Peripartum cardiomyopathy: Characteristics and outcomes among women seen at a referral hospital in Lusaka, Zambia

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ABSTRACT

Background: Peripartum cardiomyopathy (PPCM) disproportionately affects women of African descent, however knowledge about this disease in African countries is limited.

Objectives: To describe the phenotype of women with PPCM seen at a referral hospital in Zambia and examine outcomes at 6 months.

Methods: A prospective observational study describing characteristics and 6-month outcomes was performed at the University Teaching Hospital Echocardiography Lab in Lusaka, Zambia.

Results: We enrolled 45 participants with PPCM and 38 were seen at 6-month follow up; 3 (7 %) died and 4 (9 %) were lost to follow up. Mean age was 32.9 years (SD:7.0); mean BMI was 25.3 kg/m^2 (SD:4.1), mean parity was 3.4 (SD:2.2) children and twin pregnancies occurred in 4 (9 %). Median time from symptom onset to diagnosis was 60 days (IQR: 1–280). 20 (44 %) reported gestational hypertension and 10 (22 %) reported preeclampsia. Baseline median left ventricular ejection fraction (LVEF) was 36 % (IQR: 11–45), median left ventricular end-diastolic volume (LVEDV) was 150 mL (IQR: 58–229) and 79 % described New York Heart Association (NYHA) functional class IV symptoms. Median LVEF after 6 months was 49 % (IQR: 23–68; $p < 0.001$) and median LVEDV was 121 mL (IQR: 66–200; $p < 0.001$). At 6-month follow up 45 % had LVEF $\geq$ 50 %, 42 % had LVEDV $\leq$ 106 mL and 1 (3 %) had NYHA functional class IV symptoms.

Conclusions: Hypertension was prevalent in this cohort. Overall mortality rate was low and clinically significant improvements in cardiac parameters were seen in over 40%. Further research is needed to identify and mitigate gaps in diagnosis and management.

1. Background

Peripartum cardiomyopathy (PPCM) is an idiopathic disease defined as systolic heart failure occurring between the last few months of pregnancy and the early postpartum period in patients with no known risk for heart failure [1]. PPCM disproportionately affects women of African descent who tend to be diagnosed later, have poorer systolic function on diagnosis with larger cardiac dimensions and less favorable outcomes [2–5]. While the exact pathophysiology of the disease is unclear, recent data have suggested vascular dysregulation as an important factor in the setting of an underlying genetic or other medical predisposition [6–9].

The recovery rate among patients with PPCM varies geographically as was seen in the multi-regional cohort study EURObservational Research Programme (EROP) [8,10]. At 6-month follow up, only 37 % of African patients had recovered compared to 57 % and 62 % in Europe and Asia-Pacific respectively. This supports other data that showed women of African descent do not fare as well as their non-African counterparts. Hypertension and preeclampsia increase the risk for PPCM and other risk factors including advanced maternal age, multi-parity and twin pregnancies have also been implicated [3,5,8].

Recently, data from the PEACE registry, the largest population study

done in Africa, described PPCM among Nigerian patients [11]. They noted multiparity in 71 % of the participants and average body mass index (BMI) of 19.9 kg/m^2 (SD:6.5). Gestational hypertension was observed in 9.8 % and preeclampsia in 17.6 %. Hypertension and pre-eclampsia were not as common in the PEACE registry when compared to findings from the African cohort of the EROP [10,11]. This suggests that risk factors may differ among sub-Saharan countries, which poses a challenge to the development of standardized screening and manage-ment protocols. There is a need for early recognition of patients at high risk for PPCM because delayed diagnosis negatively impacts recovery [1,4]. We therefore sought to describe the phenotype and 6-month outcomes of patients with PPCM presenting to the University Teaching Hospital (UTH) Echocardiography Lab.

2 Methods

2.1. Study design

For this prospective observational study, participants were recruited from the UTH Echocardiography Lab in Lusaka, the main referral center in Zambia between January 2021 and June 2021. The study was approved by the University of Zambia Biomedical Research Ethics Committee, the National Health Research Authority of Zambia and the Vanderbilt University Medical Center Institutional Review Board for Human Use.

