JAMA Cardiology | Brief Report

Effectiveness of Implanted Cardiac Rhythm Recorders With Electrocardiographic Monitoring for Detecting Arrhythmias in Pregnant Women With Symptomatic Arrhythmia and/or Structural Heart Disease

A Randomized Clinical Trial

Karen Sliwa, MD, PhD; Feriel Azibani, PhD; Mark R. Johnson, MBBS, MRCO; Charle Viljoen, MBChB, MMed, FCP; Johann Baard, MBChB; Ayesha Osman, MBChB; Olivia Briton, DGNM; Mpiko Ntsekhe, MD, PhD; Ashley Chin, MBChB, MPhil

IMPORTANCE Arrhythmias are an important cause of maternal morbidity and mortality but remain difficult to diagnose.

OBJECTIVE To compare implantable loop recorder (ILR) plus 24-hour Holter electrocardiographic (ECG) monitoring with standard 24-hour Holter ECG monitoring alone in terms of acceptability, ability to identify significant arrythmias, and effect on management and pregnancy outcome in women who were symptomatic or at high risk of arrythmia because of underlying structural heart disease.

DESIGN, SETTING, AND PARTICIPANTS This single-center, prospective randomized clinical trial recruited 40 consecutive patients from the Cardiac Disease and Maternity Clinic at Groote Schuur Hospital in Cape Town, South Africa. Pregnant patients with symptoms of arrhythmia and/or structural heart disease at risk of arrhythmia were included.

INTERVENTION Patients were randomized to standard care (SC; 24-hour Holter ECG monitoring [n = 20]) or standard care plus ILR (SC-ILR; 24-hour Holter ECG monitoring plus ILR [n = 20]). Only 17 consented to ILR insertion, and the 3 who declined ILR were allocated to the SC group.

MAIN OUTCOMES AND MEASURES Arrhythmias considered included atrial fibrillation, atrial flutter, premature ventricular complexes, supraventricular tachycardia, ventricular tachycardia, or ventricular fibrillation.

RESULTS Among the 40 women in this trial, the mean (SD) age was 28.4 (5.5) years. Holter monitoring detected arrhythmias in 3 of 23 patients (13%) in the SC group and 4 of 17 patients (24%) in the SC-ILR group compared with 9 of 17 patients (53%) patients who had arrhythmias detected by ILR. Seven patients (4 with supraventricular tachycardia, 1 with premature ventricular complexes, and 2 with paroxysmal atrial fibrillation recorded by ILR) did not have arrhythmias detected by 24-hour Holter monitoring. Three of these 7 patients (43%) had a change in management as a result of their ILR recordings. There were no maternal deaths. However, the SC group had a significantly lower mean (SD) gestational stage at delivery (35 [5] weeks vs 38 [2], $P = .04$).

CONCLUSIONS AND RELEVANCE The ILR was better than 24-hour Holter monitoring in detecting arrhythmias, which led to a change in management for a significant proportion of patients. Our findings suggest that ILR may be beneficial for pregnant women at risk of arrhythmia.

TRIAL REGISTRATION ClinicalTrials.gov Identifier: NCT02249195

JAMA Cardiol. doi:10.1001/jamacardio.2019.5963
Published online February 19, 2020.

Supplemental content

Author Affiliations: Hatter Institute for Cardiovascular Research in Africa, Department of Medicine, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa (Sliwa, Azibani, Viljoen, Baard, Briton); Division of Cardiology, Department of Medicine, Groote Schuur Hospital, University of Cape Town, Cape Town, South Africa (Sliwa, Viljoen, Briton, Ntsekhe, Chin); Imperial College London, Chelsea and Westminster Hospital, London, United Kingdom (Johnson); Division of Obstetrics and Gynecology, Groote Schuur Hospital, University of Cape Town, Cape Town, South Africa (Osman).

