Speckle Tracking Echocardiography in Hypertensive Pregnancy Disorders

Volume 75, Number 8
OBSTETRICAL AND GYNECOLOGICAL SURVEY

CME REVIEW ARTICLE 20

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Speckle Tracking Echocardiography in Hypertensive Pregnancy Disorders: A Systematic Review

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Importance: Hypertensive pregnancy disorders (HPDs) are associated with an increased risk of long-term cardiovascular disease. Speckle tracking echocardiography (STE) might be useful in the early detection of preclinical cardiac changes in women with HPDs.

Objective: The aim of this study was to study whether STE is a suitable method to detect differences in cardiac function in pregnant women with HPD compared with normotensive pregnant women or between women with a history of a pregnancy complicated by HPD compared with women with a history of an uncomplicated pregnancy.

Evidence Acquisition: The databases Medline, EMBASE, and Central were systematically searched for studies comparing cardiac function measured with STE in pregnant women with HPD or women with a history of HPD and women with a history of normotensive pregnancies.

Results: The search identified 16 studies, including 870 women with a history of HPD and 693 normotensive controls. Most studies during pregnancy (n = 12/13) found a decreased LV-GLS (left ventricular global longitudinal strain) in HPD compared with normotensive pregnant controls. LV-GRS (left ventricular global radial strain) and LV-GLCS (left ventricular global circumferential strain) are decreased in women with early-onset and severe preeclampsia. Women with a history of early-onset preeclampsia show lasting myocardial changes, with significantly decreased LV-GLS, LV-GLCS, and LV-GRS.

Conclusions and Relevance: LV-GLS is significantly decreased in pregnant women with HPD compared with normotensive pregnant women. Other deformation values show a significant decrease in women with severe or early-onset preeclampsia, with lasting myocardial changes after early-onset preeclampsia.

All authors, faculty, and staff in a position to control the content of this CME activity and their spouses/life partners (if any) have disclosed that they have no financial relationships with, or financial interests in, any commercial organizations relevant to this educational activity.

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Target Audience: Obstetricians and gynecologists, family physicians, cardiologists.

Learning Objectives: After participating in this activity, the learner should be better able to identify the test characteristics of STE; describe the differences in STE between HPDs and normotensive pregnant controls; and explain which HPD causes lasting myocardial changes after pregnancy.

Hypertensive pregnancy disorders (HPDs) are one of the most common medical problems encountered during pregnancy, affecting 5% to 10% of pregnancies.[1–4]

Hypertensive pregnancy disorder, defined as gestational hypertension (GH), chronic hypertension (CH), preeclampsia (PE), or superimposed PE,[5] provokes serious maternal and fetal complications and are the leading cause of maternal death worldwide.[5–7] Besides increased maternal cardiovascular complications in pregnancy, HPDs are also associated with an increased risk of long-term cardiovascular disease (CVD).[8–10] Failure of the maternal cardiovascular system to adapt to pregnancy is hypothesized to be the primary mechanism leading to HPD.[11,12] Due to this inability to adapt, the maternal myocardium changes subtly in shape, size, and function.[11,13–15] Early detection of these subtle changes, with the institution of appropriate screening and treatment, may reduce the risk of future CVD.[16,17] Myocardial changes can be identified by ultrasound.[10,12,18] However, conventional echocardiography, measuring left ventricular ejection fraction and diastolic function, was shown to be unsuitable for the detection of early subclinical myocardial changes, as these measures provide an indirect estimate of myocardial contractile function and change late in the cascade of myocardial dysfunction due to compensatory mechanisms.[17,19] Speckle tracking echocardiography (STE), a relatively new echocardiographic method, could overcome this problem.

Speckle tracking echocardiography is a grayscale-based ultrasound technique, based on frame-by-frame tracking of acoustic reflections, speckles. Speckle tracking echocardiography is increasingly used in the assessment of left ventricular cardiac function,[20,21] as it has advantages over conventionally used techniques.[17,19,22,23] It directly quantifies the extent of myocardial contraction function, and STE has equal to superior reproducibility.[24,25] Speckle tracking echocardiography is proven to be suitable for the detection of subclinical cardiac changes.[12,17,20,22] Speckle tracking echocardiography abnormalities are also shown to have prognostic value in patients with hypertension and hypertensive heart disease.[26,27] Therefore, STE might also be useful in the detection of cardiac changes in HPD affected mothers. The aim of this systematic review is to study whether STE detects differences in cardiac function between pregnant women with HPD compared with normotensive pregnant women and between women with a history of a pregnancy complicated by HPD compared with women with a history of an uncomplicated pregnancy.

