

Clinical Outcomes of Implantable Cardioverter-Defibrillator in Pediatric Patients

— A Korean Multicenter Study —

Mi Kyoung Song, MD; Jae-Sun Uhm, MD, PhD; Jae Suk Baek, MD;
Ja Kyoung Yoon, MD; Jae Yoon Na, MD; Hee Tae Yu, MD, PhD;
Ji-Hyuk Yang, MD, PhD; Seil Oh, MD, PhD; Sang Weon Park, MD, PhD;
Jinyoung Song, MD, PhD; June Huh, MD, PhD; Eun-Jung Bae, MD, PhD

Background: Implantable cardioverter-defibrillator (ICD) therapy is important for the prevention of sudden cardiac death, but data on clinical outcomes of ICD therapy in Asian pediatric patients are scarce. The aim of this Korean multicenter study was to evaluate the current state and elucidate the clinical outcomes of ICD therapy in children.

Methods and Results: Data from 5 pediatric cardiology centers were retrospectively collected from 2007 to 2019. Altogether, 99 patients were enrolled (mean age 13.9 ± 4.1 years). The most common underlying disease was a primary electrical disease (56%). An ICD was implanted for primary prevention in 19%. Appropriate shock occurred in 44% of patients at a median of 1.6 years after implantation. There was no significant difference in the appropriate shock rate between patients with primary and secondary prevention indications (32% vs. 48%, respectively). A total of 33 patients (33%) experienced inappropriate shock, which was associated with primary electrical disease and follow-up duration on multivariate analysis. 17% of patients had ICD-related complications.

Conclusions: The utilization rate of ICD for primary prevention was still low in the pediatric population in Korea, but there was a substantial rate of appropriate shock in these patients. Efforts to increase ICD usage to save the lives of high-risk patients and reduce the incidence of inappropriate shock are required.

Key Words: Congenital heart disease; Implantable cardioverter-defibrillator; Pediatrics; Sudden cardiac death

The implantable cardioverter-defibrillator (ICD) is a widely accepted therapy for adult patients with a high risk of sudden cardiac death (SCD),^{1,2} and the pediatric indication has increased for both primary and secondary prevention of SCD.³ However, data on ICD outcomes in pediatric patients are limited due to the heterogeneous patient group and the small number of patients.³ A high complication rate (~32%) and inappropriate shocks (19–47%), as well as ICD-related deaths of 0.5–3.5% in children and young patients, make the decision

regarding ICD implantation difficult.^{4–6} Additionally, clinical reports of ICD for pediatric patients in Asian populations are scarce.

This Korean multicenter study aimed to evaluate the current state and clinical outcomes of ICD implantation in pediatric patients.

Methods

We conducted a multicenter retrospective study of pediatric

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Department of Pediatrics, Seoul National University Children's Hospital (M.K.S., E.-J.B.), Department of Internal Medicine, Seoul National University Hospital (S.O.), Seoul National University College of Medicine, Seoul; Division of Cardiology, Department of Internal Medicine, Severance Hospital, Yonsei University College of Medicine, Seoul (J.-S.U., H.T.Y.); Department of Pediatrics, University of Ulsan College of Medicine, Seoul (J.S.B.); Department of Pediatrics (J.K.Y.), Division of Cardiology (S.W.P.), Sejong General Hospital, Bucheon, Gyeonggi-do; Departments of Pediatrics, Hanyang University College of Medicine, Seoul (J.Y.N.); and Department of Thoracic and Cardiovascular Surgery (J.-H.Y.), Department of Pediatrics, Heart Vascular Stroke Institute (J.S., J.H.), Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea

The first two authors contributed equally to this work (M.K.S., J.-S.U.).

Mailing address: Eun-Jung Bae, MD, PhD, Department of Pediatrics, Seoul National University College of Medicine, 101 Daehangno, Jongno-gu, Seoul, 03080, Republic of Korea. E-mail: eunjbak@snu.ac.kr and June Huh, MD, PhD, Department of Pediatrics, Heart vascular stroke institute, Samsung Medical Center, Sungkyunkwan University School of Medicine, 81 Irwon-ro Gangnam-gu, Seoul, 06351, Republic of Korea. E-mail: herzhuh@gmail.com

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Table 1. Demographic Data of Pediatric Patients

Variable	n=99
Age at implantation (years)	13.9±4.1
Follow-up duration (years)	4.9±3.7
Height at implantation, median (range), cm	162 (53–191)
Weight at implantation, median (range), kg	52.3 (3.9–100)
Male, n (%)	68 (69%)
Primary prevention, n (%)	19 (19%)
Secondary prevention, n (%)	80 (81%)
Cardiac arrest before ICD, n (%)	72 (73%)
VT before ICD, n (%)	28 (28%)
VF before ICD, n (%)	60 (61%)
Syncope before ICD, n (%)	40 (40%)
Family history of SCD, n (%)	17 (17%)
Age at implantation by underlying disease, median (range), years	
Primary electrical disease (n=55)	14.8 (0.2–18.7)
Congenital heart disease (n=12)	14.7 (12.3–17.5)
Cardiomyopathy (n=29)	14.7 (0.6–18.0)
Others (n=3)	14.1 (2.7–15.6)
CRT-D, n (%)	3 (3%)
Death, n (%)	3 (3%)
Transplantation, n (%)	1 (1%)
High-rate ICD therapy zone, n (%)	58 (59%)
Ventricular pacing mode	95 (96%): 74 in VVI/21 in DDD