Corresponding Author: Karen Sliwa, MD, PhD, Hatter Institute for Cardiovascular Research in Africa, Department of Medicine, Faculty of Health Sciences, University of Cape Town, Chris Barnard Building, Fourth Floor, Anzio Road, Observatory, Cape Town 7530, South Africa (karen.sliwa-hahnle@uct.ac.za).

Cardiovascular disease (CVD), the leading cause of maternal mortality worldwide,[1,2] can be explained by several contributing factors, including delaying pregnancy until later in life and an increase in comorbidities (eg, diabetes, hypertension, and obesity). More women with repaired congenital or valvular heart disease reach reproductive age and become pregnant. Persisting structural cardiac abnormalities are associated with arrhythmias, heart failure, and sudden death during pregnancy, with arrhythmias reportedly accounting for up to 31% of cases of maternal death.[3]

It remains difficult to conduct research (especially blinded randomized clinical trials) during pregnancy. In observational studies, such as the Cardiac Disease in Pregnancy (CARPREG),[4] Zwangerschap bij Aangeboren Hartafwijkingen (ZAHARA),[5] and Registry of Pregnancy and Cardiac Disease (ROPAC)[6] studies, women with arrhythmias were often excluded. Specifically, no study, to our knowledge, has investigated diagnostic approaches for arrhythmias or whether its improved diagnostic yield would affect management and/or pregnancy outcome. This single-center, prospective randomized clinical trial compared implantable loop recorder (ILR) plus 24-hour Holter electrocardiographic (ECG) monitoring vs standard 24-hour Holter ECG monitoring alone in terms of acceptability, ability to identify significant arrythmias, and effects on management and pregnancy outcome in women who were symptomatic (eg, palpitations) or at high risk of arrythmia because of underlying structural heart disease (SHD).

Key Points

Question Does the addition of an implantable loop recorder to 24-hour Holter electrocardiographic monitoring increase the yield of arrhythmias and effect on pregnancy outcome in pregnant women with structural heart disease and/or symptoms suggestive of arrhythmias?

Findings In this randomized clinical trial of 40 pregnant women with symptoms of arrhythmia and/or structural heart disease, the implantable loop recorder detected arrhythmias that were not detected by prior 24-hour Holter monitoring, leading to a change in management in a significant proportion of patients.

Meaning An implantable loop recorder in addition to 24-hour Holter monitoring was better than 24-hour Holter monitoring alone in detecting arrhythmias in pregnant women with structural heart disease and/or symptoms suggestive of arrhythmias.

Methods

Study Design

In 2010, a dedicated weekly Cardiac Disease and Maternity Clinic was established at Groote Schuur Hospital, Cape Town, South Africa, to provide multidisciplinary care for pregnant women with suspected or previously known CVD (trial protocol in Supplement 1). Heart failure and maternal mortality were reduced through intensified management.[7,8] Patients were referred from primary or secondary care facilities or within the tertiary hospital (eFigure 1 in the Supplement 2). All evaluable women were pregnant (second or third trimester) at the time of consultation and underwent clinical evaluation, ECG, and echocardiography before enrollment. Patients were stratified according to the modified World Health Organization risk classification for pregnant women with cardiac disease.[9] All data were deidentified. Ethical approval was obtained at the University of Cape Town. All patients provided written informed consent before inclusion. This study followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guideline.

Inclusion Criteria

Patients classified to modified World Health Organization risk groups II to IV were included. Patients were eligible if they presented with arrhythmic symptoms (eg, palpitations) or were thought to be at risk of arrhythmia because of underlying SHD. All eligible patients were randomized according to a computer-generated randomization list to receive either standard care (SC) or standard care plus an implantable loop recorder (SC-ILR).

At entry, 24-hour Holter monitoring was performed with an ambulatory recorder (SEER Light recorder, General Electric) with a continuous 2-channel ECG recording available for analysis for all patients. Patients randomized to the SC-ILR group also received an ILR reading (REVEAL XT model 9529 ILR, Medtronic). The ILR readings were obtained at clinic visits or when patients were symptomatic. All Holter recordings and ILR readings were reviewed by an electrophysiologist (A.C.). Arrhythmias considered in this study included atrial fibrillation (AF), atrial flutter, premature ventricular complexes (PVCs), supraventricular tachycardia (SVT), ventricular tachycardia (VT), or ventricular fibrillation. Sinus tachycardia, a physiologic adaptation to pregnancy, was not included as an arrhythmia. The **Figure** shows the CONSORT flow diagram.