MATERIALS AND METHODS

Inclusion and Exclusion Criteria

All published studies that compared cardiac STE features between human females with a history of HPD and a normotensive control group were included in this review. We included studies that compared pregnant women with HPD to normotensive pregnant women, and we included studies that compared women with a history of a pregnancy complicated by HPD to women with a history of an uncomplicated pregnancy.

Studies that compared pregnant women with HPD with normotensive nonpregnant women were excluded. Studies that used ultrasound techniques other than STE to measure maternal heart function were excluded. Furthermore, review studies, guidelines, editorials, comments, and conference abstracts were also excluded. No language restrictions or restrictions imposed on year of publication were applied. In the event an article in a language other than English or Dutch was found eligible based on title or abstract, the full text was retrieved and translated by a native speaker.

Search Strategy

The databases of Medline (PubMed), EMBASE, and CENTRAL were systematically searched from inception up to and including September 2019. The search consisted of the following terms and a wide variety of their synonyms: PE, HPDs, STE, and strain. A professional medical research librarian assisted to set the search strategy. The search strings are shown in Appendix 1. The review process was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses Checklist (PRISMA),[28] and prospectively registered in the international prospective register of systematic reviews, PROSPERO (CRD42019124031, Available at: http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42019124031).

Study Selection and Data Extraction

Two reviewers, S.M. and N.H.M.v.O., independently reviewed the titles and abstracts to judge their eligibility for inclusion. The full text of these potentially eligible studies was retrieved and independently assessed for eligibility. Disagreement was solved by consensus; if needed, a third reviewer, M.W., was consulted. After that, we hand-searched all references and related articles of the selected articles to identify additional relevant publications.

Relevant information was extracted from each article by 2 researchers (S.M. and N.H.M.v.O.) independently, using a predetermined form. The retrieved data comprised study characteristics such as year of publication, number of included women, inclusion and exclusion criteria, and methods including study design, timing of echocardiography, and ultrasound device and STE software used.

Outcome Measures

Speckle tracking echocardiography is an imaging technique that analyzes the motion of tissues in the heart by using the naturally occurring speckle pattern in the myocardium resulting from scattering of the ultrasound beam by the tissue.[19,29] The STE software measures the change in distance between speckles over time, which is expressed as strain.[19,21] Strain rate (SR) is the rate at which the myocardial deformation occurs in 1 per second. In cardiac STE, strain represents the myocardial shortening and lengthening during a cardiac cycle of contraction and relaxation and can be measured in different directions where it is expressed as a percentage.[19,21,29] The outcome measures of interest were the following parameters measured by STE: left ventricular global longitudinal strain (LV-GLS), left ventricular global radial strain (LV-GRS), left ventricular global circumferential strain (LV-GCS), and SR. The GLS is measured in the apical long-axis images, and the short-axis images are used to measure GRS and GCS.[19,21,29]

Quality Assessment and Data Analysis

The methodological quality of the eligible studies was assessed using the Newcastle-Ottawa Quality Assessment Form for Case-Control Studies (NOS) according to the guidelines of the Dutch Cochrane Center.[30–32] The NOS is a qualitative assessment tool for observational studies. Assessment is done using the following 3 dimensions; selection, comparability, and exposure. A maximum of 9 stars can be awarded to a single study.[30] The studies were classified in categories as suggested by Losilla et al,[33] by which studies with 0 to 3, 4 to 6, or 7 to 9 stars were classified as low, moderate, and high quality, respectively. Two authors (S.M. and N.H.M.v.O.) completed the quality and risk of bias assessment independently. Disagreement was solved by consensus; if needed, a third reviewer, M.W., was consulted. Data from the included studies were aggregated to provide a narrative synthesis of the findings.

RESULTS

Search Results

A total of 200 studies were identified through database searching. The process of study inclusion according to the PRISMA statement is shown in Figure 1. After removing duplicates, 158 studies remained. From these articles, 63 articles were found eligible for full-text assessment. When multiple articles from the same authors were found eligible, authors were contacted to ensure no duplicate study populations would be included. One study was excluded for this reason.[34] After full-text assessment, 16 articles were included in this review.[12,16,18,35–47] No additional articles were identified by hand-searching the references of the included articles. One article was published in Chinese[42] and translated to English by a native Chinese speaker.

The study characteristics of the included studies are summarized in Table 1. All included studies had an observational case-control design, of which 3 were longitudinal studies. Hypertensive pregnancy disorders were defined according to the definition by the International Society for the Study of Hypertension in Pregnancy,[12,38–40,43,47] American College of Obstetricians and Gynecologists,[16,18,35–37,46] the National High Blood Pressure Education Program Working Group on High Blood Pressure in Pregnancy,[41,45] the definition as stated in Obstetrics and Gynecology by Xie and Gou,[42] or by the classification by Davey et al.[44,48]

The 16 selected studies included a total number of 1563 patients. Ten studies evaluated women during their pregnancy, including 601 women with a pregnancy complicated by HPD and 523 controls with a normotensive pregnancy. In 3 studies, cardiac function was measured postpartum only, including 128 women with a history of HPD and 86 controls with a history of normotensive pregnancy. Three studies analyzed women both during their pregnancy and as well as postpartum. Of these, 141 women had HPD and 84 had a normotensive pregnancy. The characteristics and quality of the included studies are presented in Table 1.

