an accepted technique to maintain breathing in patients with Ondine's curse,⁶⁻⁸ it may coincide with the indication for cardiac pacing. Our report shows that cardiac pacing is possible despite electromagnetic interference by unipolar diaphragm pacing.

Since sinus arrest was the index arrhythmia for cardiac pacing, single chamber atrial pacing may have been sufficient to avoid syncopes in our patient. However, we preferred a dual chamber cardiac pacing system to ensure cardiac stimulation in the case of subsequent development of atrioventricular block and for hemodynamic advantages in the case of a vasovagal or neurocardiogenic mechanism of the syncopes.

Implantation and programming of the cardiac pacemaker system was facilitated in our patient by the fact that large

intrinsic cardiac signals could be obtained. This allowed a relatively insensitive programming of the atrial and ventricular channel to avoid interference with the unipolar pacing artifacts of the diaphragm pacemaker. Oversensing of the pacing artifact of the diaphragm pacemaker can lead to inhibition of the cardiac pacemaker, inappropriate loss of atrioventricular synchrony in patients with atrioventricular block or asynchronous cardiac pacing in the noise reversion mode.⁹

Because diaphragm pacemakers do not have sensing capabilities (stimulation is asynchronous), interference caused by the cardiac pacemaker is not possible. However, interference of the cardiac pacemaker by the diaphragm pacemaker can occur.

There are several possibilities to minimize the risk for interdevice interactions. This may be increasingly important because of the expanding variety of implantable electronic devices, for example, neural stimulators.

The use of bipolar cardiac pacing electrodes and achievement of excellent sensing thresholds for the cardiac signals are essential. However, it is possible that safety margins between the threshold for noise detection and the sensing threshold of the intrinsic cardiac signal are not sufficient to obtain a correct pacemaker function (e.g., relatively small intracardiac signals, high pacing output of the phrenic pacemaker). In these cases, switching to a bipolar phrenic pacemaker system, which would significantly decrease the risk for interactions, or the initiation of ventilation via a nasal or face mask may be discussed as options. However, this would either impose a further operation or a potentially lengthy adaptation to a new breathing system. Thus, all efforts should be taken to reach satisfactory safety margins on the implantation of the cardiac pacemaker.

It may be helpful to choose leads with a small dipole distance, to place them perpendicular to the main direction of the electromagnetic field created by the phrenic pacing system, and to place them as far as possible from the diaphragm receiver/stimulator unit (if the diaphragm pacing system is unipolar) or as far as possible from the lead insertion to the phrenic nerve (if the diaphragm pacing system is bipolar). This may result in atypical lead locations that may require special tools (e.g., steerable guiding catheters) to reach and/or active fixation of the pacemaker lead to obtain a stable lead position.

During the implantation procedure, testing for the interference threshold with the diaphragm pacing system at its maximal output is mandatory to ascertain that the safety margin between noise detection and detection of intrinsic cardiac signals is sufficient, as pacing amplitudes of the diaphragm pacemaker may require adjustment over time. At follow up, interference between the two pacing systems should be ruled out during pacemaker checks and possibly by routine Holter tracings. However, it may not be necessary to put the diaphragm pacemaker at its maximal output at every visit. If a change in the pacing settings of the diaphragm pacemaker is necessary, interference with the cardiac pacing system needs to be ruled out, notably if the output of the phrenic nerve stimulation has to be increased.

Conclusion

Patients with idiopathic congenital central hypoventilation syndrome (Ondine's curse) may develop an indication for



Figure 2. (A and B) Top line shows the surface ECG, middle-line marker annotations of the cardiac pacemaker (AP = atrial pacing; AS = atrial sensed event; VP = ventricular pacing; VR = ventricular event within refractory period; VS = ventricular sensed event), and the bottom line the bipolar ventricular electrogram. On panel 2a, the ventricular sensitivity of the pacemaker is set at 1.0 mV and pacing artifacts (arrows) of the diaphragm pacemaker are sensed by the cardiac pacemaker (see annotations in marker channel). After reducing the ventricular sensitivity (Panel 2b), the pacing artifacts of the diaphragm pacemaker are no longer sensed by the cardiac pacemaker.

cardiac pacing due to bradyarrhythmias. Cardiac pacing in the presence of a unipolar diaphragm pacing system is feasible and safe if thorough testing for possible interdevice interactions is performed. However, the experience gained from this patient is not transferable to the implantation of other cardiac pacing systems, such as implantable cardioverter defibrillators, because the sensing behavior is significantly different in these devices.

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References

- Weese-Mayer DE, Silvestri JM, Menzies LJ, Morrow-Kenny AS, Hunt CE, Hauptmann SA: Congenital central hypoventilation syndrome: Diagnosis, management, and long-term outcome in thirty-two children. *J Pediatr* 1992;120:381-387.
- Silvestri JM, Hanna BD, Volgmann AS, Jones PJ, Barnes SD, Weese-Mayer DE: Cardiac rhythm disturbances among children with idiopathic congenital hypoventilation syndrome. *Pediatr Pulmonol* 2000;29:351-358.
- O'Sullivan J, Cottrell AJ, Wren C: Ondine's curse and neurally mediated syncope—A new and important association. *Eur Heart J* 1993;14:1289-1291.
- Trang H, Girard A, Laude D, Elghozi JL: Short-term blood pressure and heart rate variability in congenital central hypoventilation syndrome (Ondine's curse). *Clin Sci* 2005;108:225-230.
- Schöber JG, Neumayer S, Meisner H, von Kries R: Prävalenz und Inzidenz des Ondine-Syndroms in Deutschland. *Mscr Kinderheilk* 1994;142:S32.
- Vanderlaan M, Holbrook CR, Wang M, Tuell A, Gozal D: Epidemiologic survey of 196 patients with congenital central hypoventilation syndrome. *Pediatr Pulmonol* 2004;37:217-229.
- Weese-Mayer DE, Silvestri JM, Kenny AS, Ilbawi MN, Hauptmann SA, Lipton JW, Talonen PP, Garcia HG, Watt JW, Exner G, Baer GA, Eleftheriades JA, Peruzzi WT, Alex CG, Harlid R, Vincken W, Davis GM, Decramer M, Kuenzle C, Saeterhaug A, Schöber J: Diaphragm pacing with a quadripolar phrenic nerve electrode: An international study. *Pacing Clin Electrophysiol* 1996;19:1311-1319.
- Weese-Mayer DE, Hunt CE, Brouillette RT, Silvestri JM: Diaphragm pacing in infants and children. *J Pediatr* 1992;120:1-8.
- Kolb C, Halbfaß P, Zrenner B, Schmitt C: Paradoxical atrial undersensing due to inappropriate atrial noise reversion of atrial fibrillation in dual-chamber pacemakers. *J Cardiovasc Electrophysiol* 2005;16:696-700.