Safety and Efficacy of Implantable Cardioverter-Defibrillator During Pregnancy and After Delivery

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Background: There are few studies of pregnancy and delivery in patients with an implantable cardioverter-defibrillator (ICD). The purpose of this study was to investigate maternal and fetal outcome in these patients.

Methods and Results: Six pregnant women with an ICD were retrospectively reviewed. All women underwent implantation of an ICD before pregnancy and delivered at the National Cerebral and Cardiovascular Center. The mean age at pregnancy and the mean follow-up period after ICD implantation were 28±3 years old and 5±3 years, respectively. There was no device-related complication during pregnancy. In 4 women, the number of tachyarrhythmias such as non-sustained ventricular tachycardia increased after the end of the second trimester of pregnancy and anti-arrhythmic medications were gradually increased. No patient received discharges or shocks from the ICD during pregnancy, however, and only one required anti-tachycardia pacing at 27 weeks’ gestation. Mean gestational age at delivery was 37±2 weeks and all deliveries were by cesarean section, including 5 as emergency deliveries due to a fetal indication. After delivery, 2 mothers had reduced cardiac function and 1 received an ICD shock for the first time.

Conclusions: Pregnancy did not increase the risk of an ICD-related complication under appropriate management. Additional caution might be required in the postpartum period as well as during pregnancy and labor. (Circ J 2013; 77: 1166–1170)

Key Words: Beta-blocker; Delivery; Implantable cardioverter-defibrillator; Pregnancy; Ventricular tachycardia

Cardiac disease complicates approximately 1% of all pregnancies, and women with arrhythmias comprise only a small number of these cases. Although arrhythmias are uncommon during pregnancy, they may jeopardize the health of both mother and fetus. Ventricular tachyarrhythmia may be triggered during pregnancy as a result of hemodynamic changes and autonomic nervous system modification. Recurrence of malignant ventricular arrhythmias can be treated by defibrillation and anti-tachycardia pacing (ATP) to prevent sudden cardiac arrest. An implantable cardioverter-defibrillator (ICD) improves survival in patients with life-threatening arrhythmias. The number of women with congenital heart disease continues to increase and the use of an ICD has resulted in an increasing number of these women reaching a reproductive age. Natale et al performed a multicenter retrospective analysis of 44 pregnant women with ICDs and found that the majority completed and tolerated pregnancy without serious complications. There are few studies, however, of pregnancy with an ICD managed at a single center and it remains unclear how to manage pregnant women with ICDs. The aim of this study was to investigate the maternal and fetal outcomes in these patients during pregnancy and after delivery.

Methods

Study Design

The subjects were all pregnant women with an implanted ICD who delivered at the National Cerebral and Cardiovascular Center. Data were retrospectively collected for age at the time of initial ICD implantation and delivery; heart disease and arrhythmia; New York Heart Association class; anti-arrhythmic medications and other anti-arrhythmic treatment; indication...
for ICD implantation; device information; device-related complications; number of ICD discharges and shocks; gestational age at delivery; mode of delivery; total blood loss at delivery; device status at time of delivery; and fetal and neonatal complications.

Data for maternal age, gestational age, left ventricular ejection fraction (LVEF), total blood loss during cesarean section, complications.

Device Implantation
All ICDs were implanted via transvenous placement of a ventricular lead for defibrillation and pacing using standard techniques under fluoroscopic guidance. Pacemaking, sensing and defibrillation thresholds were tested during implantation. The devices used were manufactured by Medtronic (Minneapolis, MN, USA), Guidant (St Paul, MN, USA), and Boston Scientific (Natick, MA, USA).

Management of Pregnancy and Delivery
Fetal growth restriction was defined as an estimated fetal body weight <–1.5 SD of the Japanese standard value. Non-reassuring fetal status was diagnosed by cardiotocogram. Induction and augmentation of labor was performed according to obstetric or maternal indications using i.v. oxytocin following meconium-stained amniotic fluid. Augmentation of labor was performed according to obstetric or maternal indications using i.v. oxytocin following meconium-stained amniotic fluid.

Results
Baseline Characteristics
Six Japanese women with an ICD who delivered between 2006 and 2012 were enrolled in the study. The mean follow-up after ICD implantation was 5±3 years (range, 2–9 years). The baseline pre-pregnancy characteristics of the 6 patients are given in Table 1. The indication for ICD implantation was second- or shocks from the ICD, and only 1 (patient 1) received ATP therapy.