The type of ultrasound machine and STE software used to perform STE varied among the studies. The patients in the studies performed during pregnancy varied with regard to the gestational age included (Table 1). The included gestational ages varied from 23 to 42 weeks. Most studies included both preterm and term women,[16,18,35–39,41,42,45–47] whereas one study included

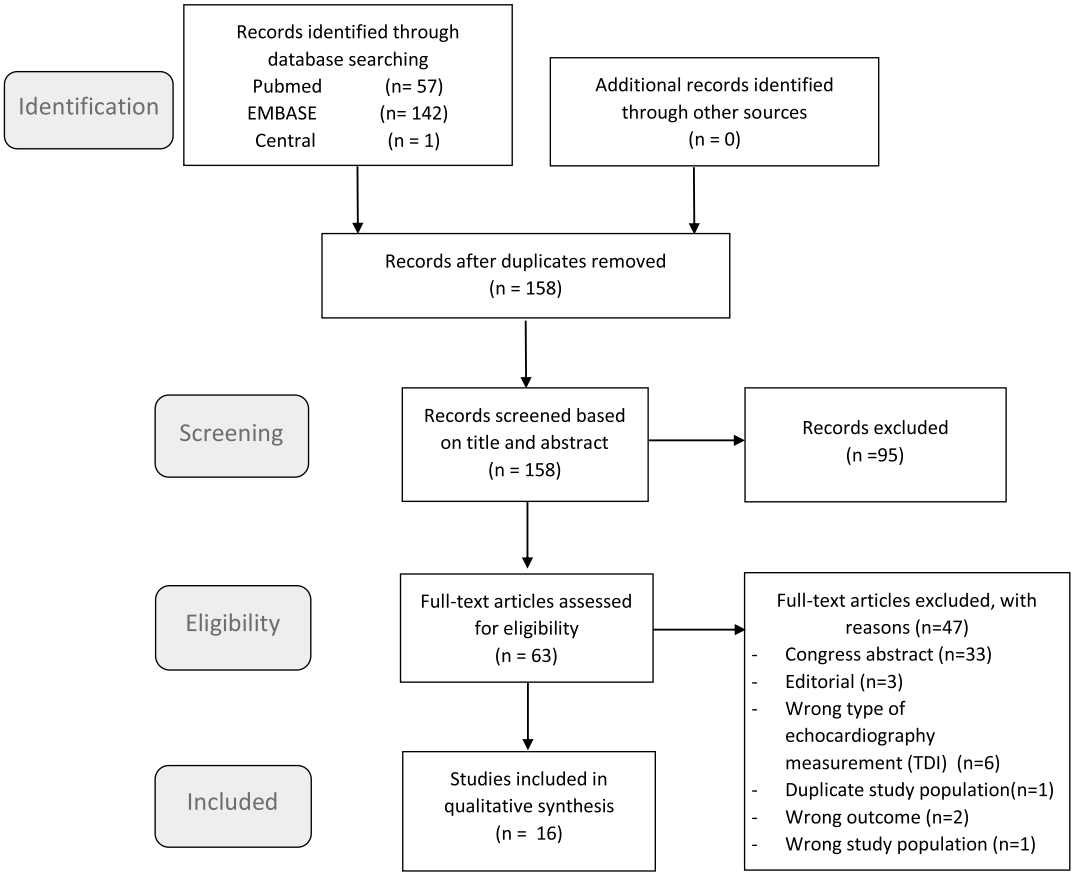

FIG. 1. PRISMA flow diagram demonstrating an overview of the selection process.

term women only.[12] The population in the studies concerning postpartum women showed a wide variation with regard to the period between delivery and the timing of the study measurement, ranging from 6 weeks to 13 years postpartum.[35,40,43–46]

Three studies differentiated between early-onset PE (EO-PE) and late-onset PE (LO-PE), that is, occurring before or after 34 weeks of gestation, respectively.[39,40,43]

Quality Assessment

The risk of bias of the included studies is reported in Table 1. The risk of bias score varied between 4 and 9 stars on the NOS, which corresponds with moderate to high quality.

Echocardiographic Measurements

An overview of STE results during pregnancy is presented in Table 2. Table 3 presents an overview of STE results postpartum.