Follow-up and Management

Baseline data, including age, parity, medical comorbidities, prior cardiac surgery or interventions, symptoms and signs, New York Heart Association (NYHA) functional class, medication, and ECG and echocardiographic findings were recorded at the first visit. Follow-up data were collected until 42 days after delivery. The frequency of visits depended on severity of disease. Arrhythmias detected by Holter or ILR were managed with treatment deemed to be safe in pregnancy. Mode of delivery and perinatal outcome were obtained. Obstetric events were defined as death, pregnancy-induced hypertension, and (pre)eclampsia. Neonatal events were defined as premature birth (<37 weeks' gestation), low birth weight (<2500 g), and stillbirth (>20 weeks' gestation, birth weight >500 g).

Statistical Analysis

Statistical analyses were performed with GraphPad Prism software for Windows, version 7.03 (GraphPad Software Inc). Categorical variables were expressed as frequencies and percentages. Continuous data were expressed as mean (SD) or median (interquartile range) depending on data distribution. Comparison of means and proportions between subgroups at baseline was performed by independent, 2-tailed, unpaired *t* test

and χ^2 statistics (or Fisher exact test when necessary), respectively, and when data were not normally distributed, a Mann-Whitney test was used. A 2-sided $P < .05$ was considered to be statistically significant.

Results

Baseline Maternal Characteristics

The study randomized 20 women to the SC-ILR group and 20 to the SC group (mean [SD] age, 28.4 [5.5] years); however, only 17 consented to ILR insertion (SC-ILR group), and the 3 who declined ILR were allocated to the SC group. Thirty-five women (87%) presented with NYHA functional class I or II. Twenty-three women (57%) had a prior diagnosis of CVD. There was no significant difference between the SC and SC-ILR groups in mean (SD) maternal age (27.1 [4.9] vs 30.3 [5.6] years, $P = .07$), preexisting CVD (14 [61%] vs 9 [53%], $P = .75$), NYHA functional class (21 [91%] vs 14 [82%] with class I-II and 2 [9%] vs 3 [18%] with class III-IV, $P = .63$), blood pressure (systolic: 116 [12] vs 116 [14] mm Hg, $P = .92$; diastolic: 71 [9] vs 69 [11] mm Hg, $P = .55$), and mean (SD) gestational age at presentation (<12 weeks: 2 [10%] vs 2 [12%]; 12-24 weeks: 8 [38%] vs 8 [47%]; >24 weeks: 11 [52%] vs 7 [41%]; $P = .79$). Echocardiographic variables (left ventricular end diastolic diameter: 48.9 [7.9] vs 45.4 [6.1] mm, $P = .14$; left ventricular end systolic diameter: 34.6 [9.2] vs 33.1 [6.2] mm, $P = .20$; and left ventricular ejection fraction: 57.6% [13.2%] vs 59.2 [11.7%], $P = .69$) and rates of SHD (previously operated on CVD: 4 [17%] vs 2 [12%], $P > .99$) were similar in both groups (**Table 1**).

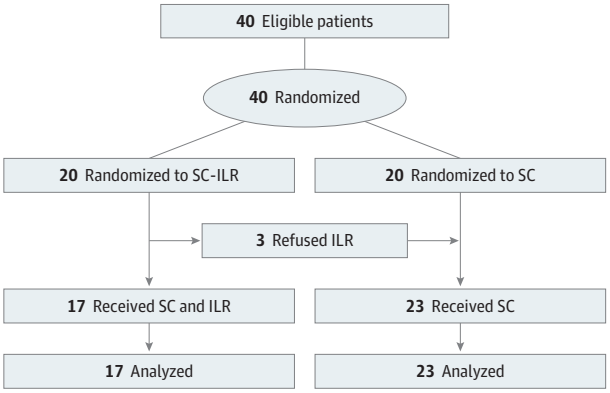
Arrhythmias Detected in the SC-ILR and SC Groups

