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Original Article

Predictors of perinatal outcomes and economic costs for late-term induction of labour

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ABSTRACT

Objective: We aimed to predict the perinatal outcomes and costs of health services following labour induction for late-term pregnancies.
Materials and methods: We conducted a cohort study of 245 women who underwent labour induction during their 41st week of gestation. The cervical condition was assessed upon admission using the Bishop score and ultrasound cervical length measurements. We estimated the direct costs of labour induction, and a predictive model for perinatal outcomes was constructed using the decision tree analysis algorithm and a logit model.
Results: A very unfavourable Bishop score at admission (Bishop score <2) (OR, 3.43 [95% CI, 1.77–6.59]), and a history of previous caesarean section (OR, 7.72 [95% CI, 2.43–24.43]) or previous vaginal delivery (OR, 0.24 [95% CI, 0.09–0.58]) were the only variables with predictive capacity for caesarean section in our model. The mean cost of labour induction was €3465.56 (95% confidence interval [CI], 3339.53–3591.58). Unfavourable Bishop scores upon admission and no history of previous deliveries significantly increased the cost of labour induction. Both of these criteria significantly predicted the likelihood of a caesarean section in the decision tree analysis.
Conclusion: The cost of labour induction mostly depends on the likelihood of successful trial of labour. Combined use of the Bishop score and previous vaginal or caesarean deliveries improves the ability to predict the likelihood of a caesarean section and the economic costs associated with labour induction for late-term pregnancies. This information is useful for patient counselling.

Introduction

The American College of Obstetrics and Gynaecology defines late-term pregnancies as those that reach 41 weeks (287–293 days) of gestation [1]. An extensive body of evidence has established that late-term pregnancies are associated with an increased risk of adverse maternal and neonatal outcomes [2,3]. Induction of labour (IOL) at 41 weeks compared to watchful expectancy decreases the risk of macrosomia and meconium-stained amniotic fluid [4]. IOL is also associated with lower [5] or similar [6], perinatal mortality rates with a decrease in the rates of caesarean section deliveries [5–7]. Based on previous data, some international organizations recommend offering IOL during the 41st week of gestation [8,9]. However, IOL is thought to be associated with longer hospital stays and increased rates of prolonged labour, failed induction, or caesarean delivery [10] paired with the obvious consequences of increased costs [11].

Despite extensive research on the subject, the variables that determine the risk of caesarean delivery after IOL in different clinical scenarios have not yet been identified [12–15]. Reliable predictions regarding maternal and neonatal outcomes and the financial costs following late-term IOL are needed. We conducted a prospective cost analysis study using individual patient data to investigate the clinical determinants of perinatal outcomes and health services costs associated with IOL at 41 weeks of gestation in a tertiary level hospital.

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Methods

Study cohort

We conducted a prospective study in our hospital that included all consecutive pregnancies during 2 years. Singleton low-risk pregnancies were scheduled for IOL within the 41st week of gestation (287–293 days). In all cases, estimated due dates were calculated from crown–rump lengths [16] measured between 11 and 13^{+6} weeks of gestation. The hospital ethics committee approved the study, and written informed consent was obtained from all women after the study was fully explained.

Procedures

IOL was managed at the discretion of an attending senior obstetrician. The condition of the cervix was assessed upon admission using the Bishop score [17] and the cervical length was measured with a Voluson 730 Expert ultrasound machine (GE Medical Systems, Wisconsin, USA) equipped with a 7-MHz transvaginal transducer according to standard methodologies [18]. A very unfavourable cervix was defined as a Bishop score < 2 [19]. For cases when the Bishop score was <6, cervical ripening was carried out with prostaglandins (Propess®, Ferring S.A.U. Spain) for up to 24 h according to the manufacturer's instructions. IOL was performed using membrane rupture and intravenous oxytocin if a previous delivery was performed via caesarean section, the Bishop score was >6, regular spontaneous uterine contractions were occurring, or 24 h of cervical ripening had been performed.

Labour and delivery management was conducted according to clinical standards [20,21]. Neonatal metabolic acidosis was defined as the presence of an umbilical artery pH < 7.15 and base excess > −12 mEq/L in the new-born [22]. Uncomplicated postpartum hospital discharge policy includes a 2-day stay for spontaneous and assisted vaginal deliveries and 3–4 days for uncomplicated caesarean deliveries.

Cost evaluations

Economic evaluations were carried out following previously described methods [11,23]. Delivery costs were expressed in Euros. Only economic costs were considered; charges for equipment use and supplies, as well as intangible or psychosocial costs were not included [24].

