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CASE REPORT

Anesthesia-Induced Atrioventricular Block Predicted by Exercise Stress Test: A Case Report

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ABSTRACT: Background: Many anesthetics suppress atrioventricular conduction and may exacerbate atrioventricular block (AVB), which has led to the establishment of pediatric perioperative guidelines. However, the perioperative management of patients with a history of AVB who have recovered to an apparent sinus rhythm remains unclear. Case presentation: We report the case of a 13-year-old girl who developed complete AVB following surgery for congenital heart disease in infancy and subsequently recovered sinus rhythm. She experienced a recurrence of AVB after anesthesia induction for scoliosis surgery. An implantable pacemaker was inserted in infancy after the onset of complete AVB. At age 8 years, sinus rhythm was confirmed at rest; although AVB was still observed during an exercise stress test, the pacemaker was removed at her parents' request. This case provides important insights into the role of exercise stress testing in the evaluation of atrioventricular conduction. As atrioventricular conduction is strongly influenced by autonomic tone, exercise usually promotes conduction through sympathetic activation and parasympathetic suppression. In contrast, conduction below the His-Purkinje system is not regulated by the autonomic nervous system. Consequently, if abnormalities exist at this level, not all atrial impulses can be conducted to the ventricles during exercise, and AVB may be induced. Conclusion: For patients who appear to have recovered atrioventricular conduction, an exercise stress test may serve as a valuable screening tool to identify residual conduction disorders and assess the risk of intraoperative AVB recurrence.

KEYWORDS: Exercise stress test; anesthetics; atrioventricular block; perioperative care; temporary pacemaker; case report

1 Introduction

Anesthetic agents are known to influence cardiac conduction, and several of them have been associated with delayed or impaired impulse transmission within the atrioventricular conduction pathway. Consequently, the possibility of anesthesia-related recurrence of atrioventricular block (AVB) requires careful consideration. However, existing pediatric recommendations focus mainly on patients with persistent AVB, and less is known about how to manage those who appear to have recovered normal sinus rhythm after a prior episode [1]. In addition, current perioperative guidelines from major professional societies, such as the American Heart Association and the European Society of Cardiology, primarily address patients with persistent or suspected AVB and do not provide specific recommendations for patients with apparently resolved AVB [2,3]. We describe a patient with a history of AVB and apparent recovery of sinus rhythm who experienced recurrent AVB after anesthesia induction. Two years before the surgery, the patient developed AVB during an exercise stress test. This report highlights the potential utility of a preoperative

exercise stress test for detecting latent atrioventricular conduction disorders and assessing the risk of anesthesia-induced AVB recurrence.

2 Case Presentation

A 13-year-old girl was admitted for surgery to correct idiopathic scoliosis diagnosed at age 7 years. She had a past surgical history: repair of aortic coarctation and ventricular septal defect at age 1 month. Shortly after the surgery, she developed complete AVB, requiring pacemaker implantation at age 2 months. At age 8 years, sinus rhythm was confirmed on the resting electrocardiogram (ECG) with no pacing at ventricular rate-responsive pacing (VVI) setting of 40 beats per minute (bpm). However, AVB developed during the exercise stress test. The test was performed using a treadmill according to the Bruce protocol, and the patient reached Stage 4 with a peak exercise capacity of 11.6 METs. The heart rate at the start of exercise was 85 bpm (Fig. 1A), and second-degree AVB occurred when the heart rate increased to 140 bpm (Fig. 1B). Sinus rhythm was restored approximately 1 min after termination of exercise.

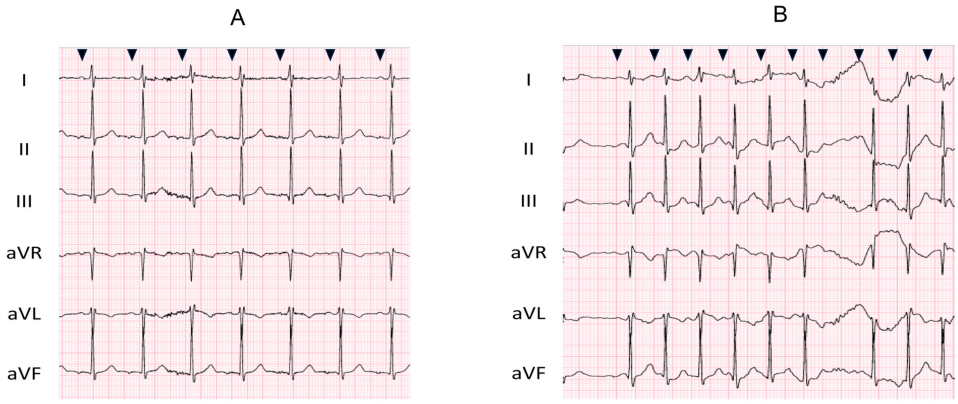

Figure 1: Exercise stress limb lead ECG at age 8 years. (**A**) The sinus rhythm at rest with a heart rate of 85 bpm. (**B**) Exercise stress-induced second-degree AVB (Mobitz type II) at a heart rate of 140 bpm. The arrowheads indicate P waves.