Left Ventricular Global Longitudinal Strain

Results During Pregnancy. All included studies reported results on LV-GLS. Twelve studies showed a significant decrease in LV-GLS in pregnant participants with HDP compared with normotensive participants.[12,18,35–39,41,42,45–47] In one study, the same trend of decreased LV-GLS was observed in women with PE compared with normotensive pregnant women; however, this was not significant.[16]

Results Postpartum. Six studies measured LV-GLS postpartum.[35,40,43–46] The measurement timing ranged from 6 weeks[46] to 13 years[40] postpartum. Three studies, evaluating women up to 1 year postpartum, showed a significant decreased LV-GLS after a pregnancy complicated by PE compared with women after a normotensive pregnancy.[35,45,46] One study, comparing women 11 years after a pregnancy complicated by PE with women with a history of a normotensive pregnancy, did not demonstrate a significant difference in LV-GLS.[44] Two studies differentiated between EO-PE and LO-PE.[40,43] Both studies showed a decreased LV-GLS after EO-PE, whereas LO-PE was shown not significantly different from normotensive controls.[40,43]

Comparing women with a history of a pregnancy complicated by GH or CH to women with a history of a normotensive pregnancy, one study found a decreased

TABLE 1
Characteristics and Quality of Included Studies

Author Year	Total No. Women	Population (n)	HPD Definition Inclusion and Exclusion Criteria	Methods	Mean GA (wk) or Period Postpartum at Assessment	Quality Assessment and Risk of Bias (NOS)	Losilla et al[33] Quality Categories
Studies examining women during their pregnancy							
Ajmi et al[18]	60	Cases: HPD (30) Control: NTP (30)	HPD definition: ACOG Inclusion: Age 18–42, GA 28–38 wk Exclusion: preexisting hypertension, cardiac, pulmonary, renal disease, or other pathology that may influence ultrasound data EF <55%, difficult interpretation or poor quality of photographs	Study design: case control Machine: Vivid TM E9, GE STE software: not described	Cases: 32 Control: 33	7 (3/2/2)	High quality
Buddeberg et al[12]	70	Cases: PE (30) Control: NTP (40)	HPD definition: ISSHP Inclusion: GA at term, before start of any antihypertensive medication Exclusion: any cardiovascular comorbidity	Study design: case control Machine: Vivd Q, GE STE software: EchoPAC	Cases: 39.3 ± 1.0 Control: 38.3 ± 1.5	5 (3/0/2)	Moderate quality
Cho et al[41] 2011	199	Cases: GH (106) Control: NTP (93)	HPD definition: NHBPEPWG on HBPP Inclusion: pregnancy Exclusion: DM, essential hypertension, or symptomatic coronary artery disease	Study design: case control Machine: Vivid 7, GE STE software: EchoPAC	Cases: 33.3 ± 3.6 Control: 35.1 ± 3.4	4 (2/0/2)	Moderate quality
Cong et al[39]	165	Cases: EO-PE (43) LO-PE (41) Control: NTP <34 wk (41) NTP >34 wk (40)	HPD definition: ISSHP Inclusion: singleton pregnancy Exclusion: preexisting medical conditions	Study design: case control Machine: Vivid E9, GE STE software: EchoPAC	Cases: EO-PE: 28.9 ± 2.7 LO-PE: 36.4 ± 1.3 Control < 34: 28.2 ± 2.9 Control ≥ 34: 36.4 ± 1.3	7 (3/2/2)	High quality
Cong et al[38]	86	Cases: PE (45) Control: NTP (41)	HPD definition: ISSHP Inclusion: singleton pregnancy Exclusion: poor quality images, smoking history, or any previous medical condition	Study design: case control Machine: Vivid E9, GE STE software: EchoPAC	Cases: 31.8 ± 4.2 Control: 32.7 ± 3.7	8 (3/2/3)	High quality
Pan et al[47]	53	Cases: s-PE (33) Control: NTP (20)	HPD definition: ISSHP Inclusion: nonsmoking Exclusion: comorbidities	Study design: case control Machine: Vivid E9, GE STE software: not described	Cases: 34.7 ± 5.0 Control: 34.7 ± 3.4	7 (3/2/2)	High quality

(Continued on next page)