Analysis

Maternal social and demographic characteristics and perinatal outcomes were recorded in a database as hardcopies at the time of the study. Student's t-tests and Pearson's Chi-squared tests or Fisher's exact tests were used to compare quantitative and qualitative data, respectively. Predictive models for the occurrence of a caesarean section were constructed using the Decision Tree Analysis algorithm (SPSS 20.0) and a logit model. The decision tree was developed using the Classification and Regression Trees CHAID method (Quick, Unbiased, and Efficient Statistical Tree), which generates binary decision trees with the *p* inset at 0.05 (Bonferroni-adjusted for multiple comparisons) and a cut-off value selected automatically for all parameters [28] including, maternal age (years), body mass index (kg/m^2), smoking status (non-smoker vs. smoker), previous vaginal delivery, previous caesarean section, gestational age at induction, birth weight, ultrasound cervical length, and Bishop score.

To determine the variables that can help discriminate the risk of a caesarean section, we also estimated a logit model. We selected the final model by following a general-to-particular strategy in which the starting model uses all of the possible explanatory variables included in our data set; subsequently, the non-significant variables are removed one-by-one. Statistical analyses were conducted using the SPSS 20.0 version software (SPSS Inc., Chicago, IL, USA).

Results

A total of 251 late-term patients met the study criteria, were informed about the risks and benefits, and gave informed consent. Of these, 245 (97.6%) underwent a scheduled IOL within the 41st week of gestation (287–293 days).

Predictions for caesarean sections following late-term IOL yielded a two-tiered classification via decision tree analysis. The first level was determined by a very unfavourable Bishop score ($p = 0.001$). At the second level, the group with Bishop scores ≥2 was sub-stratified by histories of previous vaginal deliveries ($p = 0.003$). Thus, the analysis profiled three groups of increasing risk for caesarean section: 9% for those with a Bishop score ≥2 and a previous vaginal delivery, 27.6% for those with a Bishop score ≥2 without a previous vaginal delivery, and 53.2% for those with a very unfavourable cervix (Figure 1).

Since the Bishop score was the best predictor for caesarean sections in all of the predictive models, we summarized the demographic characteristics and perinatal outcomes of the study population according to these scores, which were taken upon admission (Tables 1 and 2). Most patients included in the study were Caucasian (86.5%) and nulliparous (71%). No social or demographic differences between groups were observed. Patients with either Bishop scores <2 at admission or lower rates of previous vaginal deliveries, but longer ultrasound cervical lengths, more commonly required cervical ripening with prostaglandins. A very unfavourable Bishop score upon admission also increased labour duration, hospital stay, the need for caesarean section due to failure to progress, and the overall rate of caesarean sections administered. However, no differences were found between groups regarding maternal or neonatal outcomes or the rate of caesarean sections for foetal distress.

A logit model including all of the clinical variables was performed to determine the risk of caesarean section. A very unfavourable Bishop score upon admission (OR, 3.43 [95% CI, 1.77–6.59]) and a history of previous caesarean sections (OR, 7.72 [95% CI, 2.43–24.43]) or previous vaginal deliveries (OR, 0.24 [95% CI, 0.09–0.58]) were the only variables with predictive capacity in our model. The model can correctly classify approximately 72% of the observed results, and the Pearson goodness-of-fit test (1.80) indicates that our model fits quite well. We also found that all of the explanatory variables included in the model are dichotomous. When using a standard value of 50% for discriminating between the two options, the estimated model exhibited a somewhat low sensitivity value (48.35%), but the specificity was high (85.71%). However, we propose that this specificity is not high enough to aid clinical decisions, as for clinical practice we need to avoid a false positive result, meaning that a caesarean section might ultimately be performed on a patient who would have delivered vaginally. However, if we increase the threshold point to a very demanding 66%, then the specificity greatly increases to 97.5% with a sensitivity of 12.7%. We describe the estimated probability of having a caesarean section for late-term IOL according to the clinical variables included in our logit model (Table 3).