2.2. Participants

Women 15 to 49 years old who met diagnostic criteria for PPCM or had a prior history of PPCM and provided consent were enrolled in the study as described in Fig. 1. Between January and June 2021, 158 women who met the age criteria were referred for echocardiograms with indications of "heart failure", "biventricular heart failure", "congestive cardiac failure", "dilated cardiomyopathy" or "cardiomegaly". Of those, 45 (28 %) had current or prior PPCM with abnormal left ventricular systolic function (LVEF) and were enrolled in the study. PPCM was

diagnosed based on the European Society of Cardiology criteria which defines it as (1) heart failure secondary to left ventricular systolic dysfunction with an LVEF ≤ 45 %, (2) occurrence towards the end of pregnancy or in the months following delivery and (3) absence of another identifiable cause of heart failure [12]. There is a lack of availability of coronary angiography in this community to definitively exclude other causes of heart failure like coronary atherosclerosis. In addition, other imaging mechanisms that could exclude other cause of heart failure like cardiac magnetic resonance imaging and cardiac computed tomography are not available. The exclusion of other causes of heart failure was made by obtaining comprehensive medical histories, reviewing electrocardiograms and assessing echocardiograms for any wall motion abnormalities, valvular dysfunction or congenital heart defects. Additionally, these were young women of childbearing age who were at low risk for ischemic heart disease. Once the diagnosis of PPCM was made, participants were referred to the cardiology clinic managed by a physician experienced in heart failure management and were initiated on appropriate guideline-directed medical therapy (GDMT). Available GDMT in Zambia focused mainly on medication management (beta blockers, mineralocorticoids, diuretics, angiotensin-converting enzyme inhibitors, angiotensin receptor blockers and digoxin), most of which was available at little or no cost at the UTH pharmacy.

2.3. Study procedures

During the initial visit, complete demographic information, medical and family history were obtained and available clinical data (including medication use and prior echocardiogram reports) were reviewed. Height and weight were recorded and resting blood pressure and heart rate were obtained using a McKesson electronic blood pressure machine (Irving, TX). Echocardiograms were performed using a General Electric Healthcare LOGIQ ultrasound machine (Chicago, IL). At the 6-month follow up visit, current clinical information including medical thera-pies were reviewed and echocardiograms were performed. Participants who died before follow up or were lost to follow up were excluded from the follow up analysis. The LVEF was calculated using the modified
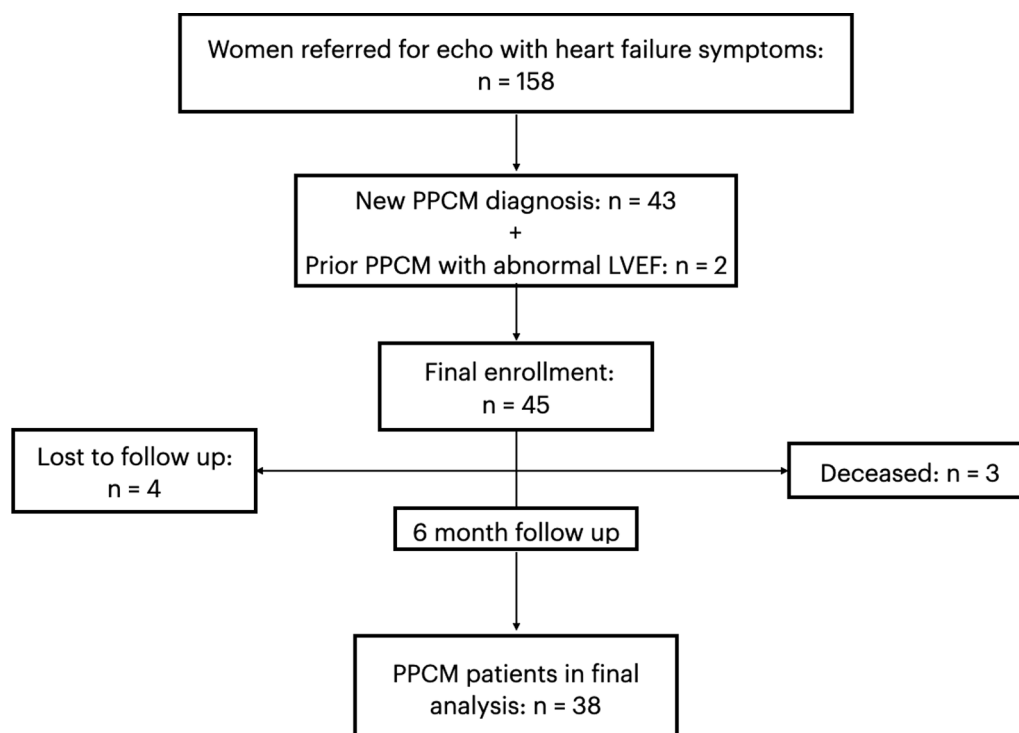