TABLE 1. *(Continued)*

Author Year	Total No. Women	Population (n)	HPD Definition Inclusion and Exclusion Criteria	Methods	Mean GA (wk) or Period Postpartum at Assessment	Quality Assessment and Risk of Bias (NOS)	Losilla et al[33] Quality Categories
Shahul et al[37]	28	Cases: PE (11) Control: NTP (17)	HPD definition: ACOG Inclusion: Age ≥18, singleton pregnancy, GA 24–41 wk Exclusion: preexisting CVD, pulmonary disease, DM, or poor image quality	Study design: case control Machine: Siemens X-300 STE software: Tomtec	Cases: 36.6 (32.7–37.4) Control: 38.0 (35.6–39.6)	5 (3/0/2)	Moderate quality
Shahul et al[36]	167	Cases: PE (48) Control: NTP (105)	HPD definition: ACOG Inclusion: Age ≥18, singleton pregnancy, GA <41 wk Exclusion: preexisting cardiomyopathy, ischemic or valvular heart disease, pulmonary disease, DM, or labor	Study design: case control Machine: Philips CX-50 STE software: Autostrain, Tomtec	Cases: 32.8 ± 3.7 Control: 30.7 ± 4.3	5 (3/0/2)	Moderate quality
Vaught et al[16]	99	Cases: s-PE (49) Control: NTP (36)	HPD definition: ACOG Inclusion: Singleton pregnancy, GA >23 wk Exclusion: SLE, congenital or valvular heart disease, APS, cardiomyopathy, pulmonary hypertension or embolism, cardiac surgery, connective tissue or interstitial lung disease, poor image quality	Study design: case control Machine: GE or Philips ultrasound machine STE software: Epsilon software	Cases: 33.1 ± 3.6 Control: 31.8 ± 4.9	6 (3/1/2)	Moderate quality
Xia et al[42]	197	Cases: m-PE (73) s-PE (50) Control: NTP (51)	HPD definition: as in Obstetrics and Gynecology by Xie and Gou Inclusion: gestational age ≥32 wk Exclusion: congenital heart disease, other serious comorbidities	Study design: case control Machine: Vivid E9, GE Software: EchoPAC	Mild PE: 35.9 ± 3.3 Severe PE: 35.2 ± 3.1 Control: 34.9 ± 2.7	5 (3/0/2)	Moderate quality

Studies examining women postpartum							
Al-Nashi et al[44]	31	History of: Cases: PE (15) Control: NTP (16)	HPD definition: ACOG Inclusion: primiparous women during index pregnancy Exclusion: smoking, cardiovascular risk factors	Study design: case control Machine: Vivid 7, GE STE software: EchoPAC	Mean period after index pregnancy: 11.2 ± 0.6 y Years after last pregnancy: Cases: 7.9 ± 3.3 y Control: 6.6 ± 2.4 y	8 (3/2/3)	High quality
Clemmensen et al[40]	93	History of: Cases: EO-PE (31) LO-PE (22) Control: NTP (40)	HPD definition: ISSHP Inclusion: women who gave birth between 1998–2008 Exclusion: new pregnancy, breastfeeding, natural menopause, or address >100 km away from study site	Study design: case control Machine: Vivid E9, GE STE software: EchoPAC	Time since index pregnancy in years EO-PE cases: 13 ± 4 y LO-PE cases: 12 ± 3 y Control: 12 ± 3 y	8 (3/2/3)	High quality
Orabona et al[43]	90	History of: Cases: EO-PE (30) LO-PE (30) Control: NTP (30)	HPD definition: ISSHP Inclusion: women who had normal blood pressure and no pathological proteinuria 6 mo after delivery Exclusion: smoking, dyslipidemia, obesity, DM, chronic hypertension, cardiopathy, nephropathy, immune disorders, PE superimposed on CH, multiple pregnancy, chromosomopathy, or fetal malformation	Study design: case control Machine: Vivid 7, GE STE software: not described	Time since delivery: 6 mo–4 y Mean time since delivery: EO-PE: 2.3 ± 0.7 LO-PE: 2.5 ± 0.8 Control: 2.2 ± 0.6	9 (4/2/3)	High quality
Studies examining women both during their pregnancy as postpartum							
Levine et al[46]	58	Cases: s-PE (29) Control: NTP (29)	HPD definition: ACOG Inclusion: Age ≥18 Exclusion: preexisting CVD, chronic hypertension without superimposed PE, or multiple gestations	Study design: longitudinal case control Machine: Vivid E9 and E95, GE STE software: Tomtec	GA at assessment during pregnancy Cases: 31.3 ± 3.9 Control: 31.7 ± 3.6 Time since delivery at assessment postpartum: 4–12 wk postpartum Cases: 6 (5–6) Control: 7 (6–9)	7 (3/2/2)	High quality

(Continued on next page)

