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Original Article
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Effect of pregnancy prolongation in early-onset pre-eclampsia on postpartum maternal cardiovascular, renal and metabolic function in primiparous women: an observational study

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Objective To evaluate the association between deferred delivery in early-onset pre-eclampsia and offspring outcome and maternal cardiovascular, renal and metabolic function in the postpartum period.

Design Observational study.

Setting Tertiary referral hospital.

Population Nulliparous women diagnosed with pre-eclampsia before 34 weeks' gestation who participated in a routine postpartum cardiovascular risk assessment programme. Women with hypertension, diabetes mellitus or renal disease prior to pregnancy were excluded.

Methods Regression analyses were performed to assess the association between pregnancy prolongation and outcome measures.

Main outcome measures Offspring outcome and prevalence of deviant maternal cardiovascular, renal and metabolic function.

Results The study population included 564 women with a median pregnancy prolongation of 10 days (interquartile range [IQR] 4–18) who were assessed at on average 8 months (IQR 6–12) postpartum. Pregnancy prolongation after diagnosis resulted in a decrease in infant mortality (adjusted odd ratio [aOR] 0.907, 95% CI 0.852–0.965 per day prolongation). This improvement in offspring outcome was associated with an elevated risk of moderately increased albuminuria (aOR 1.025, 95% CI 1.006–1.045 per day prolongation), but not with aberrant cardiac geometry, cardiac systolic or diastolic dysfunction, persistent hypertension or metabolic syndrome.

Conclusion Pregnancy prolongation in early-onset pre-eclampsia is associated with improved offspring outcome and survival. These effects do not appear to be deleterious to short-term maternal cardiovascular and metabolic function but are associated with a modest increase in risk of residual albuminuria.

Keywords Albuminuria, cardiovascular health, deferred delivery, early-onset pre-eclampsia, hypertension, metabolic syndrome.

Tweetable abstract Pregnancy prolongation in pre-eclampsia has only a limited effect on postpartum maternal cardiovascular function.

Linked article This article is commented on by R Orabona and F Prefumo, p. 130 in this issue. To view this mini commentary visit https://doi.org/10.1111/1471-0528.16540.

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Introduction

Pre-eclampsia, a gestational hypertensive disorder, substantially increases maternal and offspring morbidity and mortality.[1] It is thought to be an endothelial disease where pathogenesis involves suboptimal placental function and cardiovascular maladaptation, mostly superimposed upon subclinical pre-existing cardiovascular and metabolic risk factors.[2,3] Forty percent of women with preterm pre-eclampsia have asymptomatic structural cardiac alterations or dysfunction at 1 year postpartum, and within 15 years after delivery, pre-eclampsia relates to a two- to seven-fold increased risk of coronary heart disease, stroke and related death and a four-fold increased risk of end-stage renal disease.[4,5] Hypertension is prevalent in 25% of women within a few years after pregnancy and up to 20% of women meet the criteria for metabolic syndrome by that time.[4,6] It is not evident whether the postpartum sequelae are a consequence of the pre-existing underlying maternal cardiovascular risk factors or due to the deleterious effects of the gestational disease itself on the maternal cardiovascular system.[7–9]

Delivery is currently the only definite treatment of pre-eclampsia and scheduled delivery is clinically dependent on gestation at diagnosis, severity of maternal disease and fetal condition. This decision often presents a management dilemma because premature birth increases the risk of neonatal morbidity and mortality, whereas expectant management increases maternal jeopardy from deterioration of the pre-eclamptic condition.[10] International guidelines generally recommend expectant management with continued, vigilant surveillance of mother and fetus, with scheduled delivery for features of severe maternal disease or signs of fetal compromise.[11,12] Risk of maternal peripartum complications can be estimated by the PIERS model, which predicts adverse maternal outcomes based on a few parameters that are readily obtainable in clinical practice.[13]

Prolongation of pregnancy by a week in women with gestational hypertensive disorders at term did not relate to increased prevalence of metabolic syndrome.[14] However, it does seem to be associated with persistence of postpartum hypertension and with the risk of severe cardiovascular diseases, suggesting that prolonged exposure to pre-eclampsia affects remote maternal cardiovascular health.[15,16] There is a real paucity of evidence on the effect of expectant management of severe, early-onset pre-eclampsia on postpartum maternal cardiovascular recovery and function. The objective of this observational study was to evaluate the association between duration of gestational disease exposure and offspring outcome and maternal cardiovascular, renal and metabolic function in primiparous women.