Fig. 1. Patient enrollment.

Simpson's method measured in the apical 4-chamber view as recommended by the American Society of Echocardiography (ASE) [13]. Based on the diagnostic criteria for PPCM [12] and the chamber quantification guidelines from the ASE [13], LVEF < 45 % and left ventricular end-diastolic volume (LVEDV) > 106 mL was defined as abnormal. Full cardiac recovery was defined as LVEF ≥ 50 %.

2.4. Statistical analysis

Study data were collected using REDCap hosted at the Vanderbilt University Medical Center (Nashville, TN) [14–16]. Descriptive statistics including mean ± standard deviation (SD), median (interquartile range, IQR) and proportions were calculated at baseline and 6-month follow up. Comparisons of baseline and 6-month follow up on key data points of left ventricular size and function were conducted using the Wilcoxon signed-rank test. Exact McNemar's test was used to compare the difference in NYHA functional classification at baseline and 6-month follow up. A p-value < 0.05 was considered statistically significant. Statistical analyses were performed using GraphPad Software version 9.3.1 (San Diego, CA).

3. Results

Forty-five participants met inclusion criteria with current or prior PPCM *and* left ventricular systolic dysfunction and were enrolled into the study. 38 participants had 6-month follow up (3 died prior to follow up and 4 were lost to follow up due to relocation). Baseline demographics and clinical characteristics are summarized in Table 1. Mean age was 32.9 years (SD:7.0); mean BMI was 25.3 kg/m² (SD:4.1), mean parity was 3.4 (SD:2.2) children and twin pregnancies were present in 4 (9 %). 40 (89 %) of the fetuses survived to term and 36 (80 %) participants were breastfeeding at time of diagnosis. Median time from symptom onset to diagnosis was 60 days (IQR:1–280). 20 (44 %) reported a diagnosis of gestational hypertension and 10 (22 %) reported preeclampsia. 7 (16 %) had required induction of labor and the cesarean section rate was 22 %. 13 (29 %) reported alcohol use and 1 (2 %) reported tobacco use. A majority reported symptoms of dyspnea (98 %), orthopnea (91 %), postural nocturnal dyspnea (91 %) and lower extremity edema (87 %) at baseline and<45 % were on GDMT at enrollment. At baseline, the median LVEF was 36 % (IQR: 11–45), median LVEDV was 150 mL (IQR: 58–229) and 79 % described New York Heart Association (NYHA) functional class IV symptoms at their initial visit. Table 2 and Fig. 2 depict comparison of baseline and 6-month follow up data and trends. Median LVEF at 6-month follow up was 49 % (IQR: 23–68) and median LVEDV was 121 mL (IQR: 66–220) both of which were statistically significant (p < 0.01). At 6-month follow up 17 (45 %) participants had recovered LVEF (≥50 %), 16 (42 %) had normalized LVEDV (≤106 mL) and only 1 (3 %) had persistent NYHA functional class IV symptoms. There was a significant increase in use of GDMT noted at 6-month follow up compared to baseline as seen in Fig. 3. The use of almost all medication classes increased 2-fold with the exception of Digoxin which was discontinued in all participants.