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arrest caused by VF at 30 years of age. ICD implantation was performed following aortic valve replacement with a Carpentier-Edwards perimount valve. Patient 4 had sick sinus syndrome with repeated syncpe and underwent permanent pacemaker implantation (dual-chamber inhibits and triggers) at 23 years old. This patient had wide QRS tachycardia, and ICD implantation was performed for spontaneous VT causing hemodynamic instability. This patient had experienced 16 ICD shocks in response to VF following paroxysmal atrial fibrillation (PAF) caused by acute pharyngitis. Patient 5 had repeated syncpe once a year since 3 years of age and had been diagnosed with long QT syndrome type 1 on genetic testing at 10 years old. After introduction of atenolol at 18 years old, syncpe reduced to once every 3 years. The severe long QT syndrome was linked to a double-point mutation in the potassium voltage-gated channel KQT-like subfamily, member 1 in re-testing at 25 years old. Her corrected QT time was 470–500 ms. Patient 6 had experienced repeated syncpe since 25 years of age and had been diagnosed with long QT syndrome type 2 on genetic testing at 26 years old. Her corrected QT time was 430–470 ms.

Patients 1 and 4 had implanted dual-chamber ICDs with DDI pacing. The other 4 patients had implanted single-chamber ICDs with VVI pacing. All devices were programmed for the VF zone and (patients 1–4) were also programmed for the VT zone with ATP such as burst and ramp pacing and cardioversion. Patient 2 had inappropriate ICD shocks due to sinus tachycardia, and the VT zone was used only for sensing before pregnancy. Patient 3 had no inappropriate ICD shocks due to discrimination of supraventricular tachycardia. Patient 4 received propranolol before pregnancy to avoid a recurrence of PAF during pregnancy.

Pregnancy and Labor
Baseline pregnancy and labor patient characteristics are given in Tables 2, 3. There were no device-related complications. In 4 women the number of arrhythmias (patients 1–3, non-sustained VT; patient 4, PAF) increased after the end of the second trimester and anti-arrhythmic medications were gradually increased. During pregnancy, no patient received discharges or shocks from the ICD, and only 1 (patient 1) received ATP at 27 weeks’ gestation. After ATP in patient 1, the detection zone was changed from 2 zones (VT 180 beats/min with 3 burst ATPs; VF 240 beats/min) to 3 zones (VT-1 160 beats/min with 3 burst and 3 ramp ATPs; VT-2 180 beats/min with 3 burst ATPs; VF 220 beats/min).

Labor was induced as planned in 3 cases: 2 (patients 1, 2)
After Delivery

Baseline post-delivery patient characteristics are listed in Table 3. All but 2 women with DCM (patients 1, 2) breast-fed the neonate. Patient 1 had reduced LVEF before delivery and recovered within 1 month after delivery. She received an appropriate ICD shock after unsuccessful ATP for VT at 6 weeks after delivery. After an increase of β-blockers and construction of 2 more burst ATPs, there were no ICD shocks except for 6 ATP shocks for VT in 1 year after delivery. All ATP shocks were appropriate and successful. Patient 2 had reduced LVEF for 1 week and recovered within 1 month after delivery. In patient 4, PAF increased until 1 week after delivery. In the 2 for maternal indication of increased non-sustained VT and reduction of cardiac function at 37 weeks’ gestation, and 1 (patient 5) for fetal indication of fetal growth restriction and growth arrest at 35 weeks’ gestation. All patients delivered by cesarean section under spinal and epidural anesthesia due to fetal indications. The ICD was turned off in patients 1–5 and turned on in patient 6 during labor and cesarean section. Electrocautery was not used during cesarean section. During delivery, there were no syncopal or hypotensive episodes and no patients received ICD discharges or shocks.

Table 2. Baseline Pregnancy Patient Characteristics

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age at conception</th>
<th>LVEF in pregnancy (%)</th>
<th>NYHA class</th>
<th>No. ICD shocks</th>
<th>LVEF at delivery (%)</th>
<th>Anti-arrhythmic medications (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1st trimester</td>
</tr>
<tr>
<td>1</td>
<td>26</td>
<td>61.1</td>
<td>2</td>
<td>0</td>
<td>48.4</td>
<td>Metoprolol 40</td>
</tr>
<tr>
<td>2</td>
<td>27</td>
<td>47.7</td>
<td>2</td>
<td>0</td>
<td>44.2</td>
<td>Carvedilol/ Mexiletine/ Aprindine/ Digoxin 5/200/ 20/0.125</td>
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<tr>
<td>3</td>
<td>33</td>
<td>76.1</td>
<td>1</td>
<td>0</td>
<td>72.4</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>61.8</td>
<td>1</td>
<td>0</td>
<td>68.8</td>
<td>Bisoprolol 2.5</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>54.8</td>
<td>1</td>
<td>0</td>
<td>51.3</td>
<td>Atenolol 50</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>56.2</td>
<td>1</td>
<td>0</td>
<td>57.3</td>
<td>Bisoprolol 5</td>
</tr>
</tbody>
</table>

Mean ± SD 28±3 60±10 57±11

ATP, anti-tachycardia pacing. Other abbreviations as in Table 1.