Material and methods

Study population

There were no patients involved, or public involvement in the design and conduct of this research. No core outcome set has been used. Informed consent related to the use of clinically acquired data for scientific analysis was obtained as is customary in the Maastricht University Medical Centre (MUMC). From 1996, postpartum assessment was offered to all women with pre-eclampsia and related complications during pregnancy. The clinical service was accessible to all women in the country and approximately 65% of women were referred by physicians from other hospitals, who mainly refer women with severe complications during their pregnancy. The assessment took place at least 4, but preferably 6 months postpartum, and women were only scheduled when not breastfeeding to measure plasma volume by the Iodine[125] albumin indicator dilution technique (not evaluated in this study). For our analysis, we included only women admitted to the assessment within 2 years after delivery, and with onset of pre-eclampsia before 34 weeks' gestation, as in these women, pregnancy prolongation is assumed to benefit offspring outcome. General management of these women was according to international guidelines, recommending a temporising management plan in women without features of severe disease, and an individualised approach in women with features of severe disease. Women who presented with pre-eclampsia before 24 weeks were excluded, as expectant management was not typically offered as a standard treatment option.[17] Women who presented with stillbirth at the time of admission were excluded, as the clinical consideration of whether to terminate pregnancy for the benefit of the fetus is no longer an issue. Multiparous women and women with pre-pregnancy hypertension, diabetes mellitus or renal disease were also excluded.

Postpartum assessment

Assessment of cardiovascular, renal and metabolic risk factors was performed in standardised conditions at a morning clinic after an overnight fast. Clinical data on obstetric history, medical history and use of medication were collected from medical files, referral letters and direct patient enquiry. Diagnosis of pre-eclampsia was taken as the gestational age at which hypertension and proteinuria were observed for the first time. Glucose, insulin, creatinine and lipid-spectrum levels were obtained from fasting blood samples. Urine was collected in the 24 hours preceding the measurements and was assayed for albumin, creatinine and total protein. Body mass index [BMI] was calculated by dividing the bodyweight in kilograms by the squared height in meters. Arterial blood pressure was measured in sitting position by a semiautomatic oscillometric device (Dinamap Vital Signs Monitor 1846; Critikon, Tampa, FL, USA) every 3 minutes. The median value of 11 measurements was reported. Transthoracic echocardiography was performed according to the American Society of Echocardiography (ASE) guidelines using a commercially available phased-array echocardiographic Doppler system (iE33 system with S5-1 or X5-1 transducers, Philips Medical Systems, Best, Netherlands).[18] All images were acquired in left lateral position, recorded as ECG-gated digital loops and stored for off-line analysis. Using M-mode in the parasternal long-axis view, we measured left ventricular end-diastolic

(LVEDd) and end-systolic (LVESd) diameters, end-diastolic interventricular septum thickness (IVST) and the posterior (inferolateral) wall thickness (PWT). As recommended by the ASE, left ventricular mass (LVM; g) was determined using the Devereux formula: $0.8 \times \{1.04\ ([LVEDd + PWT + IVST]^3 - [LVEDd]^3) + 0.6\}$, indexed for body surface area.[19,20] Relative wall thickness (RWT) was computed using the formula: $2 \times PWT/LVEDd$.[20] Left ventricular end-diastolic (EDV) and end-systolic volumes (ESV) were determined using the Teichholz formula. Left ventricular ejection fraction (%) was calculated using the formula: $([EDV\text{-}ESD]/EDV) \times 100$.

Definitions

Pre-eclampsia was defined as new-onset hypertension with a systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg in two repeated measurements along with de novo proteinuria (≥0.3 g/24 hours or ≥2+ on dipstick analysis) after 20 weeks' gestation. Early-onset pre-eclampsia was defined as diagnosis before 34 weeks' gestation. HELLP syndrome was defined as haemolysis (LDH >600 U/l), elevated liver enzymes (AST and ALT >70 U/L) and low platelets (platelet count $<100.10^9$/l). Small-for-gestational-age (SGA) birth was defined as neonatal birthweight below the 10th percentile of the national birthweight charts, corrected for sex of the neonate and parity.[21] Infant mortality was defined as death within 1 year after delivery.