The Holter monitor identified arrhythmias (all PVCs) in 3 patients (13%) in the SC group (**Table 2**). In the SC-ILR group, Holter monitoring detected arrhythmias in 4 patients (24%; persistent AF in 1, PVCs in 2, and nonsustained VT in one), whereas the ILR identified arrhythmias in 9 of the 17 patients (53%; paroxysmal AF in 2, persistent AF in 1, PVCs in 3, and SVT in 4) (eFigure 2 in Supplement 2). In 7 of 9 patients (78%), arrhythmias were detected by the ILR that were not detected by Holter monitoring (4 with SVT, 2 with paroxysmal AF, and 1 with PVCs). All 4 patients with SVT had short, nonsustained episodes of atrial tachycardia or atrioventricular junctional-dependent reentrant tachycardia.

Change in Management Based on Arrhythmias Detected

In the SC-ILR group, 3 of 7 patients (43%) had a change in management as a direct result of the ILR recordings (arrhythmias not detected by Holter monitoring). One patient with a perimembranous ventricular septal defect and paroxysmal AF (CHA_2DS_2VASC [congestive heart failure, hypertension, age ≥75 years (doubled), diabetes, stroke/transient ischemic attack/thromboembolism (doubled), vascular disease (prior myocardial infarction, peripheral artery disease, or aortic plaque), age 65-75 years, sex category (female)] score of 1) was given carvedilol for rate control of AF. Another patient with cardiac sarcoidosis with left ventricular dysfunction and paroxysmal AF (CHA_2DS_2VASC score of 1) underwent anticoagulation. Another patient with frequent symptomatic PVCs was admitted for the initiation of β-blockade and underwent investigations that excluded arrhythmogenic right ventricular cardiomyopathy. Three patients with PVCs in the SC group had a low PVC burden and did not require treatment.

Figure. CONSORT Flow Diagram



ILR indicates implantable loop recorder; SC, standard care.

Overall Obstetric and Fetal Outcomes

The eTable in Supplement 2 summarizes maternal and fetal outcomes per group. No maternal deaths occurred within 42 days postpartum. Mean (SD) gestational stage at delivery was 35 (5) weeks for the SC group and 38 (2) weeks for SC-ILR group ($P = .04$).

Discussion

This prospective randomized clinical trial that investigated the use of an ILR compared with 24-hour Holter ECG monitoring for the detection of arrhythmias during pregnancy found that arrhythmias were common in pregnant women with SHD who were symptomatic of arrhythmias (eg, palpitations). Arrhythmias were confirmed in 30% of patients with SHD. In this patient cohort, PVCs, SVTs, and AF accounted for all underlying arrhythmias.

Physiologic changes in pregnancy are known to increase the risk of arrhythmias.[10,11] Arrhythmias may occur for the first time in pregnancy. Pregnancy may also worsen preexisting arrhythmias.[5] In our study, ILR monitoring significantly increased the yield of arrhythmias during pregnancy compared with 24-hour Holter monitoring alone. Holter monitoring may fail to detect infrequent episodes of paroxysmal AF, which were detected by ILR in this study. The efficacy of ILRs to detect arrhythmias in pregnant patients with SHD seems to be consistent with other population groups, such as patients with cryptogenic stroke and patients with high CHA_2DS_2VASC scores who are at risk of underlying AF.[12,13] The detection of arrhythmias is important because it has previously been reported that

Table 1. Baseline Maternal Characteristics of 40 Cohort Patients[a]