CRT-D, cardiac resynchronization therapy-defibrillator; ICD, implantable cardioverter-defibrillator; SCD, sudden cardiac death; VF, ventricular fibrillation; VT, ventricular tachycardia.

patients, aged younger than 19 years, who underwent ICD implantation between April 2004 and January 2019; 5 tertiary hospitals of the Republic of Korea participated in this study. Medical records, including demographic data, underlying heart disease, ventricular function, ICD analyses, complications, and data on delivered therapies were collected. The indications for ICD implantation were retrospectively analyzed with reference to the medical record at the time of implantation and re-evaluation at the time of this study. Type and size of shock leads, date of shock lead change, causes of lead failure, and cases of removal or turned-off ICD were investigated. The data from ICD interrogation included the date of the first appropriate shock, the number of appropriate shocks, the occurrence of inappropriate shocks, antitachycardia pacing, and ventricular pacing with pacing mode. ICD therapy zones were divided into high- (≥ 200 /min) and low- (< 200 /min) rate therapy zones according to the heart rate that triggered the shock therapy.

Patients were categorized into 4 groups according to the underlying heart disease: primary electrical disease, congenital heart disease (CHD), cardiomyopathy, and others. Patients with both CHD and long QT syndrome were classified into the primary electrical disease group for group comparison by age at ICD implantation, appropriate and inappropriate shocks, complications, and lead failure. Primary electrical diseases included inherited channelopathy and idiopathic ventricular fibrillation (VF). Acute complications were defined as complications that occurred within 1 month of ICD implantation.

This study was approved by the 5 institutional review boards. The study was conducted in accordance with the Declaration of Helsinki. The institutional review boards

waived the need for informed consent from the patients to be included in the analyses and the need for review by a critical event committee because of the retrospective nature of the study, and the absence of patient identification data.

Statistical Analysis

Continuous variables were expressed as mean±standard deviation or as median and range, and the values of the normally distributed parameters were compared between groups using Student's t-test. Categorical variables are expressed as frequency (percentage). The Chi-square and Fisher's exact tests were used to compare categorical data between 2 or 3 groups. Kaplan-Meier estimates were used for the analysis of cumulative probability of the freedom from appropriate shock in patients fitted with an ICD for primary and secondary prevention, and for analysis of cumulative lead survival.

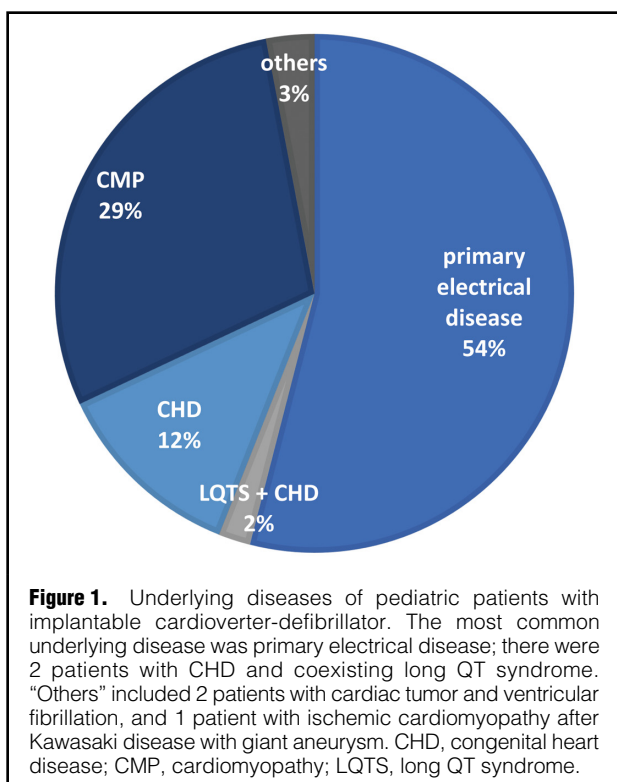
Multivariable analysis using a Cox proportional hazards model was conducted for the prediction of risk of appropriate shock and lead failure using the forward stepwise method, with criteria for entry and exit at $P<0.05$ and $P<0.1$, respectively. Multivariate logistic regression was used to determine the risk factors for inappropriate shock using the forward stepwise method, with criteria for entry and exit at $P<0.05$ and $P<0.1$, respectively.

These statistical analyses were performed using SPSS software (version 23.0, IBM Corporation, Armonk, NY, USA). A P value <0.05 was considered statistically significant.