4. Discussion

This cohort of patients provides the first description of prevalence, characteristics and 6-month outcomes of PPCM in Zambia, expanding the evidence on PPCM in African countries. The disease prevalence among our cohort was 28 %, all of whom were diagnosed in the postpartum period. Participants were young, multiparous, had normal BMI and access to prenatal care, and a majority of the fetuses survived to term. Gestational hypertension was highly prevalent, which differs from Nigerian patients (PEACE registry) [11] and the African cohort of the EROP study [8,10] (42 % vs 10 % and 33 % respectively). The rate of preeclampsia was similar to those in the PEACE and African cohort of the EROP study (22 % vs 18 % and 21 % respectively). Time from

Table 1

Baseline demographics and clinical characteristics (n = 45).

Baseline demographics	
Age, *years* (SD)	32.9 (± 7.0)
Height, *m* (SD)	1.6 (± 0.06)
Weight, *kg* (SD)	65.6 (± 11.5)
BMI, *kg/m²* (SD)	25.3 (± 4.1)
Parity (SD)	3.4 (± 2.2)
Twin pregnancies (%)	4 (9)
Access to prenatal care (%)	44 (98)
Prior PPCM diagnosis (%)	2 (4)
PPCM pregnancy outcome:	
- Live birth (%)	40 (89)
- Miscarriage (%)	3 (7)
- Stillborn (%)	2 (4)
Highest education level:	
- No formal education (%)	2 (4)
- Elementary (%)	5 (11)
- Middle school (%)	7 (16)
- High school (%)	17 (38)
- Diploma (%)	8 (18)
- Bachelor's degree (%)	6 (13)
Monthly personal income (Kwacha):	
- >10,000 (%)	3 (7)
- 5,001-10,000 (%)	2 (4)
- <5,000 (%)	13 (29)
- No income due to unemployment (%)	27 (60)
Symptom onset to diagnosis, *days* (IQR)	60 (1-280)
Number of hospitalizations (IQR)	1 (0-30)
Breastfeeding at time of diagnosis (%)	36 (80)
Family history of heart failure (%)	8 (18)
Baseline clinical characteristics	
Systolic blood pressure, *mmHg* (SD)	122 (± 22)
Diastolic blood pressure, *mmHg* (SD)	83 (± 13)
Heart rate, *bpm* (SD)	95 (± 16)
History of hypertension^π:	
Before pregnancy (%)	3 (7)
- Median systolic/diastolic pressure, *mmHg* (IQR)	118/78 (92-120/60-60)
During pregnancy (%)	20 (44)
- Median systolic/diastolic pressure, *mmHg* (IQR)	118/84 (92-178/60-103)
After pregnancy (%)	17 (38)
- Median systolic/diastolic pressure, *mmHg* (IQR)	134/90 (90-178/40-104
Preeclampsia (%)	10 (22)
Tocolysis use (%)	0
Induction of labor (%)	7 (16)
C-section (%)	10 (22)
Gestational diabetes (%)	0
Human immunodeficiency virus (%)	7 (16)
- Antiretroviral use (%)	7 (16)
History of tuberculosis (%)	6 (13)
- Treatment for tuberculosis (%)	6 (13)
Alcohol use (%)	13 (29)
Tobacco use (%)	1 (2)
Presenting symptoms:	
- Chest pain (%)	11 (24)
- Chest tightness (%)	11 (22)
- Palpitations (%)	30 (67)
- Dyspnea (%)	44 (98)
- Orthopnea (%)	41 (91)
- Postural nocturnal dyspnea (%)	41 (91)
- Lower extremity edema (%)	39 (87)
- Ascites (%)	7 (16)
- Nausea/vomiting (%)	5 (11)
- Cough (%)	12 (26)
- Dizziness (%)	3 (7)
- Fatigue (%)	4 (9)
Guideline-directed medical therapy:	
- BB (%)	18 (40)
- ACE-i/ARB (%)	19 (42)
- MRA (%)	10 (22)
- Loop diuretic (%)	18 (40)
- Aspirin (%)	12 (27)
- Digoxin (%)	6 (13)
Hemoglobin, *g/dL* (SD)	12 (± 2.5)
Hematocrit, % (SD)	38 (± 9)
Serum creatinine, *mmol/L* (SD)	75 (± 26)