Table 3. Baseline Delivery Patient Characteristics

<table>
<thead>
<tr>
<th>Patient</th>
<th>During delivery</th>
<th>After delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weeks at delivery</td>
<td>ICD mode</td>
</tr>
<tr>
<td>1</td>
<td>37</td>
<td>Off</td>
</tr>
<tr>
<td>2</td>
<td>37</td>
<td>Off</td>
</tr>
<tr>
<td>3</td>
<td>33</td>
<td>Off</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>Off</td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td>Off</td>
</tr>
<tr>
<td>6</td>
<td>38</td>
<td>On</td>
</tr>
</tbody>
</table>

Mean ± SD 37±2 547±384 53±13 19±15

Blood loss, total blood loss including amnion at cesarean section; CS, cesarean section; FGR, fetal growth restriction; NRFS, non-reassuring fetal status. Other abbreviations as in Tables 1, 2.

Table 4. Baseline Fetus and Neonate Characteristics

<table>
<thead>
<tr>
<th>Patient</th>
<th>Weeks at birth</th>
<th>Birth weight (g)</th>
<th>Apgar score (1 min)</th>
<th>Apgar score (5 min)</th>
<th>UmA pH</th>
<th>Fetal complications</th>
<th>Neonatal complications</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>37</td>
<td>2,684</td>
<td>7</td>
<td>9</td>
<td>7.312</td>
<td>NRFS</td>
<td>Hypoglycemia, Hyperbilirubinemia</td>
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<tr>
<td>2</td>
<td>37</td>
<td>2,622</td>
<td>8</td>
<td>9</td>
<td>7.283</td>
<td>NRFS</td>
<td>Hypoglycemia, Hyperbilirubinemia</td>
</tr>
<tr>
<td>3</td>
<td>33</td>
<td>1,240</td>
<td>8</td>
<td>9</td>
<td>7.332</td>
<td>FGR</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>2,750</td>
<td>8</td>
<td>9</td>
<td>7.344</td>
<td>NRFS</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td>1,776</td>
<td>9</td>
<td>10</td>
<td>7.268</td>
<td>FGR, NRFS</td>
<td>Hypoglycemia, Hyperbilirubinemia, LQTS type1</td>
</tr>
<tr>
<td>6</td>
<td>38</td>
<td>2,188</td>
<td>8</td>
<td>10</td>
<td>6.963</td>
<td>FGR, NRFS</td>
<td>Metabolic acidosis, Hypoglycemia, LQTS type2</td>
</tr>
</tbody>
</table>

Mean ± SD 37±2 2,210±603

UmA, umbilical artery. Other abbreviations as in Tables 1, 3.
women (patients 5, 6) with long QT syndrome, the corrected QT time was 505–510 ms and 460–490 ms, respectively; these were almost the same as before pregnancy, and there were no episodes of ventricular arrhythmia after delivery.

Fetus and Neonate Outcome
Baseline characteristics of fetuses and neonates are given in Table 4. Five neonates were born by emergency cesarean section due to non-reassuring fetal status. We observed persistent late decelerations in 3 fetuses and prolonged decelerations in 2 fetuses during labor on cardiotocogram. One neonate (patient 6) had metabolic acidosis that required infusion of bicarbonate. Two neonates (patients 3, 5) were born preterm and 3 (patients 3, 5, 6) were small for date. The 2 neonates of mothers with long QT syndrome (patients 5, 6) were also diagnosed with long QT syndrome on genetic testing. No major complications were observed in the observation period.

Discussion
To our knowledge, this is the largest single-center retrospective study to investigate the outcome of pregnancy in women with an ICD. According to the present 6 cases, pregnancy did not increase the risk of an ICD-related complication under appropriate management (eg, increase of β-blockers and change of the ICD setting), even though the number of ventricular arrhythmias increased after the end of the second trimester of pregnancy. Additional caution might be required in the postpartum period, as well as during pregnancy and labor.

Pregnancy and Ventricular Arrhythmia
Pregnancy is associated with reversible increases in blood volume, heart rate and cardiac output.89 In some instances, these changes can trigger maternal cardiac deterioration during pregnancy.10–13 Some studies have suggested that pregnancy may have an adverse effect on subsequent maternal cardiac outcome, perhaps as a result of the hemodynamic burden on ventricular structure and function during pregnancy.14–17 Clearly, special caution is required for patients with an ICD with regard to cardiac function and arrhythmias. In this context, pregnancy can be thought of as a physiological stress test, and complications during pregnancy identify women at high risk for late events.18 We monitored the ICD settings from before pregnancy to prevent inappropriate ICD discharges due to heart rate increases during pregnancy. In 1 case, β-blockers were introduced before pregnancy to avoid a recurrence of PAF during pregnancy. Although the number of tachyarrhythmias increased in all women after the end of the second trimester except in 2 with long QT syndrome, ICD discharges were not precipitated during pregnancy, when anti-arrhythmic medications were gradually increased and the setting of the ICD was changed.