Results

Patients' Characteristics

Altogether, 99 pediatric patients (68 males, 69%) were



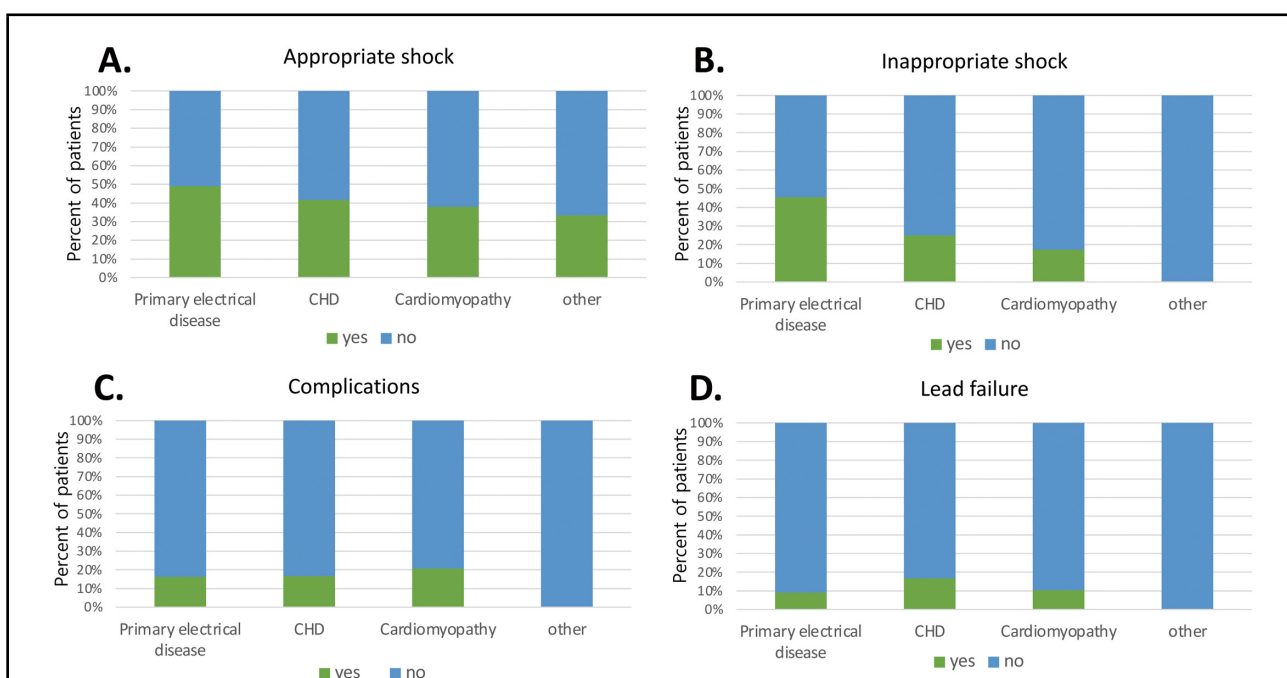
enrolled with a mean follow-up duration of 4.9 ± 3.7 years. The baseline clinical characteristics of patients are shown in **Table 1**. The mean age at ICD implantation was 13.9 ± 4.1 years (median 14.7, range 0.2–18.7 years). The median age at ICD implantation was 14.8 years in the primary electrical disease group, 14.7 years in the CHD group, 14.7 years in the cardiomyopathy group, and 14.1 years in the others group. There was no difference in implantation age according to underlying disease ($P=0.435$). Three patients with cardiac resynchronized therapy with defibrillator were included.

Underlying Heart Disease

Figure 1 shows the underlying diseases. Primary electrical disease accounted for 56% of patients ($n=55$), including 2 with coexisting CHD. Of the patients with primary electrical disease, idiopathic VF was discovered in 23, and inherited channelopathies were found in 32 patients. Among patients with channelopathy, 20 with long QT syndrome, 5 with Brugada syndrome, 3 with catecholaminergic polymorphic ventricular tachycardia (VT), 3 with early repolarization syndrome, and 1 with compound heterozygote mutation of RYR2 and ANK2 were identified. Among the patients with long QT syndrome, the diagnosis was genetically confirmed in 13 patients: 1 patient had type 1 long QT syndrome, 3 patients had type 2, 8 patients had type 3, and 1 had type 7. One patient with SCN5A mutation had both dilated cardiomyopathy and QT prolongation.

Among the patients with long QT syndrome, 2 had coexisting CHD: repaired ventricular septal defect (VSD), and large patent ductus arteriosus, respectively.