Cardiac systolic dysfunction was defined as an ejection fraction ≤55% and aberrant cardiac geometry was defined by left ventricular mass index >95 g/m^2, or RWT >0.42. Kidney function was evaluated based on the Kidney Disease Improving Global Outcomes (KDIGO) criteria, indicating that monitoring of kidney function at least once a year is required for women with a glomerular filtration rate <60 ml/minute/1.73 m^2 or an albumin-to-creatinine ratio ≥3.0 g/mol creatinine.[22]

Constituents of the metabolic syndrome were defined based on World Health Organization criteria as follows: hyperinsulinemia (fasting insulin >9.2 mU/l, fasting glucose >6.1 mmol/l, and/or homeostasis model assessment for insulin resistance [HOMA-IR] >2.2), obesity (BMI >30 kg/m^2), dyslipidaemia (triglycerides ≥1.7 mmol/l or HDL-cholesterol <0.9 mmol/l), hypertension (systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg and/or the use of antihypertensive medication) and proteinuria (albuminuria >2.5 g/mol creatinine or proteinuria >0.30 g/24 h).[23] Metabolic syndrome was defined as hyperinsulinemia along with two or more of the other constituents.

Statistical analysis

Women were divided into three groups based on duration of pre-eclampsia to give a general insight in the study population characteristics. Trends in difference between groups were analysed with pregnancy prolongation in days between diagnosis and delivery as a continuous variable, and not categorically. Logistic and linear regression analysis, whenever applicable, was performed to estimate the associations between duration of pre-eclampsia and offspring outcome, and maternal deviant cardiovascular, renal and metabolic function. Because postpartum time intervals could differ between women, we corrected for time-interval between delivery and postpartum assessment by adding time as a covariate in the multivariable regression analysis when analysing the maternal effects. In addition, adjusted odds ratios (aOR) were calculated with multivariable regression analysis. We adjusted for gestational age at delivery, maternal age, year of assessment and the presence of metabolic syndrome factors at evaluation. A two-sided *P*-value of 0.05 or below was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics version 24.0 (IBM Corp., Armonk, NY, USA).

Results

Between September 1996 and July 2018, 709 women with a history of early-onset pre-eclampsia were admitted to the MUMC for postpartum cardiovascular and metabolic risk assessment (Figure 1). Selecting primiparous women without pre-existing diseases resulted in 594 eligible women. Characteristics of women with onset of pre-eclampsia before 24 weeks' gestation (n = 23) or who presented with stillbirth (n = 7) are presented in Table S1. In the analysis were 564 women whose obstetric characteristics are presented in Table 1. Median pregnancy prolongation was 10 days, gestational age at diagnosis was lower in the group of women with the longest pregnancy prolongation, and prevalence of HELLP syndrome was highest in the group with short pregnancy prolongation.

Postpartum maternal status

Regression analysis showed no differences in postpartum cardiac geometry and function, vascular function, renal function or metabolic syndrome components with pregnancy prolongation (Tables 2 and S2). The OR adjusted for the interval between delivery and postpartum assessment showed that pregnancy prolongation was associated with moderately increased postpartum albuminuria (OR 1.022, 95% CI 1.005–1.040 per day prolongation) but not with severely increased proteinuria (Table 3). After adjustments for gestational age at delivery, maternal age, year of postpartum assessment and metabolic syndrome constituents, the association with moderately increased albuminuria persisted. Pregnancy prolongation was not associated with reduced creatinine clearance, annual monitoring of kidney function advice, deviant cardiac parameters or hypertension postpartum.

