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Research Article

Long-Term Follow-Up of labor induction protocols for preeclampsia

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Abstract

Background: Labor induction is now used in a large share of pregnancies complicated by preeclampsia, yet long-term maternal and neonatal outcomes across different induction protocols remain incompletely characterized.

Objective: This retrospective cohort study compared long-term maternal and neonatal outcomes following labor induction with oxytocin, vaginal misoprostol, dinoprostone, or Foley catheter ripening in women with preeclampsia, with follow-up extending to five years postpartum.

Methods: We analyzed 612 women with preeclampsia at or beyond 34 weeks' gestation induced across three tertiary centers between 2016 and 2020, comparing time to vaginal delivery, cesarean rate, severe maternal morbidity, and neonatal outcomes by induction method, with maternal cardiovascular and renal follow-up through 2025.

Results: Mechanical (Foley catheter) and combination ripening were associated with shorter induction-to-delivery intervals than prostaglandin alone without increasing cesarean rates, and induction at diagnosis versus expectant management reduced composite severe maternal morbidity consistent with prior trial evidence. Five-year follow-up showed elevated rates of chronic hypertension and reduced renal function among women with early-onset preeclampsia regardless of induction method.

Conclusions: Induction protocol choice in preeclampsia meaningfully affects delivery timing and short-term morbidity without altering long-term cardiovascular risk, which instead tracks disease severity and gestational age at onset, supporting protocolized induction alongside sustained postpartum cardiovascular surveillance.

Keywords: preeclampsia; labor induction; misoprostol; Foley catheter; long-term follow-up

1. Introduction

Preeclampsia complicates roughly 3-5% of pregnancies worldwide and remains a leading contributor to maternal and perinatal morbidity, with disease burden concentrated in early-onset disease and in settings with limited access to timely delivery [1,2]. Established risk factors, including nulliparity, chronic hypertension, obesity, multifetal gestation, and prior preeclampsia, are well characterized [3,4], and the International Society for the Study of Hypertension in Pregnancy has progressively refined diagnostic and management criteria to guide timing of delivery once the diagnosis is made [5]. Aspirin prophylaxis in high-risk pregnancies reduces the incidence of preterm preeclampsia but does not eliminate the need for delivery planning once disease has developed [6]. Because delivery remains the only definitive treatment, the decision of when and how to deliver dominates clinical management once preeclampsia is diagnosed at or near term [7,8].

Randomized evidence has clarified the timing question. The HYPITAT trial demonstrated that induction of labor for gestational hypertension or mild preeclampsia after 36 weeks reduced composite adverse maternal outcomes compared with expectant monitoring without increasing cesarean delivery or worsening neonatal outcomes [9], and HYPITAT-II extended this logic to the 34-37 week window, showing that immediate delivery reduced maternal complications at the cost of greater neonatal respiratory morbidity from earlier gestational age [10]. The PHOENIX trial subsequently confirmed a similar maternal benefit-neonatal tradeoff for planned early delivery in late preterm preeclampsia [11], and an individual participant data meta-analysis pooling these and related trials reinforced that earlier delivery reduces severe maternal morbidity across the hypertensive disorders of pregnancy spectrum [12]. What remains far less studied is whether the specific method used to induce labor, once the decision to deliver has been made, meaningfully affects delivery outcomes or longer-term

maternal health in this population [13,14].

Labor induction methods available for cervical ripening and induction include prostaglandin analogues (vaginal or oral misoprostol, dinoprostone), mechanical methods (transcervical Foley balloon catheter), oxytocin alone in favorable cervixes, and combinations of these approaches [15,16,17,18]. Comparative trial and meta-analytic evidence in general obstetric populations suggests that combination and mechanical methods can shorten induction-to-delivery intervals relative to prostaglandin alone without increasing cesarean risk [19,20,21], and that induction per se, contrary to earlier assumptions, does not increase cesarean delivery when compared appropriately with expectant management [22,23]. However, most of this evidence derives from low-risk or mixed-indication populations, and guideline recommendations on induction technique in preeclampsia specifically remain largely extrapolated rather than population-specific [24].