[π] - blood pressures recorded at time of enrollment, BB – beta blocker, ACE-i – Angiotensin converting enzyme inhibitor; ARB – Angiotensin II receptor blocker; MRA – mineralocorticoid receptor antagonist. Values reported as means $\pm$ SD, median (IQR) or proportions (%).

Table 2
PPCM parameters at baseline and 6-month.

Characteristics	Baseline (n = 38)	6 month follow up (n = 38)	p-values
LVEDV, *mL* (IQR)	150 (58–229)	121 (66–200)	<0.001
LVESV, *mL* (IQR)	108 (41–175)	67 (25–117)	<0.001
LVEF (biplane), *%* (IQR)	36 (11–45)	49 (23–68)	<0.001
NYHA functional class			
Class I (%)	0 (0)	26 (68)	<0.0001
Class II (%)	2 (5)	9 (24)	0.07
Class III (%)	6 (16)	2 (5)	0.29
Class IV (%)	30 (79)	1 (3)	<0.0001

Values reported as median (IQR) and proportions.
LVEDV = left ventricular end diastolic volume, LVESV = left ventricular end systolic volume, LVEF = left ventricular ejection fraction, NYHA = New York Heart Association.
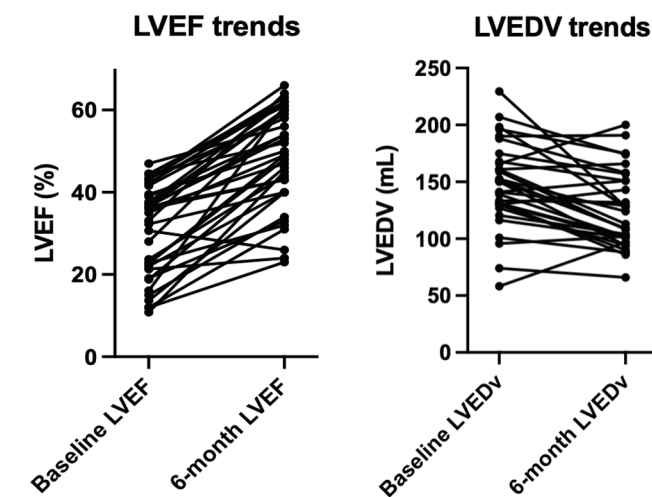

Fig. 2. LVEF and LVEDV trends.

symptom onset to diagnosis was delayed among our cohort mainly because most patients and their healthcare providers failed to recognize heart failure symptoms, which tend to mimic normal late pregnancy physiologic changes. While most women followed up in the newborn clinic for their well-child exams, many were not themselves evaluated by a healthcare provider in the early postpartum period where their symptoms could have been recognized sooner. There is opportunity to increase patient and healthcare provider knowledge about this disease and to implement proven evidence-based guidelines in clinical practice.

All available evidence indicates that early diagnosis and early initiation of GDMT improves mortality and morbidity. Among our cohort, median time to diagnosis was 60 days, which corresponded with low left ventricular ejection fraction and large cardiac dimensions. Unfortunately, <40 % of participants were on GDMT at baseline. Of those, few were on appropriate medication doses despite relatively easy access to most heart failure medications in Zambia. After 6 months on titrated GDMT, we noted that 45 % of participants had achieved normal cardiac function which differs significantly from recovery rates among the PEACE cohort and EROP African cohort (23 % and 37 % respectively). It is unclear what accounted for this difference, especially since the baseline cardiac function was similar among the groups. However, given

the higher rate of gestational hypertension among our cohort, a possible explanation could be that controlling hypertension (apparently the main driver of PPCM in this cohort) and optimizing GDMT allowed for better myocardial recovery. Further investigations will be needed to determine predictors of recovery among African patients.