Cardiomyopathy was diagnosed in 29% of patients ($n=29$), including hypertrophic cardiomyopathy (HCM) in



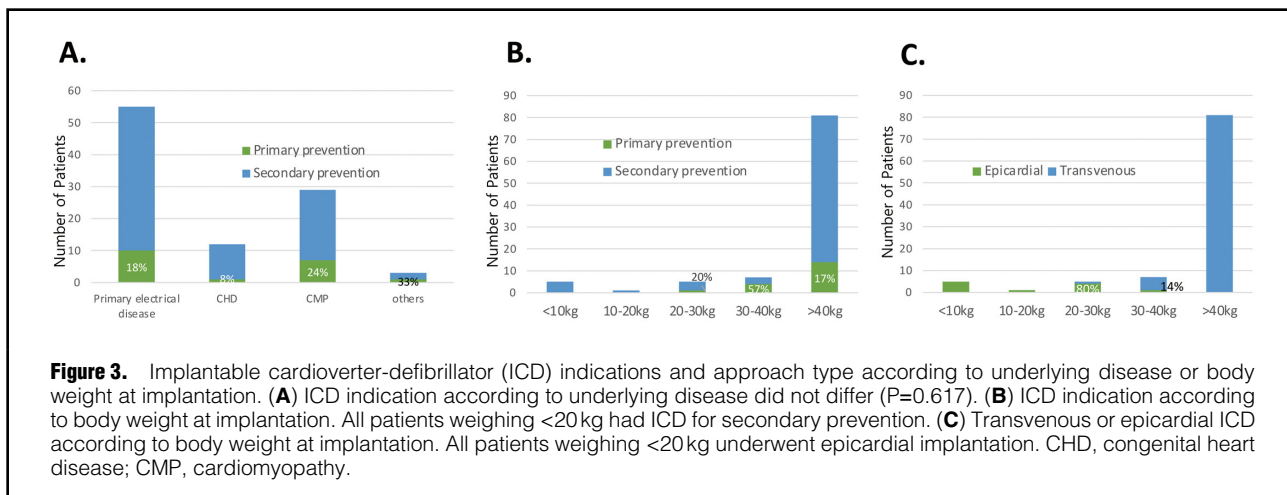


Figure 3. Implantable cardioverter-defibrillator (ICD) indications and approach type according to underlying disease or body weight at implantation. **(A)** ICD indication according to underlying disease did not differ ($P=0.617$). **(B)** ICD indication according to body weight at implantation. All patients weighing <20 kg had ICD for secondary prevention. **(C)** Transvenous or epicardial ICD according to body weight at implantation. All patients weighing <20 kg underwent epicardial implantation. CHD, congenital heart disease; CMP, cardiomyopathy.

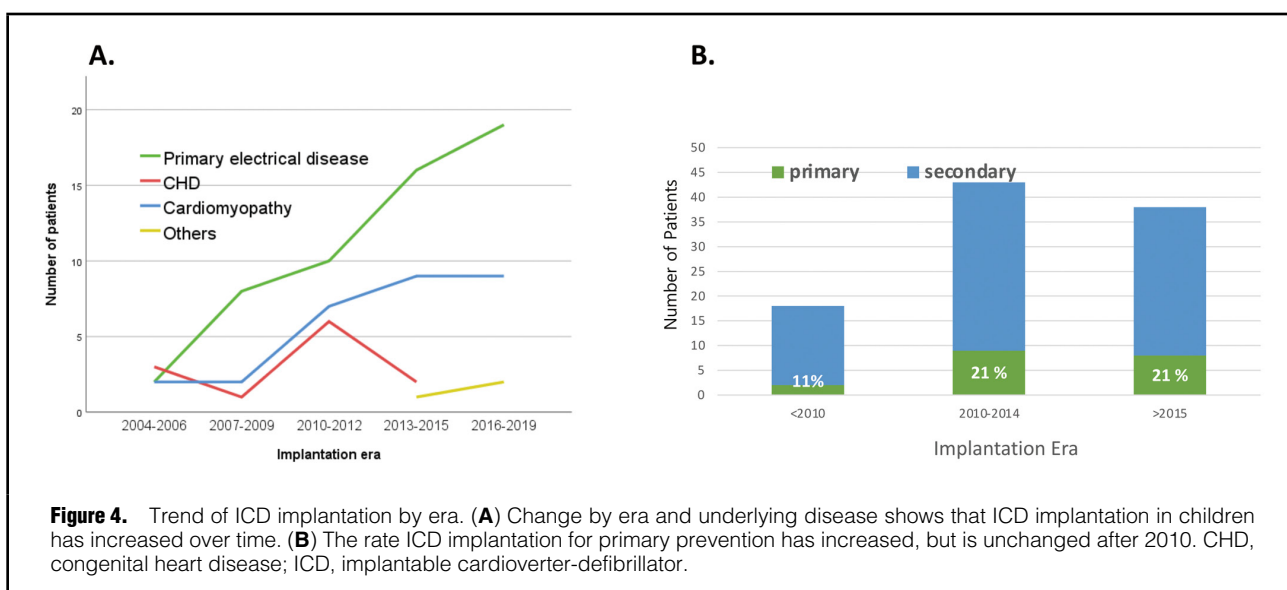


Figure 4. Trend of ICD implantation by era. **(A)** Change by era and underlying disease shows that ICD implantation in children has increased over time. **(B)** The rate ICD implantation for primary prevention has increased, but is unchanged after 2010. CHD, congenital heart disease; ICD, implantable cardioverter-defibrillator.

