

Cardiac Implantable Electronic Devices in Adults with Tetralogy of Fallot



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Patient with repaired tetralogy of Fallot (TOF) sometimes require cardiac implantable electronic devices (CIED) for tachy/bradyarrhythmias. There are no population-based studies of CIED-related outcomes in the adult TOF population. We reviewed the Nationwide/National Inpatient Sample to determine trends in CIED-related admissions in adults with TOF repair. This is a retrospective review of the Nationwide/National Inpatient Sample database from January 1, 2000 to December 31, 2014. There were 18,353 admissions in adults with TOF diagnosis, and of these, CIED were implanted in 792 (4.3%) admissions (CIED-related admissions). Of these 792 CIED-related admissions, pacemakers were implanted in 242 (30.7%) yielding an incidence of 1.3% and implantable cardioverter-defibrillators were implanted in 550 (69.4%) yielding an incidence of 3.0%. In-hospital mortality occurred in 14 (1.8%) of the CIED-related admissions. The mean hospital length of stay was 7.7 ± 1.3 days and inflation-adjusted hospitalization cost was $\$141,860 \pm \$127,516$. In 5-year intervals (2000 to 2004, 2005 to 2009, and 2010 to 2014), there was a temporal increase in the incidence of CIED-related admissions (3.7% vs 4.4% vs 4.9%, $p = 0.006$). There was a similar trend in the age at the time of implantation (37.7 ± 14.2 vs 38.2 ± 13.1 vs 39.0 ± 14.5 years, $p < 0.001$) and Charlson Comorbidity Index (1.1 ± 1.4 vs 1.4 ± 1.8 vs 1.3 ± 1.7 , $p < 0.001$). In conclusion, the incidence of CIED-related admissions was 4.3% and increased over time. Further studies are required to determine if the observed temporal increase in incidence of CIED implantations (particularly implantable cardioverter-defibrillators) is associated with a concomitant increase in incidence of aborted sudden cardiac death. © 2019 Elsevier Inc. All rights reserved. (Am J Cardiol 2019;123:1999–2001)

Surgical repair of tetralogy of Fallot (TOF) is a palliative procedure and most patients have residual or recurrent hemodynamic lesions or arrhythmogenic substrates after TOF repair.^{1,2} These arrhythmogenic substrates manifest as tachy- and bradyarrhythmias in 20% to 50% of adult TOF patients, and are associated with cardiovascular mortality.^{3–7} Cardiac implantable electronic devices (CIED) such as pacemakers and implantable cardioverter defibrillators (ICD) are sometimes required to address these arrhythmias.^{3–7} The use of CIED provide symptomatic and survival benefits in some patients, but are also associated with device-related complications such as device infection, inappropriate shocks, thromboembolism, vascular injury, and need for multiple reinterventions with its associated procedural risks.^{3–7} A recent study from the Mayo Clinic reported CIED-related outcomes in adults with TOF repair.⁸ However, there are no similar population-based studies of CIED-related outcomes in the adult TOF population. We reviewed the Nationwide/National

Inpatient Sample (NIS) to determine trends in CIED-related admissions in adults with TOF repair.

Methods

The NIS is the largest all-payer database of hospital inpatient stays in the United States. The NIS contains discharge data from a 20% stratified sample of community hospitals and is a part of the Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Healthcare Research and Quality.⁹ Information regarding each discharge includes patient demographics, primary payer, hospital characteristics, principal diagnosis, up to 24 secondary diagnoses, and procedural diagnoses. The Mayo Clinic Institutional Review Board approved this study and waived informed consent for patients that provided research authorization.