TABLE 1. *(Continued)*

Author Year	Total No. Women	Population (n)	HPD Definition Inclusion and Exclusion Criteria	Methods	Mean GA (wk) or Period Postpartum at Assessment	Quality Assessment and Risk of Bias (NOS)	Losilla et al[33] Quality Categories
Shahul et al[35]	85	Cases: PE (32) Control: GH or CH (28) NTP (25)	HPD definition: ACOG Inclusion: Age ≥18, singleton pregnancy, GA <41 wk Exclusion: preexisting cardiomyopathy, ischemic or valvular heart disease, pulmonary disease, DM, or women in labor	Study design: longitudinal case control Machine: Philips CX-50 STE software: Autostrain, Tomtec	GA at assessment during pregnancy PE: 32.2 (29.1–36.1) GH or CH: 37.9 (33.3–39.2) Control: 30.7 (26.7–32.3) Time since delivery at assessment postpartum: 12 mo	5 (3/0/2)	Moderate quality
Yu et al[45]	82	Cases: GH (27) PE (25) Control: NTP (30)	HPD definition: NHBPEPWG on HBPP Inclusion: women aged ≥18, singleton pregnancy, and nonsmoking Exclusion: gestational diabetes, previous history of hypertension, CVD, poor images quality	Study design: longitudinal case control Machine: Siemens S2000 (Axius, Siemens) STE software: Axius, Siemens Medical	GA at assessment during pregnancy PE: 32 ± 6 GH: 34 ± 3 Control: 33 ± 4 Time since delivery at assessment postpartum: 3 mo	5 (3/0/2)	Moderate quality

Data are mean ± SD or median (interquartile range).

ACOG, American College of Obstetricians and Gynecologists; APS, antiphospholipid syndrome; DM, diabetes mellitus; GA, gestational age; ISSHP, International Society for the Study of Hypertension in Pregnancy; NHBPEPWG on HBPP, National High Blood Pressure Education Program Working Group on High Blood Pressure in Pregnancy; NTP, normotensive pregnancy; m-PE, mild PE; s-PE, severe PE; SLE, systemic lupus erythematosus.

TABLE 2
Echocardiography Features During Pregnancy

Author	Ajmi	Buddeberg	Cho	Cong	Cong	Levine	Pan	Shahul	Shahul	Shahul	Vaught	Xia	Yu
Year	2018	2018	2011	2015	2018	2019	2019	2012	2016	2018	2018	2017	2018
No. participants	60	70	199	165	86	58	53	28	167	85	99	197	82
GA cases	32	39 ± 1	33 ± 4	29 ± 3/36 ± 1	32 ± 4	31 ± 4	35 ± 5	37	33 ± 4	32	33 ± 4	m-PE 36 ± 3 s-PE 35 ± 3	PE 32 ± 6 GH 34 ± 3
GA control	33	38 ± 2	35 ± 3	28 ± 3/36 ± 1	33 ± 4	31 ± 4	35 ± 3	38	31 ± 4	31	32 ± 5	35 ± 3	33 ± 4
LV-GLS	PE ↓, GH ↓	PE ↓	HPD*↓	PE ↓	PE ↓	s-PE↓	s-PE ↓	PE ↓	PE ↓	PE ↓	s-PE =	PE↓	PE↓, GH ↓
LV-GRS	PE =, GH =			EO-PE ↓, LO-PE =				PE ↓				s-PE ↓, m-PE =	PE ↓, GH =
LV-GCS	PE =, GH =			PE ↓		s-PE =		PE ↓				s-PE ↓, m-PE =	PE ↓, GH ↑
SR		PE ↓											

*Study by Cho et al included patients with GH of whom 10 developed PE.

↑, significant increase; ↓, significant decrease; =, no significant difference compared with the control group of normotensive pregnant women; empty cell, parameter not analyzed in the study; GA, gestational age in weeks; s-PE, severe PE; m-PE, mild PE.

LV-GLS in women with either GH or CH,[35] whereas another study showed no significant difference between GH and normotensive controls.[45]

Left Ventricular Global Radial Strain

Results During Pregnancy. LV-GRS was measured in 5 studies.[18,37,39,42,45] LV-GRS was shown significantly lower in women with PE in 2 studies,[37,45] whereas 1 study showed no significant difference.[18] One study differentiated between EO-PE and LO-PE.[39] Compared with normotensive pregnant women, LV-GRS was significantly decreased in EO-PE but comparable in LO-PE.[39] In the fifth study, patients suffering from either severe or mild PE were compared with normotensive pregnant women. LV-GRS was only shown significantly lower in patients with severe PE.[42]

Comparable LV-GRS was shown in 2 studies in patients with GH compared with normotensive pregnant controls.[18,45]

Results Postpartum. LV-GRS was measured postpartum in 2 studies.[43,45] The measurement timing ranged between 3 months[45] to 4 years[43] postpartum. Women suffering from PE or EO-PE showed decreased LV-GRS in 2 studies.[43,45] After a pregnancy complicated by LO-PE or CH, however, LV-GRS was shown comparable to normotensive women.[43,45]