Characteristic	All Patients (N = 40)	SC (n = 23)	SC-ILR (n = 17)	*P* Value
Age at enrollment, mean (SD), y	28.4 (5.5)	27.1 (4.9)	30.3 (5.6)	.07
Social history				
Smoking	5 (12)	2 (9)	3 (18)	.63
Alcohol use	3 (7)	1 (4)	2 (12)	.56
General medical history				
Chronic hypertension	3 (7)	1 (4)	2 (12)	.56
Hypercholesterolemia	0	0	0	>.99
HIV infection	9 (22)	4 (17)	5 (29)	.45
Syphilis	1 (2)	0	1 (6)	.42
Tuberculosis	2 (5)	1 (4)	1 (6)	>.99
Clinical history and presentation				
Known CVD	23 (57)	14 (61)	9 (53)	.75
CVD surgery	6 (15)	4 (17)	2 (12)	>.99
NYHA functional class				
I-II	35 (87)	21 (91)	14 (82)	.63
III-IV	5 (12)	2 (9)	3 (18)	
Blood pressure, mean (SD), mm Hg				
Systolic	116 (13)	116 (12)	116 (14)	.92
Diastolic	70 (10)	71 (9)	69 (11)	.55
Heart rate, mean (SD), /min	84 (11)	85 (8)	84 (13)	.93
Weight, mean (SD), kg	73 (18)	70 (21)	77 (13)	.04
Obstetric history				
Gestational age at presentation, wk[b]				
<12	4 (10)	2 (10)	2 (12)	.79
12-24	16 (42)	8 (38)	8 (47)	
>24	18 (47)	11 (52)	7 (41)	
Gravida, median (range)	2 (1-5)	2 (1-4)	2 (1-5)	.35
Parity, median (range)	1 (0-4)	1 (0-3)	1 (0-4)	.18
Nulliparous	14 (37)	9 (39)	5 (29)	.51
Twin pregnancies	1 (3)	0	1 (6)	.42
Echocardiographic findings, mean (SD)				
LVEDD, mm	47.3 (7.2)	48.9 (7.9)	45.4 (6.1)	.14
LVESD, mm	33.2 (8.1)	34.6 (9.2)	33.1 (6.2)	.20
LVEF, %	58.2 (12.5)	57.6 (13.2)	59.2 (11.7)	.69

Abbreviations: CVD, cardiovascular disease; LVEDD, left ventricular end diastolic diameter; LVEF, left ventricular ejection fraction; LVESD, left ventricular end systolic diameter; NYHA, New York Heart Association; SC, standard care (24-hour Holter electrocardiographic monitoring); SC-ILR, standard care plus implantable loop recorder.

[a] Data are presented as number (percentage) of patients unless otherwise indicated. Comparison between the 2 groups was performed using a 2-tailed, unpaired *t* test for gaussian distributed data and the Mann-Whitney test where at least 1 column was not normally distributed. Categorical variables were compared using Fisher exact tests.

[b] The sample size for gestational age at presentation was 38 (21 in the SC group and 17 in the SC-ILR group).

women who develop SVT in pregnancy are more likely to have adverse maternal and fetal outcomes.[14]

The study found that ILR was an acceptable diagnostic modality (safe and efficacious) in more than 85% of patients. Not only did the detection of arrhythmias by ILR result in a change of management in 43% of patients, but also the SC-ILR group had a significantly longer gestation period than the SC group.

Limitations

The sample size (N = 40) of this novel study was small. Ideally, Holter monitoring should have been performed for more than 24 hours. However, prolonged ambulatory ECG monitoring is not standard practice universally. Although the study population had a high risk of developing arrhythmias, this was a heterogenous cohort of pregnant women as far as symptoms and underlying SHD were concerned. The significantly higher mean gestational stage at delivery in the SC-ILR group might suggest that factor(s) in addition to ILR monitoring play a role in the outcomes of pregnant women at risk of arrhythmias.

Conclusions

This prospective randomized clinical trial provides information on the feasibility, safety, and efficacy of extended monitoring using an ILR compared with 24-hour Holter monitoring alone in detecting underlying arrhythmias during pregnancy. The ILR detected arrhythmias that were not detected by prior 24-hour Holter monitoring, leading to a change in management for a significant proportion of patients. The preliminary nature of our findings could serve as the basis for future research in detection of arrhythmias in pregnant women with symptoms of arrhythmia or significant SHD. We suggest that the role of prolonged external ambulatory ECG monitoring devices be evaluated and compared with ILR.