Using the HCUP-NIS data from 2000 to 2014, we identified adult patients (>18 years) admitted with a primary or secondary diagnosis of TOF (International Classification of Diseases 9 Clinical Modification [ICD-9CM] code 745.2) using a previously described methodology.¹⁰ All hospital admissions with CIED implantations (CIED-related admissions were identified using the ICD-9CM codes for pacemaker implantation (37.80–37.89, 00.50–00.54) and ICD implantation (ICD-9CM 37.94–37.96, 00.51). Patient characteristics (age, sex, and race, socioeconomic status, and primary payer) and hospital characteristics (teaching status and location, bed-size, and region) associated with each

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discharge were identified from the HCUP-NIS database. The Deyo's modification of Charlson Comorbidity Index was used to assess the burden of co-morbid diseases (Supplementary Table 1).^{11,12} The primary outcome was trend in the incidence CIED-related admissions. The secondary outcomes were length of stay and inflation-adjusted hospitalization costs. In order to assess temporal trends, we divided the study period into 5-year intervals (2000 to 2004, 2005 to 2009, and 2010 to 2014).

As recommended by HCUP-NIS, survey procedures using discharge weights provided with HCUP-NIS database were used to generate national estimates. Chi-square and *t* Tests were used to compare categorical and continuous variables respectively. We assessed unadjusted trends of CIED-related admissions over the study duration over the study duration. Two-tailed $p < 0.05$ was considered statistically significant. All statistical analyses were performed using SPSS version 25.0 (IBM Corp, Armonk, New York).

Results

During the period between January 1, 2000 and December 31, 2014, there were an estimated 18,353 admissions in adults with TOF diagnosis, of which CIED implantation was performed in 792 (4.3%) admissions. The baseline characteristics of the cohorts with and without CIED-related admissions are presented in Table 1. Compared with admissions without CIED implantations, the patients in the CIED-related admissions were older, more likely to be white, have private insurance, and come from a higher socioeconomic stratum. Similarly CIED-related admissions were more likely to occur in large urban hospitals. CIED-related admission was associated with higher rates of cardiac arrest (2.9% vs 1.2%, $p < 0.001$), respiratory failure requiring endotracheal intubation (8.8% vs 5.1%; $p < 0.001$), use of coronary angiography (21.7% vs 9.2%; $p < 0.001$), and right heart catheterization (18.7% vs 7.8%; $p < 0.001$, Supplementary Table 2).

Of these 792 admissions, pacemakers were implanted in 242 (30.7%) admissions yielding an incidence of 1.3% (242 of 18,353), and ICDs were implanted in 550 (69.4%) admissions yielding an incidence of 3.0% (550 of 18,353). In 5-year intervals (2000 to 2004, 2005 to 2009, and 2010 to 2014), there was a temporal increase in the incidence of CIED-related admissions (3.7% vs 4.4% vs 4.9, $p = 0.006$). There was a similar trend in the age at the time of implantation (37.7 ± 14.2 vs 38.2 ± 13.1 vs 39.0 ± 14.5 years, $p < 0.001$) and Charlson Comorbidity Index (1.1 ± 1.4 vs 1.4 ± 1.8 vs 1.3 ± 1.7 , $p < 0.001$).

In-hospital mortality occurred in 14 (1.8%) of the CIED-related admissions, and was similar to mortality for the non-CIED related admissions (1.6%, $p = 0.21$). In the survivors, 83.9% were discharged home, 2.7% to other hospitals, 4.6% to skilled nursing facilities, 8.1% to home with home health care and 0.6% against medical advice. The mean hospital length of stay was 7.7 ± 11.3 days and inflation-adjusted hospitalization cost was $\$141,860 \pm \$127,516$. There was a significant increase in inflation-adjusted hospitalization costs ($\$101,054 \pm \$58,107$, $\$152,530 \pm \$131,787$, and $\$169,908 \pm \$148,860$; $p < 0.001$), but no

Table 1
Baseline characteristics of Tetralogy of Fallot admissions

Characteristic	CIED (n = 792)
Age (years)	42.6 ± 13.9
Female sex	43.8%
Race	
White	77.2%
Black	6.6%
Others	16.2%
Primary payer	
Medicare	20.7%
Medicaid	12.3%
Private	57.1%
Uninsured	6.4%
No charge	2.1%
Others	1.3%
Quartile of median household income for zip code	
0–25th	12.5%
26th–50th	29.0%
51st–75th	23.5%
75th–100th	35.0%
Hospital teaching status and location	
Rural	0.6%
Urban nonteaching	13.9%
Urban teaching	85.5%
Hospital bed-size	
Small	5.3%
Medium	13.9%
Large	80.8%
Hospital region	
Northeast	18.1%
Midwest	23.5%
South	31.1%
West	27.4%
Charlson Comorbidity Index	
0–3	90.7%
4–6	9.3%
≥7	0.0%
Cardiac arrhythmias	
Atrial fibrillation	16.9%
Atrial flutter	15.9%
SVT	4.9%

Represented as percentage or mean ± standard deviation.