Left Ventricular Global Circumferential Strain

Results During Pregnancy. Six studies report results concerning LV-GCS during pregnancy.[18,37,39,42,45,46] Comparing women with a pregnancy complicated by PE to normotensive pregnant women, 3 studies showed a significantly decreased LV-GCS in PE,[37,39,45] whereas

TABLE 3
Echocardiography Features After Delivery

Author	Al-Nashi	Clemmensen	Levine	Orabona	Shahul	Yu
Year	2016	2018	2019	2017	2018	2018
No. participants	31	93	58	90	58	82
Mean period postpartum cases	11.2 ± 0.6	EO-PE 13 ± 4 y	6 wk	EO-PE 2.3 ± 0.7 y	1 y	3 mo
Control	11.2 ± 0.6	LO-PE 12 ± 3 Control 12 ± 3	7 wk	LO-PE 2.5 ± 0.8 Control 2.2 ± 0.6	1 y	3 mo
LV-GLS	PE =	EO-PE ↓, LO-PE =	s-PE ↓	EO-PE ↓, LO-PE =	PE ↓, GH/CH ↓	PE ↓, GH =
LV-GRS				EO-PE ↓, LO-PE =		PE ↓, GH =
LV-GCS			s-PE =	EO-PE ↓, LO-PE =		PE ↓, GH =
SR						

↑, significant increase; ↓, significant decrease; =, no significant difference compared with the control group of postpartum women after a normotensive pregnancy; empty cell, parameter not analyzed in the study; s-PE, severe PE.

2 studies showed no significant difference.[18,46] The fifth study compared women with either mild or severe PE to normotensive pregnant controls.[42] LV-GCS was only significantly decreased in severe PE.[42]

In GH, LV-GCS was increased in one study[45] and comparable to normotensive controls in another study.[18]

Results Postpartum. LV-GCS was measured in 3 studies postpartum.[43,45,46] The measurement timing ranged between 6 weeks[46] and 4 years[43] postpartum. Compared with a history of a normotensive pregnancy, LV-GCS was significantly decreased after PE in one study,[45] and comparable to a history of PE in one study.[46] One study differentiated between a history of EO-PE or LO-PE.[43] Compared with a history of a normotensive pregnancy, LV-GCS was significantly decreased after EO-PE but comparable after LO-PE.[43]

LV-GCS was not shown significantly different between women with a history of GH and women with a history of a normotensive pregnancy.[45]

Left Ventricular Strain Rate

Only one study reported on left ventricular strain rate (LV-SR) differences between pregnant women with HPD and normotensive pregnant controls.[12] LV-SR was significantly lower in patients with PE compared with normotensive pregnant women. None of the studies including women postpartum reported results of LV-SR measurements.

DISCUSSION

Main Findings

A systematic review concerning STE in women with a history of HPD compared with normotensive controls was performed. Our major finding was a significantly decreased LV-GLS in HPD during pregnancy in all studies but one. That study showed a trend toward decreased LV-GLS in PE, however, because multiple-testing correction was used in that study, this was not significant.[16] The use of multiple-testing correction could explain why the results of that study were inconsistent with all other studies.

LV-GLS represents LV myocardial shortening in the longitudinal axis and is an important index of global LV function. LV-GLS is capable of early and accurate detection of cardiac alterations that may affect subendocardial longitudinal fibers.[29] These fibers are involved in the first subclinical stages of several diseases such as ischemic injury and arterial hypertension, showing a reduced LV-GLS.

Furthermore, LV-GLS is associated with major adverse cardiac events in patients with asymptomatic hypertensive heart disease.[26] Therefore, a decreased LV-GLS in women with HPD can also be an indicator of subclinical deterioration of the myocardium and may be a useful tool for early detection of women at risk for cardiac dysfunction later in life.[26,29] As the currently used cardiac function parameter left ventricular ejection fraction is typically still normal in the subclinical phase of these diseases, LV-GLS could be a more useful tool in early detection.[29]

This review showed a difference between EO-PE and LO-PE postpartum. LV-GLS, LV-GRS, and LV-GCS were decreased in women with a history of a pregnancy complicated by EO-PE compared with normotensive controls, whereas LV-GLS, LV-GRS, and LV-GCS were shown comparable in women with a history of LO-PE and women with a history of a healthy pregnancy.[40,43] This suggests lasting myocardial changes in women suffering from EO-PE in pregnancy, up to 13 years postpartum.