Table 2. Symptoms, Diagnosis, and Treatment of the Study Participants

Study Group, Patient No.	Symptoms	SHD and Symptoms Requiring Arrhythmia Workup	24-h Holter ECG	ILR	Intervention Because of Findings on ILR
SC-ILR					
1	Palpitations	RHD, mixed mitral valve disease	No arrhythmia	SVTs	No change in management
2	Palpitations	CHD, Ebstein anomaly, TVR repair	No arrhythmia	No arrhythmia	No change in management
3	Palpitations, dizziness	Frequent palpitations	NSVT	SVTs	No change in management
4	Palpitations, dizziness	Palpitations, syncope	PVCs	PVCs	Medtronic implantable loop recorder (ventricular undersensing)
5	Palpitations, dizziness, crepitation	Frequent palpitations	No arrhythmia	PVCs	β-Blockade
6	Dizziness	Pulmonary, cardiac sarcoidosis	No arrhythmia	No arrhythmia	Medtronic implantable loop recorder (ventricular undersensing)
7	Palpitations, dizziness	CHD, dilated right ventricular outflow	No arrhythmia	No arrhythmia	No change in management
8	Syncope, palpitations, dizziness	Cardiomyopathy, syncope, palpitations, HOCM	No arrhythmia	SVTs	No change in management
9	Palpitations, dizziness	Cardiomyopathy, HOCM, troponin T mutation	No arrhythmia	No arrhythmia	No change in management
10	Palpitations, dizziness	Cardiomyopathy, familial dilated cardiomyopathy, LVNC	No arrhythmia	No arrhythmia	No change in management
11	Palpitations	RHD, severe mixed mitral valve disease, CVA	Persistent AF	Persistent AF	No change in management
12	Palpitations, dizziness	Syncope	No arrhythmia	SVTs	No change in management
13	Palpitations	Cardiomyopathy, atrial tachycardia, previous dilated cardiomyopathy	No arrhythmia	No arrhythmia	No change in management
14	Dizziness	CHD, mitral valve replacement, WPW syndrome	No arrhythmia	No arrhythmia	No change in management
15	Palpitations, dizziness	CHD, perimembranous VSD	No arrhythmia	Paroxysmal AF	β-Blockade
16	Palpitations, dizziness	Previous ablation of ventricular tachycardia	No arrhythmia	No arrhythmia	No change in management
17	Palpitations, dizziness, angina	Cardiac sarcoidosis, syncope	PVCs	Paroxysmal AF, PVCs	Low-molecular-weight heparin
SC					
1	Palpitations, dizziness, angina	CAD, angina	No arrhythmia	NA	No change in management
2	Palpitations, dizziness	Cardiomyopathy, idiopathic cardiomyopathy	PVCs	NA	No change in management
3	Palpitations	CHD, ASD, had closure, failed residual ASD	No arrhythmia	NA	No change in management
4	Palpitations	Palpitations	No arrhythmia	NA	No change in management
5	Palpitations, dizziness	Narrow complex tachycardia	No arrhythmia	NA	No change in management
6	Palpitations	Marfan syndrome, previous mitral valve replacement, dilated aorta	No arrhythmia	NA	No change in management
7	Palpitations	CHD, TOF, previous repair, PVR	No arrhythmia	NA	No change in management
8	Palpitations, dizziness	Cardiomyopathy, dilated cardiomyopathy, severe MR	No arrhythmia	NA	No change in management
9	Palpitations	Cardiomyopathy, dilated cardiomyopathy, PPCM	No arrhythmia	NA	No change in management
10	Palpitations, dizziness	CHD, VSD repair, subaortic stenosis	No arrhythmia	NA	No change in management

(continued)

Table 2. Symptoms, Diagnosis, and Treatment of the Study Participants (continued)