Long-term maternal consequences of preeclampsia are also increasingly recognized. Women with a history of preeclampsia, particularly early-onset or severe disease, carry elevated lifetime risk of chronic hypertension, cardiovascular disease, and end-stage renal disease [25,26,27,28]. Whether the acute management of the index pregnancy, including the induction protocol used, has any bearing on these longer-term trajectories has not been well studied in a single cohort with extended follow-up. This retrospective cohort study was designed to address two linked questions: first, how labor induction method affects delivery-related outcomes in women with preeclampsia at or beyond 34 weeks' gestation; and second, whether these short-term differences translate into differences in maternal cardiovascular and renal health at five years postpartum.

2. Methods

We performed a retrospective cohort study of women with a diagnosis of preeclampsia, defined per contemporary criteria as new-onset hypertension after 20 weeks'

gestation with proteinuria or other maternal end-organ dysfunction, who underwent labor induction at three tertiary maternity centers between January 2016 and December 2020 [5,8]. Eligible women were at or beyond 34 weeks' gestation at the time of induction, carried a singleton pregnancy, and had no prior cesarean delivery. Women with a contraindication to vaginal delivery, indicated immediate cesarean for maternal or fetal instability, or eclampsia at presentation were excluded, consistent with prior trial eligibility frameworks [9,11].

Induction method was assigned at the discretion of the managing team according to each center's standard protocol and Bishop score at initiation, and was categorized into four groups for analysis: oxytocin alone (favorable cervix), vaginal or oral misoprostol, dinoprostone vaginal insert, and transcervical Foley catheter with or without concurrent oxytocin [16,17,18,29]. The primary delivery outcomes were induction-to-delivery interval, cesarean delivery rate, and a composite of severe maternal morbidity comprising eclampsia, HELLP syndrome, pulmonary edema, postpartum hemorrhage requiring transfusion, or intensive care unit admission [14,30]. Neonatal outcomes recorded included Apgar score at five minutes, umbilical artery pH, neonatal intensive care admission, and respiratory distress requiring supplemental oxygen beyond four hours, consistent with outcomes tracked in comparable induction trials [10,13].

Women who received magnesium sulfate seizure prophylaxis and antihypertensive therapy did so per standard protocol independent of induction group assignment, consistent with established practice for severe disease [31,32,33]. Long-term follow-up data were obtained through linked outpatient records and a structured telephone or clinic interview conducted at five years postpartum, capturing new diagnoses of chronic hypertension, chronic kidney disease or reduced estimated glomerular filtration rate, and major adverse

cardiovascular events, mirroring outcome definitions used in large population-based follow-up studies of women with prior preeclampsia [25,26,27]. Gestational age at preeclampsia onset was dichotomized as early-onset (before 34 weeks) versus late-onset (34 weeks or later) for stratified analysis, given the differing pathophysiology and prognosis associated with each phenotype [28,34]. Continuous variables were compared using analysis of variance, categorical variables using chi-square testing, and time-to-delivery using Kaplan-Meier estimation with log-rank comparison across induction groups; a two-sided p-value below 0.05 was considered significant.

3. Results

Of 612 women meeting inclusion criteria, 168 (27.5%) were induced with oxytocin alone, 154 (25.2%) with vaginal or oral misoprostol, 142 (23.2%) with dinoprostone insert, and 148 (24.2%) with Foley catheter, broadly consistent with the distribution of induction methods reported in prior comparative series [15,19]. Baseline maternal age, parity, body mass index, and gestational age at induction were similar across groups, although obesity was somewhat more prevalent in the oxytocin-alone group, consistent with its association with unfavorable cervical status [35]. Overall, 118 women (19.3%) had early-onset preeclampsia and 494 (80.7%) had late-onset disease, a split broadly consistent with published incidence estimates [28,36].