22, dilated cardiomyopathy in 6, and uremic cardiomyopathy in 1.

A total of 12 patients (12%) were classified into the CHD group. All patients were under follow-up after corrective surgery. Of them, 4 had tetralogy of Fallot, 3 had VSD, and there was 1 patient each with transposition of great arteries, Taussig-Bing anomaly, Ebstein anomaly, congenital aortic steno-insufficiency, and congenitally corrected transposition of great arteries.

Among the patients with repaired VSD, 1 had pacemaker-induced cardiomyopathy after pacemaker implantation for postoperative complete atrioventricular block, 1 had undergone aortic valve replacement 17 years after VSD repair due to severe steno-insufficiency of the aortic valve, and 1 patient had severe pulmonary hypertension.

Other underlying diseases included cardiac tumor with VF in 2 patients, and ischemic cardiomyopathy after Kawasaki disease with giant aneurysm in 1.

Figure 2 shows the outcomes of ICD implantation according to underlying heart disease.

Primary Prevention vs. Secondary Prevention

ICDs were implanted for primary prevention in 19 patients (19%): 10 of 55 patients (18%) with primary electrical disease, 1 (8%) of 12 CHD patients, 7 (24%) of 29 cardiomyopathy patients, and 1 patient (33%) of the others group (**Figure 3A**). Among 32 patients with inherited channelopathy, 10 (31%) had ICD for primary prevention. There were no differences in the proportion of primary or secondary prevention cases among the patient groups with underlying diseases ($P=0.617$).

There were 6 patients who weighed <20 kg at ICD implantation, and all of those patients underwent epicardial ICD implantation for secondary prevention (**Figure 3B,C**). Among them, 4 had primary electrical disease, 1 had HCM, and 1 had a cardiac tumor. ICD placements have increased over time in patients with primary electrical disease and cardiomyopathy, and there was an increase in primary prevention indications by time period; the ratio of primary prevention was 11% and 22% before and after 2010, respectively. However, the primary prevention ratio did not change anymore after 2010 (**Figure 4**).

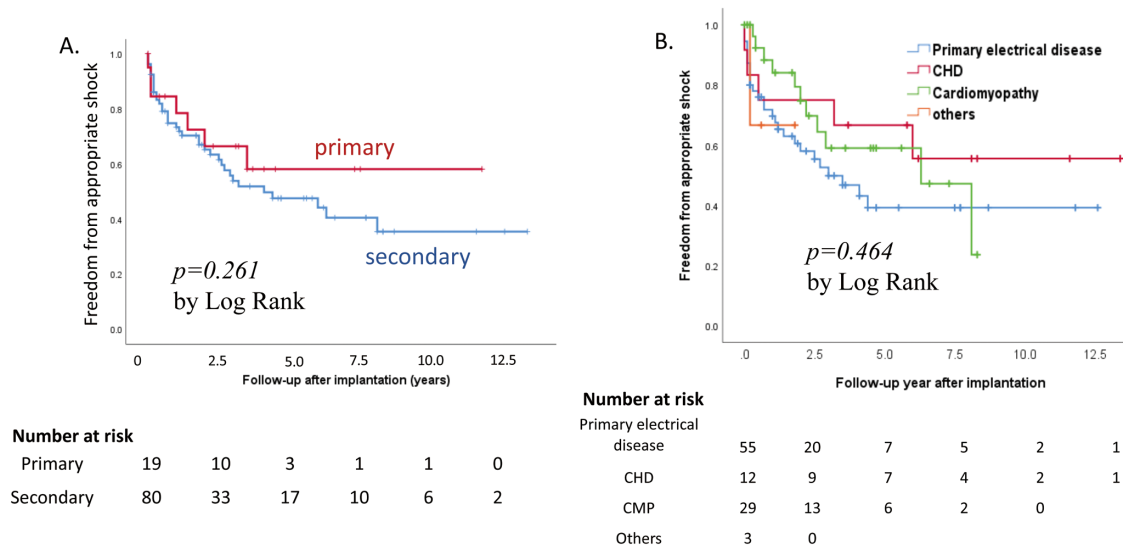


Figure 5. Kaplan-Meier estimates for analysis of appropriate shock discharge-free survival in those who received an ICD according to ICD indication (**A**) and underlying heart disease (**B**). There was no difference in appropriate shock according to ICD indication or underlying heart disease ($P=0.261$, and $P=0.464$, respectively). CHD, congenital heart disease; ICD, implantable cardioverter-defibrillator.