Growing evidence suggests that EO-PE and LO-PE have different etiologies and should be regarded as 2 different types of the disease.[10,11,14,49] EO-PE and LO-PE have a different maternal cardiovascular adaptation to pregnancy.[39,50] Also, EO-PE is associated with a higher risk of morbidity and mortality during pregnancy than LO-PE, which is probably due to differences in the severity of the disease.[9,51]

When distinguishing between the 3 different HPD (ie, GH, CH, and PE), STE parameters seem to be altered more in PE than in GH or CH, both during pregnancy as postpartum. This is in line with the findings of the review by Castleman et al about conventional echocardiography in HPD, which showed that if echocardiographic changes are seen in HPD, these changes are more severe in case of PE compared with GH.[52] This increased impact on the heart in PE is in line with the increased CVD incidence after a pregnancy complicated by PE compared with after GH or CH.[53]

Although it is not well established whether cardiovascular derangement in HPD is a primary etiological factor or a secondary effect, the differences in STE results between the separate HPD attribute to our understanding of the differences between these disorders.

Strengths and Limitations

One of the strengths of this systematic review is our rigorous search without restrictions on language or year of publication. It is conceivable that studies are more likely to be published in an international English-language journal if results are significant, whereas nonsignificant findings are more likely to be published in a local, non-English journal.[32] Another strength of this review is the moderate to high quality of the included studies.[30,33]

A limitation of this review is that the generalizability of the results remains unclear. Due to heterogeneity of the studies, a meta-analysis was not performed as suggested by the Cochrane handbook for systematic reviews of interventions.[32]

Clinical Implications and Future Research

The use of STE for various clinical settings has increased remarkably over recent years.[29] In the acute phase of myocardial infarction, reduced LV-GLS has been proven to be the single most powerful marker of manifest LV hemodynamic deterioration.[54] Moreover, in heart failure, LV-GLS is an independent predictor of mortality and a superior compared with other echocardiographic parameters.[55,56]

However, the use of STE in pregnancy is not very widespread in clinical practice yet. This review shows a decrease in cardiac function, especially in LV-GLS, starting during pregnancy and lasting up to 13 years after pregnancies complicated by HPD compared with normotensive controls. This could indicate that women with echocardiographic abnormalities measured during their pregnancy may benefit from more strict surveillance and treatment to decrease cardiovascular risks during life.

Because STE might be a tool to detect subclinical cardiac changes, more sensitive than conventional echocardiography,[12,17,20,22] STE might be promising for prediction and prevention of CVD after HPD.

A recommendation for future research is to measure STE in mother and fetus simultaneously. Growing evidence shows that, like the mothers, the offspring of pregnancies complicated by HPD also have increased risk of developing CVD later in life compared with offspring of uncomplicated pregnancies.[57–62] A recent study by Yu et al[63] already showed signs of diastolic dysfunction in fetuses of mothers with PE compared with fetuses of healthy mothers. This study also shows that STE appears to be more sensitive than conventional echocardiography for the evaluation of fetal cardiac function.[63] Early identification of children with altered strain measurement during and after a pregnancy complicated by HPD might help to provide adequate screening and treatment for children at risk for CVD.

One study by Shahul et al[64] studied the predictive value of abnormal strain during pregnancy in women with CH. Women with CH who had a decreased LV-GLS midgestation had a significantly higher risk of developing superimposed PE. Future research should continue to focus on the clinical relevance of an abnormal strain during pregnancy, as well as the association between abnormal strain during pregnancy and the development of CVD later in life. Possibly, abnormal strain measurements might help to differentiate within the high-risk group of women with HPD, making appropriate screening and treatment possible based on each women's personal risk profile. Pregnancy may therefore be considered as a window of opportunity for improvement of future health.[65]

CONCLUSIONS

Speckle tracking echocardiography can detect differences between pregnant women with HPD and normotensive pregnant women, mainly in LV-GLS. This parameter is significantly decreased in pregnant women with HPD compared with normotensive pregnant controls. Other deformation values show a significant decrease in women with severe or early-onset PE, with lasting myocardial changes after early-onset PE. Future research should focus on the clinical relevance of an abnormal strain during pregnancy and its association with the development of CVD later in life.

ACKNOWLEDGMENTS

This research was performed within the framework of Eindhoven MedTech Innovation Center (e/MTIC). The authors thank Dr H.E.J. de Vries, a professional medical research librarian who helped us with the search.

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APPENDIX 1

(("Pre-Eclampsia"[Mesh]) OR (pre eclampsia[tw] OR preeclampsia[tw] OR gestosis[tw] OR toxemia*[tw] OR toxicosis[tw]) OR (("Hypertension, Pregnancy-Induced"[Mesh]) OR ("Pregnancy"[Mesh] AND "Hypertension"[Mesh])) OR ((pregnan*[tiab] OR gestation*[tiab] OR maternal[tiab]) AND hypertens*[tiab])) AND ((speckle*[tw] OR strain*[tw]) AND (echocardiograph*[tw] OR imaging[tw])