Study Group, Patient No.	Symptoms	SHD and Symptoms Requiring Arrhythmia Workup	24-h Holter ECG	ILR	Intervention Because of Findings on ILR
11	Palpitations	Long QT syndrome	No arrhythmia	NA	No change in management
12	Palpitations, dizziness	WPW syndrome	No arrhythmia	NA	No change in management
13	Palpitations	Palpitations, previous SVT	No arrhythmia	NA	No change in management
14	Palpitations	Marfan syndrome	No arrhythmia	NA	No change in management
15	Palpitations, dizziness	Cardiomyopathy, PPCM, familial dilated cardiomyopathy	No arrhythmia	NA	No change in management
16	Palpitations	Cardiomyopathy, postmyocarditis CMO, idiopathic	PVCs	NA	No change in management
17	Palpitations, dizziness	Congenital, AV nodal reentry tachycardia, mitral valve repair	No arrhythmia	NA	No change in management
18	Palpitations	Congenital, TOF, previous repair, Holt-Oram syndrome	No arrhythmia	NA	No change in management
19	Palpitations	Cardiomyopathy, familial DMCO	No arrhythmia	NA	No change in management
20	Palpitations, angina	Atrial tachycardia	No arrhythmia	NA	No change in management
21	Palpitations, dizziness	CHD	No arrhythmia	NA	No change in management
22	Palpitations	Cardiomyopathy, dilated cardiomyopathy	No arrhythmia	NA	No change in management
23	Palpitations	Mitral valve replacement, submitral aneurysm repair	PVCs	NA	No change in management

Abbreviations: AF, atrial fibrillation; ASD, atrial septal defect; AV, atrioventricular; CAD, coronary artery disease; CHD, congenital heart disease; ECG, electrocardiography; HOCM, hypertrophic obstructive cardiomyopathy; ILR, implantable loop recorder; LVNC, left ventricular noncompaction; NA, not applicable; NSVT, nonsustained ventricular tachycardia; PPCM, peripartum cardiomyopathy; PVC, premature ventricular contraction; PVR, pulmonary vascular resistance; RHD, rheumatic heart disease; SC, standard care (24-hour Holter electrocardiographic monitoring); SC-ILR, standard care plus implantable loop recorder; SHD, structural heart disease; SVT, sustained ventricular tachycardia; TOF, tetralogy of Fallot; TVR, tricuspid valve replacement; VSD, ventricular septal defect; WPW, Wolff-Parkinson-White.

ARTICLE INFORMATION

Accepted for Publication: December 1, 2019.

Published Online: February 19, 2020. doi:10.1001/jamacardio.2019.5963

Author Contributions: Dr Azibani had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Sliwa, Ntsekhe, Chin.
Acquisition, analysis, or interpretation of data: Sliwa, Azibani, Johnson, Viljoen, Baard, Osman, Briton, Chin.
Drafting of the manuscript: Sliwa, Azibani, Johnson, Viljoen, Baard, Briton, Chin.
Critical revision of the manuscript for important intellectual content: Sliwa, Johnson, Viljoen, Osman, Ntsekhe, Chin.
Statistical analysis: Sliwa, Azibani, Viljoen, Chin.
Obtained funding: Ntsekhe.
Administrative, technical, or material support: Sliwa, Viljoen, Baard, Osman, Briton, Ntsekhe.
Supervision: Sliwa.

Conflict of Interest Disclosures: None reported.

Funding/Support: This study was supported by the Medtronic External Research Program, Maastricht, the Netherlands. Medtronic provided the injectable loop recorders free of charge.

Role of the Funder/Sponsor: Medtronic had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Data Sharing Statement: See Supplement 3.

REFERENCES

1. Knight M, Nair M, Tuffnell D, Kenyon S, Shakespeare J, Kurinczuk JJ, eds.; MBRRACE-UK. *Saving Lives, Improving Mother's Care: Lessons Learned to Inform Maternity Care From the UK and Ireland: Confidential Enquiries Into Maternal Deaths and Morbidity 2013-2015*. Oxford, United Kingdom: National Perinatal Epidemiology Unit, University of Oxford; 2017.

