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SPOTLIGHT

Modified procedures of subcutaneous implantable cardioverter defibrillator implantation for a child with small body size

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In addition to the traditional transvenous implantable cardioverter defibrillator (TV-ICD), the subcutaneous implantable cardioverter defibrillator (S-ICD) has been widely used to prevent sudden cardiac death because of ventricular arrhythmias. Recently, a multicenter study reported the efficacy and safety of S-ICD implantation in patients <18 years old.[1] However, S-ICD implantation in pediatric patients with particularly small body sizes remains challenging as a result of concerns regarding the optimal placement of a relatively long subcutaneous lead and a large generator, considering their thin subcutaneous tissue and the potential for future growth. Furthermore, a modified implantation procedure for pediatric patients has not yet been established. Herein, we report the case of a pediatric patient implanted with an S-ICD for secondary prevention based on a method that consolidates previous findings.

A 6-year-old girl (body height, 114 cm; body weight, 21.3 kg) with an inoperable intracardiac tumor and syncope because of ventricular arrhythmias was a candidate for an implantable cardioverter defibrillator. Echocardiography revealed a large intracardiac tumor (40 × 64 mm) attached to the left ventricular free wall and compressing the right ventricle (Figure 1A). The tumor was found during her fetal life and was considered a fibroma based on the clinical course (slowly enlarged) and findings on magnetic resonance imaging (Figure 1B). Polymorphic ventricular tachycardia was documented in Holter monitoring (Figure 1C). An S-ICD system (EMBLEM MRI®, Boston Scientific, Watertown, Massachusetts) was selected as the implantation device because the estimated risk of future lead complications was relatively low compared with the TV-ICD system.[2]

The implantation procedure was performed under general anesthesia. Considering the eligibility test results and the small amount of subcutaneous tissue around the sternum, the right parasternal position, crossing diagonally toward the right clavicle, was chosen as the implantation location for the subcutaneous lead (Figure 2A). Two-incision technique was used. The anterior border of the latissimus dorsi muscle was checked using ultrasonography, and the generator implantation position was determined to be posterior from the border. The lateral incision line was designed at the anterior site with enough distance from the generator position (Figure 2A). Ultrasonography was also used to check the subcutaneous level of the electrode insertion tool (tunneler) during the penetration. The subcutaneous lead was implanted straightly without a bending tunneler, in accordance with the preoperatively designed line (Figure 2B). Ultrasound sonography revealed a subcutaneous lead implanted directly on the muscular fascia (Figure 3).

The sensing test was passed except for an alternative vector showing low-amplitude R waves. A defibrillation threshold test was conducted and passed through the secondary vector. The S-ICD appropriately detected the induced ventricular fibrillation and successfully defibrillated it with a single shock of 65 J after 18.0 s of detection and charging. The device was programmed to have a ventricular fibrillation shock zone of 220 bpm. The PRAETORIAN score was 30 (<90; low risk of conversion failure, Figure 2B).[3] Good healing of the incision was achieved (Figure 2C). No complications or shock have been experienced after implantation.

The important points of the S-ICD implantation procedure for small children are as follows: (1) the subcutaneous lead implantation location should be designed carefully, considering their body size, future growth, and eligibility test results; (2) the generator implantation location and incision lines should be determined considering the