Table 2. Predictors of Appropriate Shocks by Univariate and Multivariate Analyses				
Univariate analysis	Total (n=99)	Appropriate shock		P value
		Yes (n=44)	No (n=55)	
Male	68	31 (46%)	37	0.734
Follow-up duration (years)		6.0±3.7	4.0±3.5	0.009
Age at implantation (years)		14.1±3.9	13.8±4.3	0.725
Primary prevention	19	6 (32%)	13	0.209
Secondary prevention	80	38 (48%)	42	
Primary electrical disease	55	27 (49%)	28	
Congenital heart disease	12	5 (42%)	7	
Cardiomyopathy	29	11 (38%)	18	
Others	3	1 (33%)	2	0.761
Channelopathy	32	19 (59%)	13	
Idiopathic VF	23	8 (35%)	15	
Cardiac arrest	72	35 (49%)	37	
Pre-implant VT	28	15 (54%)	13	
Pre-implant VF	60	28 (47%)	32	0.581
Nonsustained VT	14	7 (50%)	7	0.652
SVT	8	1 (13%)	7	0.075
Syncope	40	20 (50%)	20	0.36
Family history for SCD	17	7 (41%)	10	0.766
LV dysfunction (<35%)	9	3 (33%)	6	0.727
High-rate ICD therapy zone, n (%)	58	23 (40%)	35	0.254
Multivariate analysis (Cox hazard model)	Hazard ratio		95% CI	P value
Cardiac arrest	2.579		1.195–5.536	0.015
Pre-ICD VT	2.037		1.108–4.092	0.031
Channelopathy	2.344		1.333–4.554	0.006

CI, confidence interval; LV, left ventricle; SVT, supraventricular tachycardia. Other abbreviations as in Table 1.

Table 3. Risk Factors for Inappropriate Shocks by Univariate and Multivariate Analyses

Univariate analysis	Total	Inappropriate shock		P value
		Yes (n=33)	No (n=66)	
Age at implantation (years)		14.4±4.2	13.7±4.1	0.449
Follow-up duration (years)		5.8±3.9	4.5±3.5	0.005
Male	68	24 (35%)	44	0.54
Primary prevention	19	5 (26%)	14	0.47
Secondary prevention	80	28 (35%)	52	
Primary electrical disease	55	25 (46%)	30	0.031
Congenital heart disease	12	3 (25%)	9	
Cardiomyopathy	29	5 (17%)	24	
Others	3	0	3	
Channelopathy	32	12 (38%)	20	0.543
Idiopathic VF	23	13 (57%)	10	0.007
ICD insertion era				
<2010	18	10 (56%)	8	0.086
2010–2014	43	12 (28%)	31	
≥2015	38	11 (29%)	27	
LV dysfunction (<35%)	9	2 (22%)	7	0.458
Cardiac arrest	72	25 (35%)	47	0.632
Lead failure	10	6 (60%)	4	0.079
Pre-implant VF	60	24 (40%)	36	0.081
Pre-implant VT	28	8 (29%)	20	0.528
Nonsustained VT	14	4 (29%)	10	0.769
SVT	8	4 (50%)	4	0.432
Family history of SCD	17	6 (35%)	11	0.851
Syncope	40	12 (30%)	28	0.562
High-rate ICD therapy zone, n (%)	58	19 (33%)	39	0.885
Multivariate analysis (log regression)		Odds ratio	95% CI	P value
Primary electrical disease		4.915	1.787–13.518	0.002
Follow-up duration (years)		1.160	1.022–1.319	0.023

Abbreviations as in Tables 1,2.

ICD Shock Therapy

Appropriate shock was delivered in 44 patients (44%) after a mean follow-up interval of 1.6 ± 1.9 years, with a median of 3 shocks (range, 1–38) per patient. One patient with laminopathy and dilated cardiomyopathy with apical aneurysm and myocardial fibrosis on MRI had frequent appropriate ICD shock for VT after ICD implantation for secondary prevention. Antitachycardia pacing was turned on in 76 patients, with 15 (20%) experiencing VT termination by antitachycardia pacing. Patients with primary and secondary prevention indications received their first appropriate shock 1.3 ± 1.7 years (median 1.2, range 6 days to 3.5 years) and 1.6 ± 2.0 years (median 0.7 years, range 2 days to 8.1 years) after ICD implantation, respectively. Appropriate shock rates did not differ between patients with primary and secondary prevention indications (32% vs. 48%, $P=0.209$; **Figure 5A**). Among 19 patients with an indication for primary prevention, 5 of 10 patients (50%) with channelopathy and 1 of 7 patients (14%) with cardiomyopathy experienced appropriate shock therapy. There were no significant differences in underlying heart disease (**Figure 5B**), ventricular dysfunction, unexplained syncope, family history of SCD, nonsustained VT, or sex for appropriate shock delivery (**Table 2**). In the multivariate analysis, pre-ICD cardiac arrest, pre-ICD sustained VT, and channelopathy were independently associated with appropriate shocks. A total of 49 patients had a successful VT

termination by antitachycardia pacing or appropriate shock therapy; among them, 7 and 42 patients had an ICD for primary and secondary prevention, respectively.

Inappropriate shocks occurred in 33 patients within a mean follow-up period of 5.8 years. Inappropriate shock therapy most frequently occurred in patients with primary electrical disease in the underlying disease group ($P=0.031$, **Figure 2B**). In the multivariate analysis, the risk factors for inappropriate shock were primary electrical disease and long follow-up duration (**Table 3**). The causes of inappropriate shock therapy were sinus tachycardia in 16 patients, supraventricular tachycardia in 9, T wave oversensing in 5, lead failure in 2, nonsustained VT in 1, and noise oversensing in 1 patient.