Data from the Investigations of Pregnancy-Associated Cardiomyopathy (IPAC) cohort [3] in the USA indicate that the 6-month recovery rate was lower among black patients than their non-black counterparts (36 % vs 42 %), even when controlled for socioeconomic differences. Among their participants (100 women), 30 % self-identified as black with a mean age of 30 years (SD:6). Of those, 17 % had a history of diabetes and 70 % had a history of hypertension (although it was unclear if this was related to pregnancy). The average time from delivery to diagnosis was 42 days (SD:25) and the majority were on ACE-i or BB (83 % and 97 %) at baseline. By comparison, the average time to diagnosis was about 60 days among our cohort and the baseline LVEF was 31 % in IPAC vs 36 % in our cohort. At 6-month follow up the LVEF among the Zambian patients was similar to the IPAC participants (49 % vs 46 %) despite the fact that more participants in the IPAC group were on GDMT at baseline compared to our patients. The findings were interesting because healthcare resources are more readily available and accessible in the US compared to Zambia, but the outcomes among our cohort were slightly better. More research is needed to understand what could account for these differences. For example, does structural racism or health system factors in the US impact diagnosis and management of this disease compared to patients in Zambia? Does medical mistrust and therefore lower compliance rates play a role in the differences seen in outcomes between black patients in the US and Zambian patients?

5. Study limitations

Our conduct of this study during the COVID-19 pandemic, when access to healthcare facilities was challenging may have impacted our results. Forty-five participants were enrolled over the 5-month enrollment period and while this represents a small sample size, it is comparable to other studies that have similar enrollment periods. In addition, we only had access at women who were referred for echocardiograms at a referral hospital, so there may be cases in community clinics and hospitals that were missed, which limits our ability estimate true prevalence and generalize our findings. There is no electronic medical record system in Zambia which limited the availability of medical data.

6. Conclusions

Among our cohort, gestational hypertension was prevalent and mortality and recovery rates were favorable after 6 months on GDMT. There is evidence to support screening for and aggressive management of gestational hypertension and early treatment of women presenting with heart failure symptoms in the peripartum period. Future research to ascertain the true prevalence and outcomes of PPCM in Zambia is needed. In addition, implementation science research to understand the gaps in screening, diagnosis and medical management in addition to improvement opportunities are also needed. It is reassuring to note that despite the limitation of medical resources in Zambia, when compared to black women in the USA, our cohort had higher rates of recovery. Research focused on understanding the clinical, social and genetic factors that may account for this difference is also warranted.

7. Funding source

ACE-i: Angiotensin converting enzyme inhibitor, ARB: angiotensin II receptor blocker, MRA: mineralocorticoid receptor antagonist
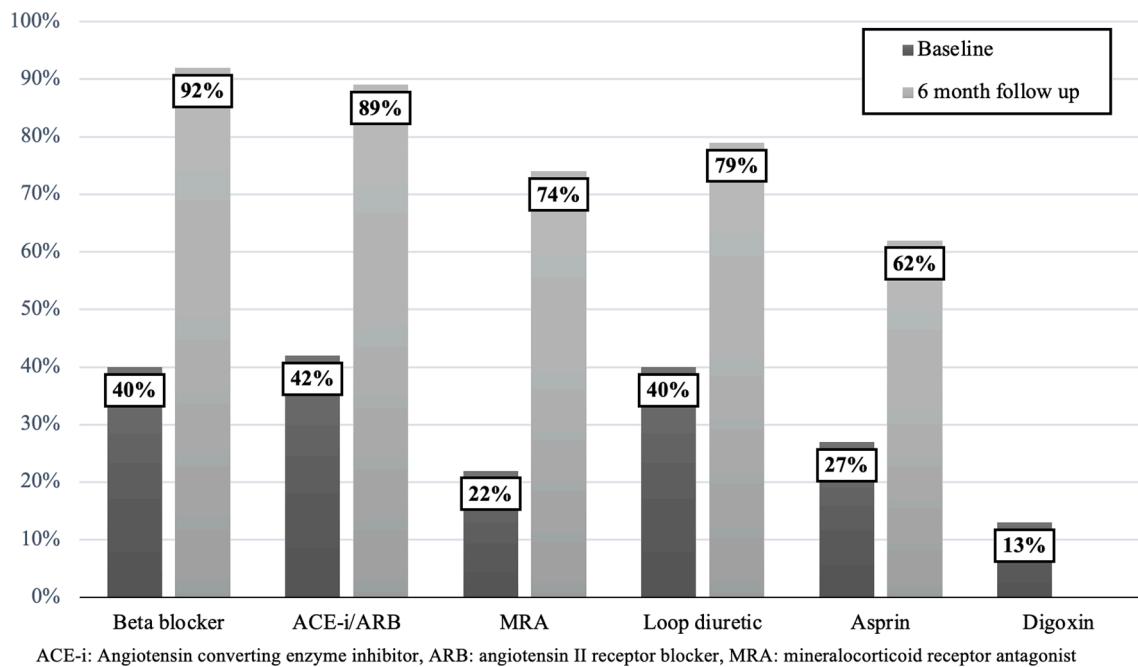
Fig. 3. Use of guideline directed medical therapy.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