CIED = cardiac implantable electronic devices; SVT = supraventricular tachycardia.

significant change in hospital length of stay (9.0 ± 14.9 , 7.5 ± 10.5 and 6.7 ± 7.5 days; $p = 0.08$).

Discussion

In this retrospective review of the NIS database, there were 792 CIED-related admissions in adults with TOF yielding an incidence of CIED-related admission of 4.3%. Of these 792 admissions, pacemakers were implanted in 242 (30.7%) admissions yielding an incidence of 1.3%, and ICDs were implanted in 550 (69.4%) admissions yielding an incidence of 3.0%. In a study of trends of hospitalization in adults with congenital heart disease using the NIS database, Opatowsky et al¹³ reported an incidence of CIED-related admission of 3.9% in adults with congenital heart disease. Of these CIED-related admissions, 38% of the admissions were for ICD implantations whereas 62% were for pacemaker implantations.¹³ In the present study using the same database (*albeit* difference time span), we showed that although the incidence of CIED-related admissions was comparable between TOF patients and the general adult congenital heart disease population, the majority of

the CIED implanted in the TOF patients were ICDs (69% of device implantations in TOF population vs 38% of device implantations in the general adult congenital heart disease population).

There are no population-based studies of CIED-related outcomes in TOF patients. A recent single center study from the Mayo Clinic reported CIED implantation in 21% of the TOF cohort (99 of 465 patients), and among the 99 patients that underwent CIED implantation, 73% received ICDs during the initial implantation or during device revision.⁸ Although a direct comparison cannot be made between this single center study and the current review of the NIS database because of significant differences in study design, both studies show that more than 2/3 of the CIED implanted in TOF patients are ICDs. This is in contrast to the predominance of pacemaker implantations in the rest of the adult congenital heart disease population reported by Opotowsky et al.¹³ Several aspects of TOF surgical repair such as patch closure of ventricular septal defect, right ventricular outflow tract patch and ventriculotomy scars create substrates for ventricular arrhythmias,^{3,5,14,15} which may explain the need for ICDs in this population compared with other adults with congenital heart disease.

We also observed a temporal increase in the incidence of CIED-related admissions from 3.7% to 4.9% during the study period. This is likely due to an “older and sicker” patient population in the different eras, and this speculation is supported by a concomitant temporal increase in the age and Charlson Comorbidity Index at the time of device implantation across the different eras in this study. A similar temporal increase in the number of pacemaker implantations in the United States has been reported.¹⁶ The inflation-adjusted hospitalization cost increased over time even though there was no significant increase in hospital length of stay. This may be related to procedural complexity and a rising cost of healthcare.¹³

One of the limitations of the present study is that the NIS is an administrative database and relies on the accuracy of the diagnosis codes and only provides very limited clinical data required for more robust analysis. Another limitation is that the NIS database contains data of hospital admissions and not individual patients, and as a result the present study reported incidence of CIED-related admissions instead of incidence of CIED implantations. We were unable to assess the incidence of device-related complications because of the same reason.

In summary, we reviewed 18,353 admissions in adults with TOF diagnosis, and the incidence of CIED-related admissions was 4.3% with a temporal increase from 3.7% to 4.9% during the study period. In contrast to data from the general adult congenital heart disease population, more than 2/3 of CIED implanted in the TOF population are ICDs. Further population-based studies are required to assess trends in device-related complications and to determine if the observed temporal increase in CIED implantations (particularly ICDs) is associated with a concomitant increase in the incidence of aborted sudden cardiac death.

Supplementary materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.amjcard.2019.03.010>.

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