The pacemaker was removed at her parents' strong request, on the condition she avoid vigorous activity. Thereafter, she did not show any symptoms. At age 10 years, she developed complete AVB after induction of general anesthesia for otolaryngologic surgery, requiring temporary pacemaker insertion.

Prior to the scoliosis surgery, we inserted a temporary pacemaker considering the risk of anesthesia-induced AVB. To monitor for potential spinal cord injury, we planned intraoperative neurophysiological monitoring using motor evoked potential (MEP). As inhalational anesthetics are known to increase the stimulation threshold for MEP, we avoided their use and managed general anesthesia with total intravenous anesthesia (TIVA). We induced anesthesia with propofol 2 mg/kg, fentanyl 2.5 μg/kg, and rocuronium 1 mg/kg. To avoid loss of MEP, we reversed neuromuscular blockade after induction with sugammadex 4 mg/kg. We maintained anesthesia with propofol and remifentanil, delivering propofol via a target-controlled infusion pump and adjusting the target plasma concentration to 3.3–3.8 μg/mL while monitoring the depth of sedation using the Bispectral Index monitor. We titrated remifentanil within a range of 0.2–0.5 μg/kg/min. ECG initially showed sinus rhythm; following anesthesia induction, 2:1 AVB developed and subsequently progressed to complete AVB. Afterward, her heart rate gradually decreased, and complete VVI pacing (80 bpm) was activated throughout the surgery (Fig. 2A). She returned to sinus rhythm 5 h postoperatively

(Fig. 2B), and we removed the temporary pacemaker on the second postoperative day. She was discharged on 11 postoperative day without AVB recurrence.

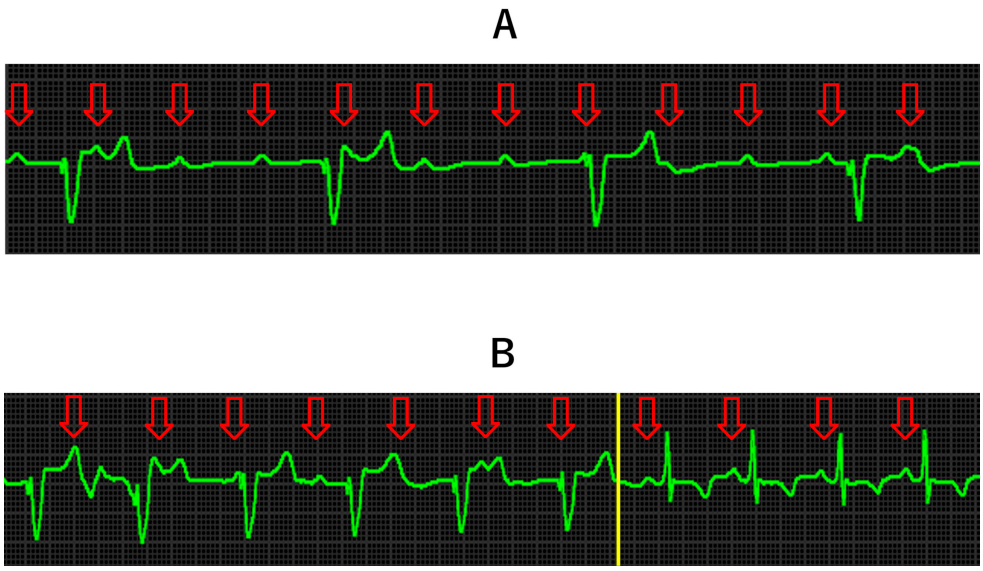

Figure 2: Monitored ECG during anesthesia. (**A**) ECG showed complete AVB after induction of anesthesia with VVI-pacing (80 bpm). The arrows indicate P waves. (**B**) ECG recovered to sinus rhythm 5 hours after surgery. The arrows indicate P waves. The vertical line indicates the timing of sinus rhythm recovery.