Balint et al recommended that women at high cardiac risk should receive closer surveillance both during pregnancy and late after delivery.19 Adverse events during pregnancy are associated with higher rates of late events, which makes it important to re-evaluate the cardiac status of women with pregnancy cardiac events more closely after pregnancy.19 In the present study, 1 woman who had ATP at 27 weeks’ gestation received her first ICD shock and several ATP events after delivery despite an increase of anti-arrhythmic medications and a change of the ICD setting. This suggests that additional caution may be required in the postpartum period, as well as during pregnancy and labor.

ICD Mode During Delivery
It remains unclear whether an ICD should be on or off during delivery. In the present study, no arrhythmias or ICD discharges were precipitated during delivery, as also reported by Natale et al.7 In this respect, the status of the ICD during delivery appears to have no effect on the overall outcome. Recurrence of VT, however, decreases placental perfusion due to maternal hypotension and could be dangerous for the fetus. In contrast, ICD shocks are a concern for the safety of the fetus, although the amount of energy transferred to the uterus is very small and the fetal heart has a high fibrillatory threshold.7,20 Based on these considerations, we have recently changed our policy to leave the device turned on during vaginal delivery or cesarean section, with the proviso that electrocautery is not used. Because elevated heart rate during labor may cause inappropriate ICD shock, a multidisciplinary approach involving specialists in maternal fetal medicine, cardiology and anesthesia is needed for total management during labor and delivery for pregnant woman with an ICD. This management needs to be designed specifically to meet these needs at each hospital.

Fetal and Neonatal Complications
Three of the present fetuses (50%) had fetal growth restriction. Gelson et al found a significant reduction in fetal growth rates associated with maternal heart disease, and concluded that the presence of maternal cyanosis and reduced cardiac output are the most significant predictors of this condition.21 These findings, however, are not necessarily applicable to the present cases.

In the present study, 5 patients (83%) were given β-blockers, and 2 of these experienced fetal growth restriction. Beta-blockers are considered to be reasonably safe for use during pregnancy, but may rarely cause fetal growth restriction, bradycardia, apnea, hypoglycemia, and hyperbilirubinemia of neonates.22–25 Five patients delivered by emergency cesarean section due to non-reassuring fetal status (ie, hypoxia of the fetus or severe cord compressions in the uterus, which also occurs during labor in those without an ICD). Beta-blockers are thought to have little effect in the unstressed fetus, but adverse effects may become apparent during fetal distress because these drugs impair fetal response to distress.25 Although the number of cases is small, β-blockers may have been related to fetal and neonatal complications, but these drugs are clearly effective for preventing life-threatening arrhythmias and inappropriate ICD shocks.26 We consider use of β-blockers permissible during pregnancy on the condition that efficacy surpasses complications. Furthermore, as few drugs as possible and the safest drugs at the lowest effective doses should be chosen for use in pregnancy.

Study Limitations
There are several limitations in the study, including its retrospective design and the relatively small sample size. First, the present 6 patients were relatively low risk: ICD shocks were delivered before pregnancy only in 3 of the 6 patients; clinically documented ventricular arrhythmias were heterogeneous (VT in 2 patients and VF in the other 4 patients); and LVEF was preserved in 4 of the 6 patients. Because risk of recurrence of ventricular arrhythmias would be strongly associated with the clinical and arrhythmia background of pregnant women, further investigation is needed, including in patients with high risk for VT and VF. Second, it may be safe to leave the device turned on during vaginal delivery or cesarean section, but the sample size may have been too small to prove this.
point. There were no ICD shocks during pregnancy, and therefore we are unable to determine whether ICD shocks are safe for the fetus. Third, the follow-up period after delivery was insufficient to permit analysis of long-term morbidity and mortality, which prevented evaluation of potential long-term benefits and the risks of use of an ICD after delivery. The present study, however, is worthwhile as a report of a single-center experience of a rare condition that we were able to follow up in 5 patients (83%) more than 1 year after delivery.

Conclusions

In the present 6 patients with an ICD, pregnancy did not increase the risk of an ICD-related complication under appropriate management (ie, increase of β-blockers and changing of the ICD setting). Additional caution may be required in the postpartum period as well as during pregnancy and labor. Guidelines are required for pregnancy and delivery in patients with an ICD. Further large prospective studies are needed to establish the most appropriate treatment strategies.

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Disclosure

None of the authors have a conflict of interest to disclose.

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