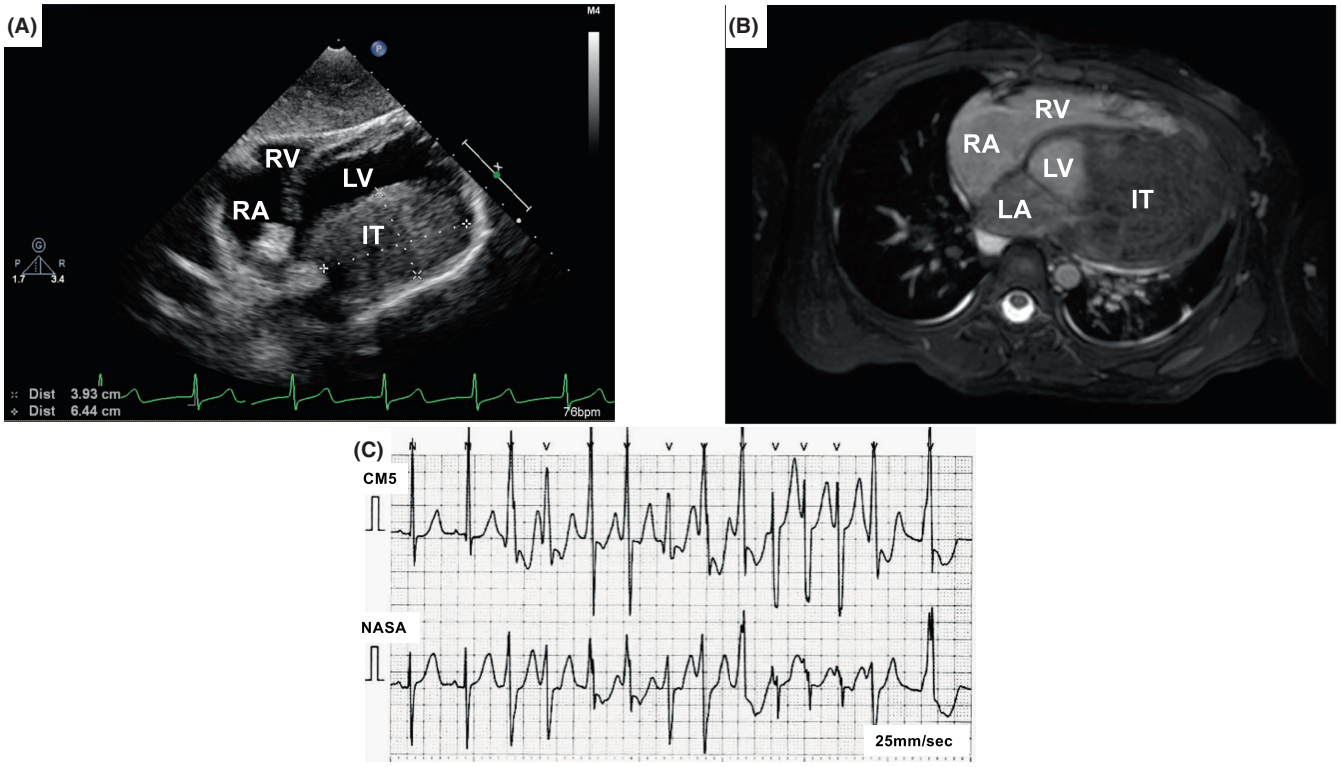


FIGURE 1 Cardiac ultrasound sonography and magnetic resonance image showing an intracardiac tumor and Holter electrocardiogram of ventricular arrhythmia. (A) Cardiac ultrasound sonography shows an intracardiac tumor (IT) attached to the left ventricular (LV) free wall and compressed right ventricle (RV). (B) A fat-suppressed T2 magnetic resonance image reveals a sharply marginated low signal tumor considered a fibroma. (C) Holter electrocardiogram shows polymorphic ventricular tachycardia. LA, left atrium; RA, right atrium.