3 Discussion

To our knowledge, no reports suggest the utility of an exercise stress test in assessing the risk of anesthesia-induced AVB. In the present case, the patient developed AVB during an exercise stress test at age 8 years. Usually, exercise activates the sympathetic and suppresses the parasympathetic nervous system, shortening the atrioventricular node's refractory periods to promote conduction. However, as the His-Purkinje system lacks autonomic innervation, its refractory period remains unaffected by exercise [4]. Therefore, patients with impaired His-Purkinje system cannot maintain 1:1 conduction at higher atrial rates, leading to exercise-induced AVB. Thus, an exercise stress test may reveal conduction disorders below the His-Purkinje system. In our patient, exercise-induced AVB suggests residual His-Purkinje system injury from prior intracardiac repair, which is consistent with the complete AVB being infranodal in location.

Furthermore, an exercise stress test may help predict the risk of intraoperative recurrence of AVB. Many anesthetics directly suppress atrioventricular conduction. Representative anesthetic agents and their effects on atrioventricular conduction are summarized in Table 1.

Table 1: Representative anesthetic agents and their effects on atrioventricular conduction.

Anesthetic Agents	Effect on Atrioventricular Conduction
Propofol	Sinoatrial conduction, Atrioventricular node Atrio-His and His-Ventricle conduction [5,6]
Fentanyl	Atrioventricular node [7]
Remifentanil	Sinoatrial node, Atrioventricular node [8]
Dexmedetomidine	Sinoatrial node, Atrioventricular node [9]
Sevoflurane, Desflurane, Isoflurane	Minimal effect on atrioventricular conduction [10]
Benzodiazepines	Minimal effect on atrioventricular conduction

Among the agents listed in Table 1, propofol, remifentanil, and fentanyl were administered in the present case. However, it is difficult to determine whether any single agent was primarily responsible for the development of AVB during surgery. Propofol has been reported to suppress sinoatrial, atrioventricular nodal, and even infranodal conduction by directly inhibiting cardiac calcium and sodium currents, as well as the transient outward potassium current [6]. Given that exercise stress testing suggested the presence of infranodal conduction disturbance, propofol acting on the same region may have contributed to intraoperative AVB. In addition, a case of intraoperative complete AVB associated with remifentanil administration has been reported [8]. In this context, the fentanyl and remifentanil used in the present case may also have been involved in AVB development through their vagotonic effects. Overall, the TIVA protocol may have exerted additive suppressive effects on atrioventricular conduction through direct ion channel inhibition and enhanced vagal tone, resulting in the unmasking of latent infranodal conduction disease and the observed intraoperative AVB. In the present case, TIVA was selected because intraoperative MEP monitoring was required. In surgical settings where such monitoring is unnecessary, alternative anesthetic techniques, including inhalational anesthetics or benzodiazepine-based regimens, may be considered because they exert less direct suppressive effects on atrioventricular conduction. However, given the potential contribution of vagally mediated suppression of atrioventricular conduction and the complex interactions among anesthetic agents, no specific anesthetic technique can currently be recommended. Therefore, in patients considered at high risk for recurrent AVB, pacing support should be considered regardless of the anesthetic regimen selected.

Electrophysiological study is the gold standard for diagnosing conduction disturbances, but its invasiveness limits routine preoperative assessment. In contrast, an exercise stress test may serve as a simple, noninvasive alternative for preoperative screening. Although exercise-induced AVB does not invariably lead to circulatory collapse and may be hemodynamically tolerated in selected patients [11], particularly those with intact myocardial function, our case highlights that patients with prior intracardiac repair and residual infranodal conduction disease may remain vulnerable to anesthesia-induced recurrence, even when exercise-related symptoms are absent. Another limitation of exercise stress testing is that ECG findings during exercise may be affected by thoracic anatomy, including a concave-shaped chest wall or reduced anteroposterior diameter, and should therefore be interpreted in the context of overall anatomical and clinical assessment [12]. In addition, the relationship between the exercise intensity or heart rate at which AVB develops and the risk of perioperative recurrence remains unclear and warrants further investigation.

In conclusion, for patients developing AVB during an exercise stress test, preoperative temporary pacemaker insertion may be considered due to the possibility of intraoperative AVB recurrence.

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Availability of Data and Materials: The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Ethics Approval: This study was reviewed by the Ethics Committee of Keio University Hospital, and waived from ethical review. A written consent was obtained from the patient's parents for publication of the visual materials. Additionally, a parental written informed consent was obtained prior to the initiation of the study.

Conflicts of Interest: The authors declare no conflicts of interest.

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