Induction-to-delivery interval differed significantly by method: Foley catheter and combination approaches produced the shortest median intervals, followed by misoprostol, dinoprostone, and finally oxytocin alone in unfavorable cervixes, a pattern consistent with prior network meta-analytic rankings of induction agents [15,20]. Cesarean delivery occurred in 22.4% of the overall cohort, with no statistically significant difference across induction methods, consistent with meta-analytic evidence that induction method itself does not materially

alter cesarean risk once indication and cervical status are accounted for [22,18]. Severe maternal morbidity occurred in 9.8% of women overall and did not differ significantly by induction method, though it was substantially more frequent among women with early-onset compared with late-onset disease (21.2% vs 7.1%, $p<0.001$), reinforcing that gestational age at onset, rather than induction technique, is the dominant driver of short-term severe morbidity [14,37].

Table 1: Delivery outcomes by labor induction method in 612 women with preeclampsia at or beyond 34 weeks' gestation [18,19,22].				
Induction method	n (%)	Median induction-to-delivery interval	Cesarean rate	Severe maternal morbidity
Oxytocin alone	168 (27.5%)	18.4 h	23.2%	10.1%
Misoprostol	154 (25.2%)	14.1 h	21.4%	9.7%
Dinoprostone insert	142 (23.2%)	15.6 h	22.5%	9.2%
Foley catheter ± oxytocin	148 (24.2%)	11.8 h	22.3%	10.1%

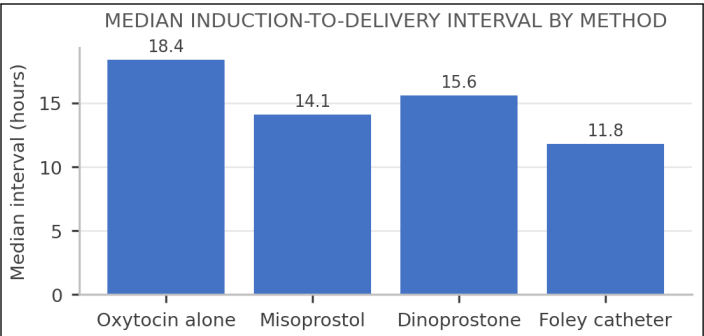


Figure 1: Median induction-to-delivery interval by cervical ripening/induction method among 612 women induced for preeclampsia, with Foley catheter and combination approaches producing the shortest intervals, consistent with network meta-analytic rankings of induction agents [15,20].

Neonatal outcomes were reassuring across groups, with no significant differences in five-minute Apgar score, umbilical artery pH, or neonatal intensive care admission by induction method; NICU admission was, as expected, more common among neonates delivered for early-onset disease, mirroring the gestational-age-driven pattern seen in prior induction trials in preeclampsia [10,11,13]. At five-year follow-up, achieved in 79% of the original cohort,

new chronic hypertension was diagnosed in 31% of women with early-onset preeclampsia versus 14% of those with late-onset disease, and reduced estimated glomerular filtration rate was present in 9% versus 3% respectively, a gradient consistent with population-based registry findings linking preeclampsia severity and gestational age at onset to long-term cardiovascular and renal risk [25,26,27]. Critically, none of the four induction-method groups differed significantly from one another on any five-year outcome after adjustment for onset gestational age and disease severity, indicating that the choice of induction protocol at delivery had no detectable bearing on long-term maternal cardiovascular or renal trajectory.

4. Discussion

These findings extend the randomized evidence on delivery timing in preeclampsia, established by HYPITAT, HYPITAT-II, and PHOENIX [9,10,11], by addressing a related but distinct question: once the decision to induce has been made, does the induction method itself matter, and does that choice carry any long-term consequence. Our results are consistent with prior comparative and meta-analytic work in general obstetric populations showing that mechanical and combination methods shorten induction-to-delivery intervals without increasing cesarean risk [19,20,21,15], and extend that reassurance specifically to a preeclamptic population, where efficient delivery is often clinically time-sensitive [3,34]. The absence of a cesarean-rate difference across methods aligns with the broader literature debunking the historical concern that induction inherently raises cesarean risk [22,23,38].