A high-rate ICD therapy zone was set in 58 patients (59%). Mortality was not increased in patients with a high-rate therapy zone compared to those with a low-rate therapy zone (0% vs. 7.3%, $P=0.068$). A high-rate ICD therapy zone was associated with neither appropriate nor inappropriate shock. However, in patients with idiopathic VF, patients with a high-rate ICD therapy zone had less frequent incidences of appropriate and inappropriate shock ($P=0.001$ and $P=0.027$, respectively) than with the other underlying heart diseases.

A total of 95 patients were in ventricular pacing mode; 74 and 21 patients were in VVI and DDD pacing mode, respectively. Ventricular pacing was <1% in 68 patients,

1–5% in 12, 5–20% in 4, 20–40% in 5, 40–80 in 1, 80–98% in 2, and 98–100% in 3 patients. Ventricular pacing rate was not associated with appropriate or inappropriate shock ($P=0.215$ and $P=0.492$, respectively).

Complications

A total of 17 patients (17%) had 22 complications related to ICD; 3 patients had acute complications: 2 had lead dislodgement, while 1 had hemothorax. Chronic complications were lead failure in 10 patients, vein occlusion in 2, skin erosion in 3, infection in 2, and psychological problems, including anxiety and depression, in 2. Complications occurred more frequently in patients who underwent ICD implantation before 2010 than after 2010 (33% vs. 12%, $P=0.027$). However, age at implantation, sex, body weight, height, somatic growth, or use of the epicardial or transvenous approach was not associated with complications. Complications did not differ according to the underlying disease (**Figure 2C**).

Shock Coil Lead Failure

A total of 108 shock coil leads were placed in 99 patients. Of these 108 leads placed, 96 were transvenous shock leads, 11 were epicardial shock leads, and 1 was a subcutaneous shock lead. Epicardial ICD implantation was performed in patients with a small body size. The median body weight of patients with epicardial implantation was 16.8 kg (range, 3.9–33.2 kg).

A total of 10 shock leads failed (2.3% per year) during a mean follow-up of 4.4 ± 3.4 years. Among them, there was only 1 epicardial shock lead; all the others were transvenous leads. Actual survival rates for all leads were 99%, 93%, and 89% at 1, 3, and 5 years after ICD implantation, respectively (**Supplementary Figure**). Of the 10 failed shock leads, 9 were replaced: 4 leads were extracted, and 5 remained. Abnormal rise in impedance in 2 patients (including 1 with ICD shock storm), noise/T wave oversensing in 2 patients, ICD pocket infection with skin erosion in 1, and lead fracture in 3 patients were identified as causes of lead change. Fidelis (Medtronic, Inc., Minneapolis, MN, USA) or Riata (St. Jude Medical, Sylmar, CA, USA), lead size, age at implantation, number of chambers (dual chamber vs. single chamber), number of coils (single coil vs. dual coil), type (screw type vs. tinned type), lead location (epicardial vs. transvenous), and underlying disease were not associated with lead failure. Generator change was performed in 25 patients, with a mean interval of 5.6 ± 0.6 years from initial ICD implantation.

Mortality

In total, 3 patients died and 1 underwent heart transplantation during follow-up. The causes of death were heart failure in 1 patient with SCN5A mutation with QT prolongation and dilated cardiomyopathy, and SCD in 2 patients (1 with ischemic cardiomyopathy after Kawasaki disease with giant coronary aneurysm, and 1 with HCM). One patient with laminopathy and dilated cardiomyopathy received a heart transplant because of frequent ICD shock therapy due to medically intractable VT and progressive heart dysfunction. There were no ICD-related deaths.

Discussion

This is the first clinical analysis of the outcomes of shock therapies for pediatric patients with ICD in an Asian pop-

ulation. There are increasing numbers of pediatric patients with ICD for primary or secondary prevention, with a high appropriate shock rate of 44%. However, the rate of primary prevention is still low compared with data from Western countries (15–19% vs. 42–60%).^{3,7–11}

Asakai et al reported a trend in pediatric ICD therapy using data from a Japanese nationwide registry, which showed a relatively low utilization of the treatment for primary prevention (15%),⁷ as was also shown in our series. However, data from both Japan and Korea showed a relatively high appropriate shock therapy rate (44%) compared with Western studies, which reported appropriate shock rate of 19–31%.^{8,9} Studies in children and young adults have reported that appropriate shocks are more common in patients with ICD for secondary prevention than in those with a primary prevention indication.^{10–12} However, there was no difference in appropriate shock therapy between primary and secondary prevention in this study; the appropriate shock rate was also substantial (32%) in patients with a primary prevention indication. A total of 7 of 19 patients (37%) with a primary prevention indication experienced life-saving interventions such as appropriate ICD shock and successful VT termination by antitachycardia pacing. Among the underlying diseases, channelopathy was significantly associated with appropriate shock therapy, which differed from other studies reporting no significant difference in appropriate shock therapy among the underlying diseases.^{10,11} For the patients with inherited arrhythmia syndrome, we implanted ICDs with reference to the consensus statements.¹³ Although based on nonrandomized studies, 50% of patients with channelopathy who had an ICD for primary prevention experienced appropriate shock.