2. Khan KS, Wojdyla D, Say L, Gülmezoglu AM, Van Look PF. WHO analysis of causes of maternal death: a systematic review. *Lancet*. 2006;367(9516):1066-1074. doi:10.1016/S0140-6736(06)68397-9

3. Vause S, Clark B, Thorne S, et al. Lessons on cardiovascular disease. In: Knight M, Nour M, Tuffnell D, et al, eds.; MBRRACE-UK. *Saving Lives, Improving Mothers' Care: Surveillance of Maternal Deaths in the UK 2012-14 and Lessons Learned to Inform Maternity Care From the UK and Ireland Confidential Enquiries Into Maternal Deaths and Morbidity 2009-14*. Oxford, United Kingdom: National Perinatal Epidemiology Unit, University of Oxford; 2016:33-68.

4. Khairy P, Ouyang DW, Fernandes SM, Lee-Parritz A, Economy KE, Landzberg MJ. Pregnancy outcomes in women with congenital heart disease. *Circulation*. 2006;113(4):517-524. doi:10.1161/CIRCULATIONAHA.105.589655

5. Siu SC, Sermer M, Colman JM, et al; Cardiac Disease in Pregnancy (CARPREG) Investigators. Prospective multicenter study of pregnancy outcomes in women with heart disease. *Circulation*. 2001;104(5):515-521. doi:10.1161/hc3001.093437

6. Roos-Hesselink JW, Ruys TP, Stein JI, et al; ROPAC Investigators. Outcome of pregnancy in patients with structural or ischaemic heart disease: results of a registry of the European Society of Cardiology. *Eur Heart J*. 2013;34(9):657-665. doi:10.1093/eurheartj/ehs270

7. Sliwa K, Libhaber E, Elliott C, et al. Spectrum of cardiac disease in maternity in a low-resource cohort in South Africa. *Heart*. 2014;100(24):1967-1974. doi:10.1136/heartjnl-2014-306199

8. Sliwa K, Azibani F, Baard J, et al. Reducing late maternal death due to cardiovascular disease: a pragmatic pilot study. *Int J Cardiol*. 2018;272:70-76. doi:10.1016/j.ijcard.2018.07.140

9. Regitz-Zagrosek V, Roos-Hesselink JW, Bauersachs J, et al; ESC Scientific Document Group. 2018 ESC guidelines for the management of cardiovascular diseases during pregnancy. *Eur Heart J*. 2018;39(34):3165-3241. doi:10.1093/eurheartj/ehy340

10. Enriquez AD, Economy KE, Tedrow UB. Contemporary management of arrhythmias during pregnancy. *Circ Arrhythm Electrophysiol*. 2014;7(5):961-967. doi:10.1161/CIRCEP.114.001517

11. Hoevelmann J, Hahnle L, Hahnle J, Sliwa K, Viljoen CA. Detection and management of arrhythmias in peripartum cardiomyopathy. *Cardiovasc Diagn Ther*. 2019;(June):1-11. doi:10.21037/cdt.2019.05.03

12. Sanna T, Diener HC, Passman RS, et al; CRYSTAL AF Investigators. Cryptogenic stroke and underlying atrial fibrillation. *N Engl J Med*. 2014;370(26):2478-2486. doi:10.1056/NEJMoa1313600

13. Reiffel JA, Verma A, Kowey PR, et al; REVEAL AF Investigators. Incidence of previously undiagnosed atrial fibrillation using insertable cardiac monitors in a high-risk population: the REVEAL AF Study. *JAMA Cardiol*. 2017;2(10):1120-1127. doi:10.1001/jamacardio.2017.3180

14. Chang SH, Kuo CF, Chou IJ, et al. Outcomes associated with paroxysmal supraventricular tachycardia during pregnancy. *Circulation*. 2017;135(6):616-618. doi:10.1161/CIRCULATIONAHA.116.025064