References

[1] J. Bauersachs, T. König, P. Meer, M.C. Petrie, D. Hilfiker-Kleiner, A. Mbakwem, R. Hamdan, A.M. Jackson, P. Forsyth, R.A. Boer, C. Mueller, A.R. Lyon, L.H. Lund, M.F. Piepoli, S. Heymans, O. Chioncel, S.D. Anker, P. Ponikowski, P.M. Seferovic, M.R. Johnson, A. Mebazaa, K. Sliwa, Pathophysiology, diagnosis and management of peripartum cardiomyopathy: a position statement from the Heart Failure Association of the European Society of Cardiology Study Group on Peripartum Cardiomyopathy, Eur. J. Heart Fail. 21 (7) (2019) 827–843.
[2] M.B. Gentry, J.K. Dias, A. Luis, R. Patel, J. Thornton, G.L. Reed, African-American women have a higher risk for developing peripartum cardiomyopathy, J. Am. Coll. Cardiol. 55 (7) (2010) 654–659.
[3] D.M. McNamara, U. Elkayam, R. Alharethi, J. Damp, E. Hsich, G. Ewald, K. Modi, J. D. Alexis, G.V. Ramani, M.J. Semigran, J. Haythe, D.W. Markham, J. Marek, J. Gorcsan, W.-C. Wu, Y. Lin, I. Halder, J. Pisarcik, L.T. Cooper, J.D. Fett, Clinical Outcomes for Peripartum Cardiomyopathy in North America: Results of the IPAC Study (Investigations of Pregnancy-Associated Cardiomyopathy), J. Am. Coll. Cardiol. 66 (8) (2015) 905–914.
[4] O.C. Irizarry, L.D. Levine, J. Lewey, T. Boyer, V. Riis, M.A. Elovitz, Z. Arany, Comparison of Clinical Characteristics and Outcomes of Peripartum Cardiomyopathy Between African American and Non-African American Women, JAMA Cardiol. 2 (11) (2017) 1256, https://doi.org/10.1001/jamacardio.2017.3574.
[5] M.B. Davis, Z. Arany, D.M. McNamara, S. Goland, U. Elkayam, Peripartum Cardiomyopathy: JACC State-of-the-Art Review, J. Am. Coll. Cardiol. 75 (2) (2020) 207–221.
[6] J.S. Ware, J.G. Seidman, Z. Arany, Shared Genetic Predisposition in Peripartum and Dilated Cardiomyopathies, N. Engl. J. Med. 374 (26) (2016) 2601–2602.