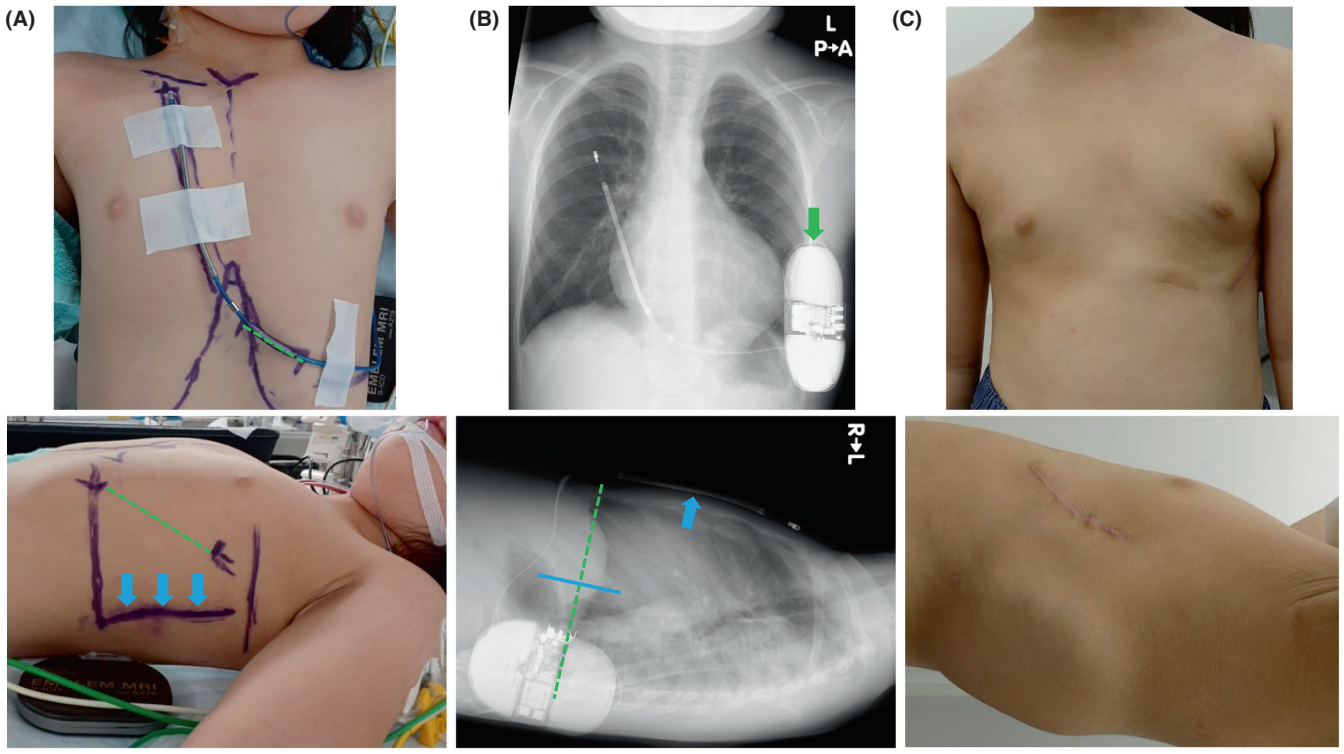


FIGURE 2 Diagonal subcutaneous lead implantation method for pediatric S-ICD recipients. (A) Preoperative design lines of lead and generator implantation with two-incision technique (green dot lines). The anterior border of the latissimus dorsi muscle (blue arrows) was identified by the ultrasound sonography. (B) A chest radiograph after S-ICD implantation using the diagonal implantation method with an inferior sensing electrode in the center (below the xiphoid) and a superior electrode in a right parasternal position. There are no great gaps between the lead and sternum (blue arrow) and the generator and rib cage (green arrow). The generator is implanted posterior from the mid-lateral line (blue line). (C) Photographs from the front and left lateral showing the position of incision lines and generator 2 months after the implantation.

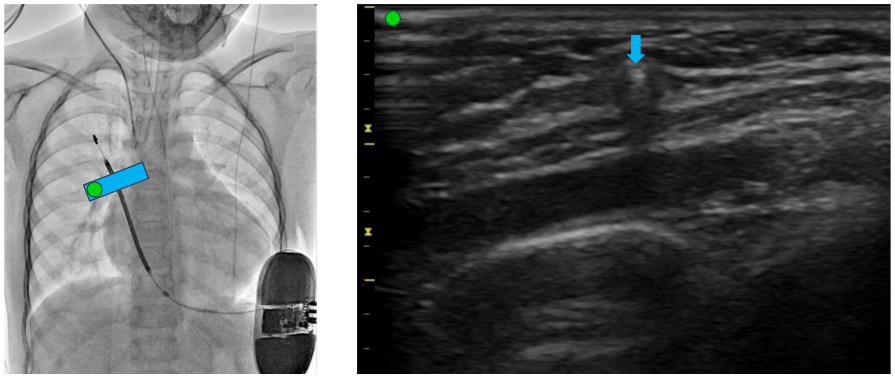


FIGURE 3 Ultrasound sonography-guided subcutaneous lead implantation. The ultrasound sonography shows a transverse section of the subcutaneous lead implanted under the subcutaneous tissues and directly on the muscular fascia.