We then estimated the total cost of IOL in late-term pregnancies (Table 4). The mean total cost of the whole sample of 245 patients was €3465.56 (95% confidence interval [CI], 3339.53–3591.58). We also performed a secondary analysis according to the method of delivery, cervical condition upon admission, and obstetrical history. IOL ending in a caesarean section was significantly more expensive

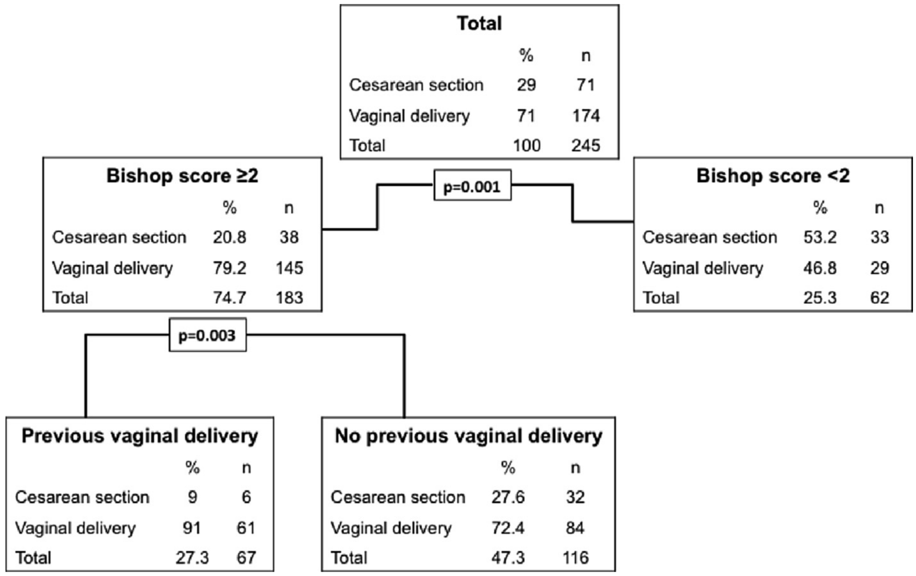

Figure 1. Decision-tree classifications for caesarean sections following late-term induction of labour.

Table 1
Demographic and maternal characteristics at admission according to cervical conditions upon admission.

	Bishop score <2 n = 62	Bishop score ≥2 n = 183	*p*
Maternal age at delivery (years)	33.14 (5.8)	32.12 (5.05)	0.190
Caucasian (%)	56 (90.3)	156 (85.2)	0.312
Smoking (%)	6 (9.7)	35 (19.1)	0.085
Previous caesarean section (%)	5 (8.1)	13 (7.1)	0.802
Previous vaginal delivery (%)	4 (6.5)	67 (36.6)	0.001
Parity (median, range)	0 (0–1)	0 (0–4)	0.001
Cervical ripening with dinoprostone (%)	57 (91.9)	136 (74.3)	0.003
Epidural anaesthesia (%)	52 (83.9)	156 (85.2)	0.794
Maternal body mass index (kg/m^2)	24.92 (5.2)	26.41 (5.2)	0.057
Cervical length upon admission (mm)	34.6 (8.1)	24.27 (9.6)	0.001

Data are expressed as the mean (standard deviation), number (%), or median (range).

Table 2
Perinatal outcomes according to cervical conditions upon admission.

	Bishop score <2 n = 62	Bishop score ≥2 n = 183	*p*
Gestational age at labour induction (days)	290.68 (1.3)	290.56 (1.6)	0.589
Duration of labour induction (hours)	28.18 (11.8)	18.52 (10.2)	0.001
Hospital stay (days)	3.98 (1.07)	3.22 (0.86)	0.001
Neonatal weight at delivery (g)	3585.64 (464.6)	3549.28 (361.8)	0.527
Female neonate (%)	31 (50)	87 (47.5)	0.738
Caesarean section (%)	33 (53.2)	38 (20.8)	0.001
Caesarean section for foetal distress (%)	5 (8.1)	13 (7.1)	0.802
Caesarean section for failure to progress (%)	28 (45.2)	25 (13.7)	0.001
Neonatal admission (%)	4 (6.5)	9 (4.9)	0.642
Neonatal metabolic acidosis (%)	4 (6.5)	7 (4.9)	0.324
Severe adverse maternal outcome (%)[a]	7 (11.3)	14 (7.7)	0.536

Data are expressed as the mean (standard deviation), number (%), or median (range).
[a] Severe adverse maternal outcome: Third or fourth degree perineal tears, postpartum curettage, postpartum hysterectomy, intrapartum caesarean scar rupture, blood transfusion, or admission to the intensive care unit.

than IOL culminating in a spontaneous or instrumental delivery. We also found significant cost differences between the three groups distinguished by cervical condition assessed upon admission. Those patients with previous vaginal delivery present the lowest cost of IOL, followed by those with previous caesarean section, and those with no previous births.