[7] R. Goli, J. Li, J. Brandimarto, L.D. Levine, V. Riis, Q. McAfee, S. DePalma, A. Haghighi, J.G. Seidman, C.E. Seidman, D. Jacoby, G. Macones, D.P. Judge, S. Rana, K.B. Margulies, T.P. Cappola, R. Alharethi, J. Damp, E. Hsich, U. Elkayam, R. Sheppard, J.D. Alexis, J. Boehmer, C. Kamiya, F. Gustafsson, P. Damm, A. S. Ersbøll, S. Goland, D. Hilfiker-Kleiner, D.M. McNamara, Z. Arany, Genetic and Phenotypic Landscape of Peripartum Cardiomyopathy, Circulation 143 (19) (2021) 1852–1862.
[8] K. Sliwa, J. Bauersachs, Z. Arany, T.F. Spracklen, D. Hilfiker-Kleiner, Peripartum cardiomyopathy: from genetics to management, Eur. Heart J. 42 (32) (2021) 3094–3102.
[9] M.F. Hoes, Z. Arany, J. Bauersachs, D. Hilfiker-Kleiner, M.C. Petrie, K. Sliwa, P. van der Meer, Pathophysiology and risk factors of peripartum cardiomyopathy, Nat Rev Cardiol 19 (8) (2022) 555–565.
[10] Sliwa K, Petrie MC, van der Meer P, Mebazaa A, Hilfiker-Kleiner D, Jackson AM, et al. Clinical presentation, management, and 6-month outcomes in women with peripartum cardiomyopathy: an ESC EORP registry. Eur Heart J. 2020;41(39): 3787-97.
[11] K.M. Karaye, H. Sa'idu, S.A. Balarabe, N.A. Ishaq, U.G. Adamu, I.Y. Mohammed, I. Oboirien, E.M. Umuerri, A.C. Mankwe, V.Y. Shidali, P. Njoku, S. Dodiyi-Manuel, T. Olunuga, V. Josephs, A.C. Mbakwem, H. Okolie, M.A. Talle, M.S. Isa, O.S. Ogah, S. Stewart, Clinical Features and Outcomes of Peripartum Cardiomyopathy in Nigeria, J. Am. Coll. Cardiol. 76 (20) (2020) 2352–2364.
[12] K. Sliwa, D. Hilfiker-Kleiner, M.C. Petrie, A. Mebazaa, B. Pieske, E. Buchmann, V. Regitz-Zagrosek, M. Schaufelberger, L. Tavazzi, D.J. van Veldhuisen, H. Watkins, A.J. Shah, P.M. Seferovic, U. Elkayam, S. Pankuweit, Z. Papp, F. Mouquet, J.J.V. McMurray, Current state of knowledge on aetiology, diagnosis, management, and therapy of peripartum cardiomyopathy: a position statement from the Heart Failure Association of the European Society of Cardiology Working Group on peripartum cardiomyopathy, Eur. J. Heart Fail. 12 (8) (2010) 767–778.
[13] R.M. Lang, L.P. Badano, V. Mor-Avi, J. Afilalo, A. Armstrong, L. Ernande, F. A. Flachskampf, E. Foster, S.A. Goldstein, T. Kuznetsova, P. Lancellotti, D. Muraru, M.H. Picard, E.R. Rietzschel, L. Rudski, K.T. Spencer, W. Tsang, J.-U. Voigt, Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging, J. Am. Soc. Echocardiogr. 28 (1) (2015) 1–39.e14.
[14] P.A. Harris, R. Taylor, R. Thielke, J. Payne, N. Gonzalez, et al., Research electronic data capture (REDCap) – A metadata-driven methodology and workflow process for providing translational research informatics support, J. Biomed. Inform. 42 (2) (2009) 377–381.
[15] P.A. Harris, R. Taylor, B.L. Minor, V. Elliott, M. Fernandez, et al., REDCap Consortium, Building an international community of software partners, J Biomed Inform, The REDCap consortium, 2019 May 9.
[16] J.S. Obeid, C.A. McGraw, B.L. Minor, J.G. Conde, R. Pawluk, et al., Procurement of shared data instruments for Research Electronic Data Capture (REDCap), J. Biomed. Inform., Available online (2012).