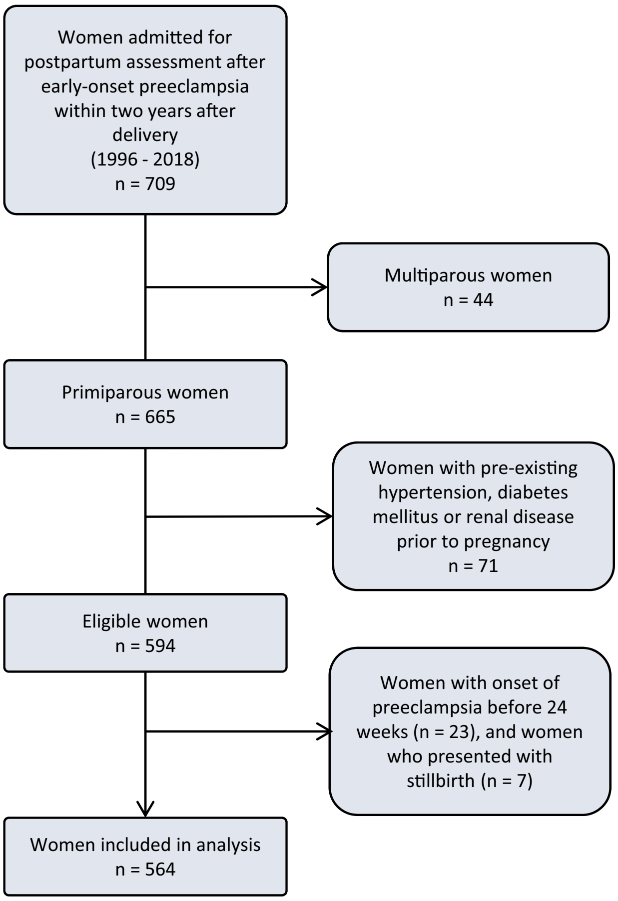

Figure 1. Flowchart for selection of women.

Offspring outcome

There were no offspring outcomes associated with pregnancy prolongation, apart from higher absolute birthweight in women whose pregnancy was prolonged longer (Table 1). Pregnancy prolongation did not increase the risk of placental abruption, stillbirth or prevalence of SGA neonates but was associated with a significant decrease in infant mortality (OR 0.952, 95% CI 0.909–0.998) (Table S3). When adjusted for gestational age at diagnosis, concurrent HELLP syndrome and eclampsia, and year of assessment, the beneficial effect of pregnancy prolongation on infant survival persisted (aOR 0.907, 95% CI 0.852–0.965).

Discussion

Main findings

This observational study demonstrates that pregnancy prolongation in early-onset pre-eclampsia is related to improved offspring outcome and survival but is not associated with deleterious effects on maternal cardiovascular, renal and metabolic function in the postpartum period, other than an increased risk of moderately increased albuminuria.

Strengths and limitations

The strength of our study is the extensive postpartum assessment of risk factors, which enabled us to correct for cardiovascular and renal risk factors. Some limitations also need to be addressed. Firstly, detailed information on antihypertensive treatment, target blood pressure and other

Table 1. Obstetric characteristics of study population categorised by duration of pregnancy prolongation

Pregnancy outcome	Total	Pregnancy prolongation			*P*-value*
	n = 564	≤6 days *n* = 186	7–13 days *n* = 173	≥14 days *n* = 205	
Prolongation in days	10 [4–18]	3 [1–4]	9 [7–11]	21 [17–30]	
GA at diagnosis	30^{0} [28^{0}–32^{0}]	31^{0} [29^{0}–32^{5}]	30^{0} [28^{0}–32^{0}]	30^{0} [27^{0}–32^{0}]	<0.001
GA at delivery	32^{0} [29^{5}–33^{6}]	31^{5} [29^{2}– 33^{1}]	31^{2} [29^{0}–33^{0}]	33^{0} [30^{5}–35^{1}]	<0.001
HELLP syndrome	404/564 (72%)	134/186 (72%)	131/173 (76%)	139/205 (68%)	0.017
Eclampsia	34/564 (6%)	17/186 (9%)	5/173 (3%)	13/205 (6%)	0.690
Birthweight, g	1400 [1000–1810]	1348 [975–1677]	1270 [875–1680]	1620 [1165–2060]	<0.001
Birthweight centile	16 [8–30]	18 [8–32]	16 [8–25]	15 [8–31]	0.805
Multifetal pregnancy	20/564 (4%)	7/186 (4%)	5/173 (3%)	8/205 (4%)	0.936
SGA birth/neonate	179/564 (32%)	54/186 (29%)	55/173 (32%)	70/205 (34%)	0.255
Placental abruption	19/564 (3%)	10/186 (5%)	5/173 (3%)	4/205 (2%)	0.109
Offspring demise	36/564 (6%)	15/186 (8%)	13/173 (8%)	8/205 (4%)	0.036
Stillbirth	8/564 (1%)	2/186 (1%)	4/173 (2%)	2/205 (1%)	0.559
Infant mortality	28/564 (5%)	13/186 (7%)	9/173 (5%)	6/205 (2%)	0.042

GA, gestational age; SGA, small for gestational age.
Data are presented as median [interquartile range], or number/known outcome (percentage in group).
**P*-value indicates trend based on regression analysis with pregnancy prolongation used as a continuous variable.