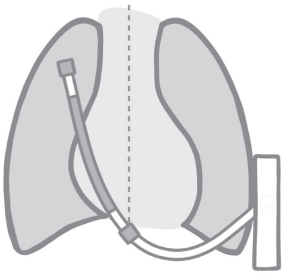
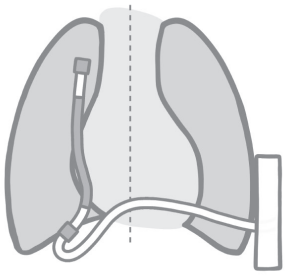
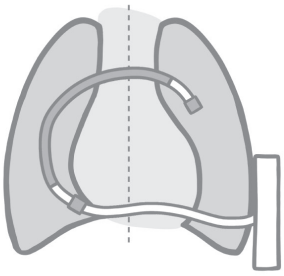
	Diagonal implantation	Parallel implantation	C-curved implantation
Examples	(A) 	(B) 	(C) 
Superior electrode position	Right side	Right side	Left side
Inferior electrode position	Center	Right side	Right side
Tunneler bending	Unnecessary	Unnecessary	Necessary

FIGURE 4 Characteristics of diagonal, parallel, and C-curved subcutaneous lead implantation methods.

small amount of subcutaneous tissue. Therefore, we modified the conventional implantation procedure.

First, a subcutaneous lead was straightly implanted in the right parasternal position crossing diagonally toward the right clavicle. This lead position enables avoiding implantation near the sternum site with the thinnest subcutaneous tissue. Furthermore, the use of ultrasound sonography during tunneling tool insertion allows for checking its subcutaneous levels and may contribute to reducing the risk of skin erosion. Straight-shaped lead implantation at the right parasternal position in the direction parallel to the sternum with superior and inferior sensing electrodes placed on the right side of the sternum and xiphoid has been previously reported.[4] Compared to the parallel implantation method, placing an inferior sensing electrode below the xiphoid enables obtaining a more natural lead shape in our novel diagonal implantation method (Figure 4A,B). Additionally, this electrode placement is beneficial in eliminating the need for tunneler bending and achieving straight-shaped lead implantation, keeping sufficient distance from the right clavicle (Figure 4A,C). In our case, the eligibility test was also passed in the parallel and C-curved lead implantation patterns. However, we chose the diagonal implantation pattern because of the thinness of the patient's subcutaneous tissue near the sternum. Although the feasibility and safety of the C-curve implantation method with tunneler bending for pediatric patients with small body sizes have been reported,[1] our novel diagonal implantation method without tunneler bending could be considered an alternative in cases with small amounts of subcutaneous tissue around the sternum.

Second, the generator was implanted more posteriorly compared to adults considering the thin subcutaneous tissue in reference to the anterior border of the latissimus dorsi muscle. Identifying the border between the latissimus dorsi and serratus

anterior muscles using ultrasound sonography and establishing a generator implantation position based on the border have been reported to be useful and safe ways to place the generator into the intermuscular space.[5] This method is further preferable for pediatric cases with small amounts of subcutaneous tissue. The lateral incision line was designed with adequate distance from the generator position to avoid skin erosion.

The S-ICD is a useful alternative to the traditional TV-ICD, and several reports,[1,4] including ours, have demonstrated the feasibility of implantation in pediatric patients with a small body size. Although further outcome surveys of these modified implantation procedures are necessary, this technology could be considered in eligible pediatric cases.

CONFLICT OF INTEREST STATEMENT

Authors declare no conflict of interests for this article.

ETHICS STATEMENT

Approval of the research protocol: M26-150-14.

INFORMED CONSENT

The patient provided informed consent for the publication of this report and associated images.

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