ICD implantation for primary prevention in children has been reported to account for 21–52% before 2010,^{5,9,10,14} but 60% of pediatric or CHD patients and 80% of the adult cohort from 2010 to 2016, according to data from the American National Cardiovascular Data Registry of the American College of Cardiology Foundation.³ However, this is quite different from Asian data. As survival benefits of ICD for primary prevention in patients at high risk of SCD have been reported in large-scale prospective randomized trials and registry data in adults, ICD implants in children also increased dramatically.^{2,3,15–17} In Korea, reimbursement guidelines of ICD for primary prevention for pediatric and CHD patients have been expanded in line with global guidelines, with subsequent increase in the application of ICD. Subcutaneous ICD has been available since March 2019 with national insurance coverage in Korea. Long-term experience in teenagers showed that 26% of appropriate shock events and 16% of inappropriate shock events happened without major complications, which is comparable to transvenous ICD.¹⁸ In children who need life-long device therapy, subcutaneous ICD may be good option if antitachycardia pacing is not needed. However, the perception of device implantation among primary care physicians and pediatricians, as well as patients and their families, is still conservative, which might serve as a barrier to the regularization of ICD implantation in Korea. It might be important to inform and educate people about the risk of SCD and the effectiveness of these devices as prevention.

Inappropriate shock occurred in 33% of the study patients, which is not low. The most common cause of inappropriate shock therapy in this study was sinus tachy-

cardia, followed by supraventricular tachycardia, T wave oversensing, lead failure, and nonsustained VT. Additionally, the risk factors for inappropriate shock were primary electrical disease and follow-up duration. As most of the patients with primary electrical disease had anatomically normal hearts, they may have more active lifestyles than patients with CHD or cardiomyopathy, and sinus tachycardia from increased activity could result in inappropriate shock. This can be reduced by programming, including higher rate cut-off (>200/min) for younger patients and the use of supraventricular tachycardia discrimination enhancements and longer detection duration.^{19,20} Our study also showed that a high-rate therapy zone was associated with both low inappropriate shock and low appropriate shock, without increased mortality, in patients with idiopathic VF.

The MADIT II and the SCD in Heart Failure trials showed that patients receiving inappropriate shocks, as well as appropriate shocks, had an increased risk of death.^{21,22} Appropriate shock is clearly associated with ventricular arrhythmia, indicating that the patients have an arrhythmogenic substrate and poor prognosis, but the mechanism of increased risk of death in patients receiving inappropriate shocks remains unclear. ICD implantation can be psychologically distressing, especially for young patients.²³ Dewitt et al reported that primary prevention ICD implantation had a 36% risk of adverse events in a pediatric cohort, and the risk-benefit ratio of ICD therapy increased with time.⁸ In light of this, ICD implantation in pediatric and CHD patients, especially in cases of primary prevention, needs to be carefully considered on a case-by-case basis with patients and their families fully informed of the risks and benefits of therapy. There have been no randomized studies of ICD in pediatric and CHD patients, and all data are retrospective due to small sample sizes and heterogeneous groups. Therefore, ICD indications in pediatric patients are usually based on adult studies and have a level of evidence of B or C.^{13,24} Further, multicenter prospective studies of pediatric patients with a high risk of SCD are required.

Study Limitations

This study was limited by its retrospective nature. The comparison between the patient groups was limited by heterogeneity in underlying disease, age, and body size, as well as in small sample size. Programming data related to ICD shock were incomplete; the association between programming and shock therapies could not be analyzed. As we did not investigate the timing of inappropriate shock after ICD implantation, a time-dependent risk analysis for inappropriate shock therapy could not be conducted.

Conclusions

The rate of ICD implantation for primary prevention is still low in Korean pediatric patients. However, appropriate shocks and antitachycardia pacing can be successfully delivered to prevent SCD, although complications and inappropriate shock are not uncommon. It is necessary to improve the utilization of ICD as well as reducing complications and selecting the patients with a high risk of SCD.

Disclosure

The authors declare nothing to disclose.

IRB Information

Institutional Review Board of Seoul National University Hospital (no. 1806-028-949); Institutional Review Board of Severance Hospital (no. 4-2018-0879); Samsung Medical Center Institutional Review Board (no. 2018-10-017); Ulsan University Hospital Institutional Review Board (no. S2019-0314); Institutional Review Board of Sejong General Hospital (no. 1840).

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None.

Data Availability

The individual identified participant data will be shared immediately after publication, ending 10 years after publication. The data will be shared on a request basis for anyone via e-mail.

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Supplementary Files

Please find supplementary file(s);
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