Table 2. Pregnancy prolongation and postpartum maternal cardiovascular, renal and metabolic function

	Total *n* = 564	≤6 days *n* = 186	7–13 days *n* = 173	≥14 days *n* = 205	*P*-value*
Time to assessment (months)	8 [6–12]	8 [6–12]	7 [6–12]	8 [6–14]	0.006
Maternal age (years)	30.4 (4.2)	29.9 (4.0)	30.6 (4.1)	30.8 (4.5)	0.090
Cardiac parameters					
LVM index (g/m^2)	70 [61–79]	69 [61–79]	69 [60–78]	71 [61–80]	0.916
Relative wall thickness	0.33 [0.30–0.35]	0.33 [0.30–0.35]	0.32 [0.30–0.35]	0.33 [0.30–0.35]	0.698
Ejection fraction (%)	64 [61–67]	64 [61–67]	64 [60–67]	64 [60–67]	0.861
Renal parameters					
Albuminuria (g/mol creatinine)	1.0 [0.5–2.3]	0.8 [0.4–1.9]	1.0 [0.6–2.2]	1.2 [0.5–2.7]	0.643
Proteinuria (g/mol creatinine)	8.2 [6.7–10.5]	8.0 [6.7–10.3]	7.9 [6.4–10.3]	8.9 [7.0–11.4]	0.941
CC (ml/min/1.73 m^2)	106 [95–117]	107 [97–118]	105 [93–117]	104 [93–115]	0.209
Vascular function					
Systolic blood pressure (mmHg)	116 [109–124]	114 [108–123]	116 [109–124]	117 [109–125]	0.784
Diastolic blood pressure (mmHg)	73 [68–78]	72 [67–78]	74 [67–80]	73 [68–77]	0.725
Hypertension	98/559 (18%)	35/185 (19%)	25/170 (15%)	38/204 (19%)	0.716
Pulse pressure	43 [39–49]	43 [39–48]	43 [39–49]	44 [38–49]	0.971
Stroke volume/pulse pressure	1.64 [1.43–1.95]	1.68 [1.43–2.02]	1.63 [1.43–1.89]	1.63 [1.43–1.96]	0.783
Metabolic syndrome	82/560 (15%)	26/185 (14%)	21/171 (12%)	35/204 (17%)	0.321
Hyperinsulinemia	295/560 (53%)	98/185 (53%)	91/172 (53%)	106/203 (52%)	0.720
Obesity	124/564 (22%)	42/186 (23%)	34/173 (20%)	48/205 (23%)	0.265
Dyslipidaemia	109/563 (19%)	34/186 (18%)	33/173 (19%)	42/204 (21%)	0.956
Albuminuria or proteinuria	121/544 (22%)	31/178 (17%)	32/168 (19%)	58/203 (29%)	0.061

cc, creatinine clearance; LVM, left ventricular mass.
Data are presented as mean (standard deviation), median [interquartile range] or number/valid measurements (percentage in group).
**P*-value indicates trend based on regression analysis with pregnancy prolongation (days) used as a continuous variable.

Table 3. Association between pregnancy prolongation after pre-eclampsia diagnosis (per day prolongation) and maternal cardiovascular, renal and metabolic function

	OR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value
Cardiac parameters				
Left ventricular mass index >95 g/m^2	1.005 (0.956–1.056)	0.853	0.987 (0.928–1.050)	0.677
Relative wall thickness >0.42	1.023 (0.971–1.078)	0.398	1.001 (0.932–1.074)	0.987
Ejection fraction <55%	0.956 (0.873–1.047)	0.333	0.931 (0.840–1.031)	0.170
Renal parameters				
Albuminuria >2.5 g/mol creatinine*	1.022 (1.005–1.040)	0.011	1.025 (1.006–1.045)	0.010
Proteinuria >30 g/mol creatinine*	0.998 (0.932–1.069)	0.995	0.994 (0.924–1.071)	0.994
Creatinine clearance <90 ml/min/1.73 m^2	1.011 (0.993–1.029)	0.234	1.001 (0.981–1.022)	0.904
Annual monitoring necessary according to KDIGO*	1.013 (0.995–1.031)	0.173	1.013 (0.993–1.034)	0.211
Metabolic syndrome*	1.012 (0.993–1.032)	0.228	1.014 (0.993–1.036)	0.182
Hyperinsulinemia*	0.998 (0.984–1.012)	0.774	1.005 (0.988–1.023)	0.540
Obesity*	1.005 (0.989–1.022)	0.534	1.008 (0.988–1.028)	0.450
Dyslipidaemia*	1.003 (0.985–1.021)	0.755	0.996 (0.975–1.017)	0.702
Hypertension*	1.004 (0.986–1.023)	0.653	1.010 (0.989–1.032)	0.339
Albuminuria or proteinuria*	1.021 (1.004–1.039)	0.014	1.024 (1.005–1.044)	0.015