Finally, we estimated the segmented costs for the different stages of IOL, hospital stay, and maternal and neonatal morbidity according to the Bishop score (Figure 2). Hospital stays were the most expensive stage of the entire IOL process (€2315.61; 95% CI, 2232.23–2398.99), distantly followed by the costs for cervical ripening and IOL (€644.71; 95% CI, 619.04–670.40). The method of delivery (spontaneous, instrumental, or caesarean section) and the need for epidural anaesthesia accounted for a mean cost of €426.97 (95% CI, 399.10–454.84). Adverse maternal and neonatal outcomes significantly increased costs, but because these occurrences were infrequent, they only accounted for a mean increased total cost of €78.25 (95% CI, 40.46–116.05). A Bishop score <2 upon admission significantly increases the costs of cervical ripening and IOL (€773.28 vs. €601.15; $p < 0.001$), delivery and anaesthesia (€547.28 vs. €386.20; $p < 0.001$), and hospital stay (€2697.08 vs. €2186.37; $p < 0.001$).

Discussion

This study is a prospective cost analysis based on individual patient data, which gives insight to the predictors of perinatal

Table 3
Estimated probability of having a caesarean section following late-term induction of labour according to a logit model.

Previous vaginal delivery	Previous caesarean section	Bishop score <2	Estimated probability	Expected result
No	Yes	Yes	0.89	High risk of caesarean
Yes	Yes	Yes	0.70	High risk of caesarean
No	Yes	No	0.70	High risk of caesarean
No	No	Yes	0.64	Moderate risk of caesarean
Yes	Yes	No	0.39	Low risk of caesarean
Yes	No	Yes	0.34	Low risk of caesarean
No	No	No	0.33	Low risk of caesarean
Yes	No	No	0.12	Low risk of caesarean

Table 4
Total costs of late-term induction of labour.

	n	Mean cost (€)	95% CI (€)
Total	**245**	**3465.56**	**3339.53–3591.58**
According to the method of delivery			
• Spontaneous delivery	136	2950.95	2831.45–3070.45
• Instrumental vaginal	38	3338.56	3075.14–3601.97
• Caesarean section	71	4519.27	4343.84–3591.58
According to Bishop score upon admission			
• Very unfavourable (<2)	62	4114.46	3853.66–4375.26
• Unfavourable (2–5)	158	3347.43	3209.91–3484.95
• Favourable (≥6)	25	2602.89	2296.57–2909.21
According to obstetrical history			
• Previous vaginal delivery	66	2770.90	2615.66–2926.14
• Previous caesarean section	18	3393.50	3020.53–3591.58
• No previous delivery	161	3758.38	3601.07–3915.70

Abbreviations: CI, confidence interval.

outcomes and the economic impact of IOL at 41 weeks of gestation. To our knowledge, this is the first published report that has focused on the cost of late-term IOL according to the clinical variables noted upon admission and the method of delivery.

Published evidence suggests that IOL at 41 weeks reduces perinatal mortality without increasing the rate of caesarean sections [6], although the differences described are minimal [25]. As IOL accounts for approximately 20% of all deliveries [26], many studies have reported different clinical variables and predictive algorithms for caesarean section following IOL [27]. However, the results are conflicting, perhaps because of the heterogeneity of patients, pathological conditions present, and methods of ripening used. In our cohort of low-risk patients induced for late-term pregnancy, a very unfavourable Bishop score (<2) was the best predictor of caesarean delivery. These results are consistent with those of Scollo [28]. Several authors have evaluated the usefulness of the Bishop score and ultrasound cervical length for predicting the success of IOL [12]. The results have been inconsistent, with some studies suggesting that ultrasound cervical length adds predictive ability, and others suggesting that it holds no additional benefit [27]. Ultrasound cervical length was not included as a predictive variable of caesarean section in any of our predictive models. These results are in line with a previous meta-analysis, which concluded that sonographic measurement of cervical length did not facilitate better predictions of vaginal delivery than the Bishop score alone [29].

As expected, based on our results, previous parity also predicts the need for a caesarean section following late-term IOL. In addition to a very unfavourable Bishop score, the antecedent of a previous caesarean section or vaginal delivery was the only variable with predictive capacity in the logit model. Moreover, our decision tree analysis determined that the risk of caesarean section in the group with a Bishop score ≥2 could be sub-stratified by the history of a previous vaginal delivery. However, those patients with a previous vaginal delivery tend to present higher Bishop scores upon admission.