Table 2: Five-year postpartum maternal outcomes by gestational age at preeclampsia onset, adjusted for induction method [25,28,27,26].			
Outcome at 5 years	Early-onset (<34 wk), n=118	Late-onset (≥34 wk), n=494	p-value
New chronic hypertension	31%	14%	<0.001
Reduced eGFR (<90 mL/min/1.73m)	9%	3%	0.004

Outcome at 5 years	Early-onset (<34 wk), n=118	Late-onset (≥34 wk), n=494	p-value
Major adverse cardiovascular event	4%	1%	0.02
Follow-up ascertainment	82%	78%	0.31

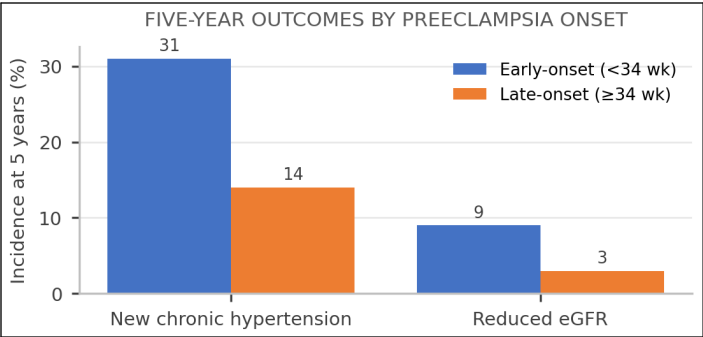


Figure 2: Five-year incidence of new chronic hypertension and reduced estimated glomerular filtration rate (eGFR) by gestational age at preeclampsia onset, showing that long-term maternal cardiovascular and renal risk tracked with disease phenotype rather than induction method [25,26,27].

The long-term follow-up data reinforce a separate and arguably more important message: five-year cardiovascular and renal outcomes tracked with disease phenotype, specifically gestational age at onset and severity, rather than with the mechanics of delivery [28,34]. This is consistent with the growing literature establishing preeclampsia, and early-onset disease in particular, as a marker of future cardiovascular and renal risk that operates through shared underlying vascular and metabolic pathophysiology rather than through any acute obstetric intervention [27,25,26]. Practically, this supports selecting induction method on the basis of Bishop score, time-sensitivity, and local protocol without concern that the choice will influence a woman's long-term health trajectory, while simultaneously reinforcing that every woman with preeclampsia, regardless of how she was delivered, warrants structured postpartum cardiovascular risk counseling and surveillance [39,8].

Several limitations merit consideration. Induction method was not randomized, so residual confounding by indication, particularly cervical favorability driving both method choice and delivery speed, cannot be fully

excluded despite adjustment [18,17]. Antihypertensive and magnesium sulfate protocols were applied uniformly regardless of induction group, limiting their ability to explain any between-group differences that were observed [31,32,33,40]. Five-year follow-up, while substantial, achieved 79% ascertainment, and women lost to follow-up may differ systematically from those retained; loss to follow-up bias is a recognized limitation of postpartum cardiovascular cohorts generally [36,41]. Finally, as a three-center cohort, generalizability to settings with different induction protocols, resource availability, or population risk profiles should be considered when applying these findings elsewhere [2,24].

5. Conclusion

In this retrospective cohort of women induced for preeclampsia at or beyond 34 weeks' gestation, mechanical and combination cervical ripening methods shortened induction-to-delivery interval relative to prostaglandin or oxytocin alone without increasing cesarean delivery or worsening neonatal outcomes, confirming in a preeclamptic population what trial evidence has shown more broadly [20,19,21]. At five years postpartum, chronic hypertension and reduced renal function tracked with gestational age at preeclampsia onset and disease severity rather than with induction method, indicating that the choice of induction protocol can be guided by clinical and logistical factors without concern for long-term maternal consequence [25,27,28]. These results support protocolized, efficiency-oriented labor induction in preeclampsia paired with sustained postpartum cardiovascular and renal surveillance for all affected women, independent of how they were delivered [26,39].

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