KDIGO, Kidney Disease Improving Global Outcomes.
ORs are adjusted for months between delivery and postpartum assessment.
aORs are adjusted for gestational age at delivery, maternal age, year of postpartum assessment, hyperinsulinemia, hypertension, obesity, dyslipidaemia, and moderately increased albuminuria, or severely increased proteinuria.
*Not adjusted for specific metabolic syndrome component(s).

treatment goals during pregnancy is lacking. Therefore, we are not able to evaluate the effect of specific treatment on pregnancy prolongation and outcomes. In addition, as we do not have detailed information on the maternal condition that contributed to the physicians' decision to terminate pregnancy, it could be possible that immediate scheduled birth was planned because of rapid deterioration of maternal condition. This would mitigate the association between pregnancy prolongation and maternal outcomes. On the other hand, pregnancy prolongation might be associated with more advanced maternal disease contributing to residual albuminuria postpartum. However, the decision to end pregnancy is often not based on increase or magnitude of proteinuria, as this does not affect maternal or perinatal outcome.[24] Lastly, as women had to attend the postpartum evaluation, we were not able to assess maternal death as outcome of a temporising management plan. Although absolute numbers of maternal deaths are low, and most maternal deaths occur after 34 weeks of pregnancy, postponing delivery in early-onset pre-eclampsia exposes the women to increased risk of mortality.[25,26]

Interpretation

In pre-eclampsia diagnosed before 34 weeks' gestation, immediate induction of labour increases the risk of neonatal mortality and morbidity, and pregnancy prolongation is preferred as long as maternal and fetal condition permits.[27,28] In our sample, pregnancy was prolonged for 10 days, which is slightly longer than in other studies despite the relatively high incidence of HELLP syndrome.[28–30] Women whose pregnancy was prolonged the longest, had earlier onset of pre-eclampsia, which probably explains the observed neonatal health gain of postponing delivery. Clinicians are more likely to take the risk of short-term maternal and fetal complications when the survival rate of the neonate is expected to be considerably improved with pregnancy prolongation.[31] Deferred delivery was associated with a decreased risk of infant mortality and resulted in higher absolute birthweight, which in turn also contributes to an increased survival rate.[32] The presumption that the in utero environment may be suboptimal for the growth potential of the fetus could not be substantiated by our observations, as the relative birthweight did not deteriorate with prolonged pregnancy.[33,34]

Prevalence of hypertension and blood pressure levels did not relate to pregnancy prolongation, nor did estimates of arterial compliance. The reason might be that clinical pre-eclampsia does not induce persistent vascular alterations, or that this contribution is minor compared with disease evolution prior to diagnosis. The changes in cardiac geometry during normotensive pregnancy generally recover in the postpartum period.[35] In contrast, after preterm pre-eclampsia, about half of women show asymptomatic structurally altered cardiac geometrics consisting mainly of concentric left ventricular remodelling, even after several years.[4] Concentric remodelling is known for its association with increased myocardial fibrosis, which decreases left ventricular compliance and consequently impairs diastolic function.[4,36] About a quarter of women in our population had a left ventricle mass index >80 g/m^2, which is above the upper limit of non-pregnant reference values.[37] In addition, the RWT of our women was comparable to other formerly pre-eclamptic women, being substantially higher than the postpartum RWT in women with uncomplicated pregnancies.[38] There was no association between pregnancy prolongation and deviant cardiac geometric indices and prevalence of global left ventricular dysfunction. A possible explanation could be that the known association with unfavourable structural alteration in pre-eclampsia may have already occurred by the time the diagnosis was made. A meta-analysis showed that the steepest change in left ventricular remodelling occurs before 30 weeks.[37] Moreover, when pre-eclampsia is diagnosed, blood pressure-lowering medication is initiated, which may temper further geometrical changes and myocardial damage.[39] It is also conceivable that the time-span of estimated disease prolongation is too short to result in deleterious effects on cardiac geometry.