When compared to expectant management, IOL for late-term pregnancy is cost-effective [30]. However, there is a lack of information available on the cost of IOL, as cervical conditions and parity have not been taken into account in previous reports [31,33]. Our results confirm previously published studies, concluding that a caesarean delivery is more expensive than a vaginal delivery, as it increases the number of required staff and maternal morbidity [32,33]. Therefore, we found significant differences for the cost of IOL according to the Bishop score upon admission and previous parity. Our estimate of the mean cost of IOL was similar to that previously published by Allen et al. [26] Both studies were performed in tertiary hospitals belonging to the public health system of a developed country; thus, the results cannot necessarily be extrapolated to those of other health management systems. Another study published by Kaimal et al. [30] also reported that IOL in a late-term population was a more expensive procedure. Nevertheless, this was a decision analysis study that was based on the literature and analysis of the National Birth Cohort dataset in the United States of America.

We believe that increasing the information flow about perinatal outcomes and costs when labour is induced at 41 weeks of gestation could aid the decision-making process within an imprecise limit of 7 days. Notably, this decision is frequently influenced by other psychological and social factors. Although economic information should always be subordinate to the pathological conditions that advise when to end a pregnancy, IOL can often be performed after reasonable lapse of time. If IOL is not immediately required in the presence of very unfavourable cervical conditions, IOL could be delayed to decrease not only the rate of caesarean sections, but also the economic costs associated with IOL. By contrast, the mean cost of IOL for patients with favourable cervical conditions was similar to the previously reported [26] economic costs of spontaneous onsets of labour. It is also important to note that the economic cost of an elective caesarean section is similar to that of a vaginal delivery after IOL, whereas a caesarean section after induction is more expensive [26]. Furthermore, compared to an elective caesarean section, a caesarean section during labour has been associated with an increased risk of adverse maternal and infant outcomes [34], as well as higher economic costs [33]. Other

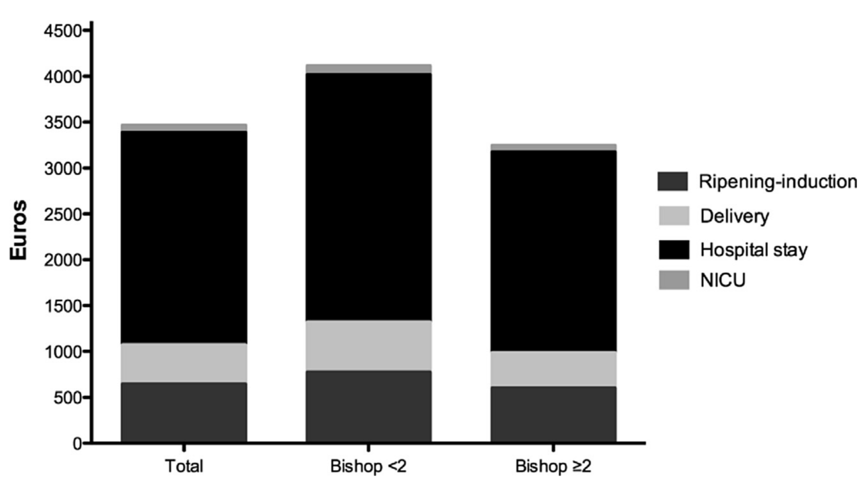

Figure 2. Distribution of costs for the entire induction of labour process. SGA, small for gestational age; NICU, neonatal intensive care unit.

studies have recently considered different threshold points of risk for performing a caesarean section upon admission for IOL; some recommend an elective caesarean section to reduce economic costs [35,36]. We also present a predictive model with a very high specificity (97.5%) to reduce the false positive rate for the prediction of caesarean section following IOL. Economic reasons could also be taken into account within a framework of patient autonomy.

The main strength of this study is the design, which allowed us to improve the quality of information obtained for patients by analysing a homogeneous and well-documented cohort of patients despite using a smaller sample size than similar reports; however, the confidence intervals for each estimate have been provided. Because we conducted a prospective cost analysis based on individual patient data, we avoided the potential bias present in retrospective and database studies. This study has some limitations that should be noted. We did not include an economic evaluation of broader costs, such as psychosocial costs for family members or informal caregivers, or the costs of equipment use in the analysis. Therefore, this study may have underestimated the costs of caesarean delivery for localities where physicians' fees are higher for operative deliveries. Additionally, this study did not attempt to address the economic implications of delivery in a subsequent pregnancy or implications on long-term maternal reproductive health.

In conclusion, the cost-effectiveness of IOL depends on the likelihood of successful trial of labour. This is the first study to report a predictive model for the perinatal outcomes and economic costs of late-term IOL. This information is useful for patient counselling.

Conflict of interest

All authors declare that they have no conflict of interest in connection with this article.

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