The median albumin-to-creatinine ratio in our population was 1.0 g/mol (0.5–2.3 g/mol), which is slightly higher than the normal range in healthy women aged between 20 and 40 years (0.7 g/mol to 0.4–1.1 g/mol).[40] Pre-eclamptic women with prolonged pregnancy have a slightly higher risk of residual moderately increased albuminuria postpartum, but glomerular filtration rate and serum creatinine level were not affected. Also, pregnancy prolongation did not increase the prevalence of severely increased proteinuria, which usually resolves within weeks to months postpartum.[15] These observations suggest a higher risk on moderate endothelial dysfunction when a policy of pregnancy prolongation is pursued. It is uncertain whether residual albuminuria reflects incomplete recovery from permanent damage incurred during pregnancy or undetected pre-existing endothelial dysfunction predisposing to pre-eclampsia and postpartum diagnosis of albuminuria.[41,42] Pre-eclampsia is associated with an upregulation of placental sFlt-1, which scavenges vascular endothelial growth factor (VEGF). Reduction of VEGF in mice results in proteinuria and glomerular endotheliosis, resembling pre-eclampsia.[43] VEGF is a signal protein produced by podocytes with autocrine function to support cell survival, and paracrine function on the glomerular endothelial cells.[44] The degree of damaged podocytes correlates with the intensity of proteinuria, and depletion up to 20% results in a transient increase in proteinuria, with preserved creatinine clearance.[45] Proteinuria itself is potentially harmful to the proximal tubule and podocytes, as proteins in the glomerular ultrafiltrate activate inflammation and fibrosis, and the presence of proteins impairs podocyte regeneration.[46,47]

Our results emphasise the importance of monitoring the presence of moderately increased albuminuria in women with early-onset pre-eclampsia, especially in women whose pregnancy is prolonged by several weeks. To date, no specific interventions to improve long-term outcomes are evidenced, but adequate blood pressure control in hypertension, lifestyle and exercise advise might lower albuminuria in screen-positive women.[48,49]

Postpartum metabolic syndrome was observed in 15% of women in our population, compared with a prevalence of 5% in Dutch women of similar age.[50] Prevalence was not related to duration of preeclampsia – nor were the individual components of the metabolic syndrome other than albuminuria. Similar results were found in women with gestational hypertensive disorders at term whose induction of labour was postponed for a week compared with immediate delivery.[14] As hypertensive complications during pregnancy are associated with exaggerated metabolic changes prior to overt clinical disease, it might be unlikely that duration of pre-eclampsia affects the development of metabolic syndrome postpartum.[51–53] These findings support the concept of Romundstad et al. who suggested that postpartum development of metabolic syndrome is attributable to shared pre-pregnancy risk factors rather than a direct influence of gestational hypertensive disorders.[7]

Conclusion

Prolongation of pregnancy in early-onset pre-eclampsia with consideration of individual context at the discretion of the attending obstetrician relates to reduced infant mortality. Moreover, it is associated with a raised prevalence of moderately increased albuminuria but does not seem to have an adverse effect on cardiovascular function or metabolic status. It is unknown how these findings translate to long-term cardiovascular morbidity. Our findings should also be evaluated in a setting with detailed information on disease severity at presentation and peripartum management.

Disclosure of interests

None declared. Completed disclosure of interest forms are available to view online as supporting information.

Contribution to authorship

EM, CG, BT and MS were involved in the design and initiation of the study. EM, CG, MS acquired ethical approval. EM and JC had full access to the data in the study and take responsibility for the integrity of the data. SvK provided statistical expertise. All authors interpreted the data. EM and JC wrote the first draft of this protocol, and all authors critically reviewed and contributed to adjustments and approved the final version of this manuscript.

Details of ethics approval

The medical ethical committee of the Maastricht University Medical Centre approved the study protocol (date of approval last study amendment: 12 August 2019, reference number: MEC azM/UM 14-4-118).

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Not applicable.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Characteristics of women with pre-eclampsia before gestational age of 24 weeks or who presented with stillbirth admitted to the postpartum within 2 years after delivery.

Table S2. Pregnancy prolongation and postpartum maternal cardiovascular, renal and metabolic function.

Table S3. Association between pregnancy prolongation after pre-eclampsia diagnosis (days) and offspring outcome. ■

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