Original Article

Influencing Factor Analysis and Prediction Model of Emergency Caesarean Delivery for Advanced-Age Nulliparous Women at the Time of Hospitalization

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Abstract

Objective: In Japan, the number of nulliparous pregnant women of advanced age, defined as 35 years or older, has increased, and the age range has lengthened towards older age with the increased use of infertility treatments. Given this trend, adverse labour outcomes, such as emergency caesarean delivery (ECD), are expected to increase. Therefore, by focusing mainly on maternal age and infertility treatment history, we aimed to establish a new prediction model for the likelihood of ECD after identifying the influencing factors related to maternal and labour-related characteristics.

Materials and methods: The medical records of 1,521 pregnant women who were nulliparous between 2017/4/1 and 2024/3/31 at our hospital were retrospectively reviewed. First, for the 675 women who were aged 30 years old or more, we calculated the rates of ECD in 8 groups classified according to maternal age, infertility treatment, and other variables. Next, we performed multivariate logistic regression analysis to assess the effect of each representative factor and established a prediction model based on the number of factors that were significant in the multivariate analysis.

Results: Simple comparisons classified by maternal age revealed a constant increase in the rate of ECD with increasing maternal age, and multivariate analysis revealed 7 significant factors, namely, advanced maternal age, history of using assisted reproductive techniques (ART), small height, high Body mass index (BMI), low Bishop score, late-term delivery, and large infant. In the prediction model constructed with these 7 factors, the rate of ECD increased as the number of these factors increased.

Conclusion: The negative impact of advanced maternal age, namely, 40 years or older, and ART history, on labour outcome is clear. A new prediction model has the potential to identify patients with an extremely high probability of needing an ECD. These results may indicate that the management of the labour process will become more difficult in the future.

Keywords: Nulliparous Pregnant Woman; Advanced Maternal Age; Assisted Reproductive Technology; Emergency Caesarean Delivery; Prediction Model

Introduction

Due to lifestyle changes and increased use of infertility treatment, delayed marriage and childbearing have become global phenomena (1-3), and in Japan, the rates of pregnancy and delivery at an advanced age have increased (4). In Japan and other countries, advanced maternal age is generally

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defined as 35 years or older at the estimated delivery date (5, 6), but various age classifications, such as 35, 38, and 40 years old, have been used to identify age-related risk factors for labour (6-8). Advanced-age pregnancy is known to increase the risk of pregnancy and labour-related complications (1, 4, 6-9), and empirically, in our hospital, which is one of the regional core hospitals in Japan, emergency caesarean delivery (ECD) and instrumental delivery (ID) have tended to increase with the increasing number of nulliparous women of advanced age. On the other hand, we have realized the relatively low likelihood of spontaneous vaginal delivery (SVD) in nulliparous women of advanced age. Additionally, with the widespread use of assisted reproductive technology (ART), including in vitro fertilization (IVF), intracytoplasmic sperm injection (ICSI) and others (10), the age range of pregnant women appears to have lengthened towards older age (11). The rates of unfavourable outcomes of labour can be expected to increase in the future. Under these circumstances, obstetricians may be required to more comprehensively manage the labour process by combining the factors derived from maternal age and other various factors that have a negative influence on labour outcomes (12, 13).

The prediction of and preparation for labour-related problems has become increasingly important. In particular, in nulliparous women older than 40 years of age, conception by ART seems to be extremely valuable. In these cases, more careful patient assessment and appropriate intervention may be needed. However, similar to our hospital, in rural areas, the problems associated with limited medical resources have become more serious. For this reason, we need to be able to identify pregnant women who have a high probability of needing an ECD as soon as possible to prepare for the ECD. In some cases, it may be justifiable to immediately perform a caesarean section without an initial attempt at vaginal delivery, if a highly accurate prediction model was available. Therefore, we aimed to establish a prediction model of labour outcome in which maternal age and infertility treatment history are the main focus. In this study, we identified influencing factors among various maternal and labour-related characteristics that were expected to have an impact on the probability of ECD based on both our experience and previous reports (12, 14, 15) and establish a new prediction model by including these factors in the model.

Materials and methods

Data collection: This study was reviewed and approved by the Human Ethical Committee of Kinan Hospital (Approval number: 288). The deidentified medical records of 731 nulliparous women aged 30 years or older who were hospitalized for spontaneous labour pain (SLP), premature rupture of membranes (PROM) or induction of labour (IOL), excluding cases with selective caesarean section and those with preterm birth (<37 gestational weeks (GWs)), from April 1, 2017, to March 31, 2024, were reviewed retrospectively. In this analysis, IOL included various labour interventions, such as the use of labour-inducing agents and cervical dilation. Patients in which ECD was almost inevitable were also excluded. Such patients included those diagnosed with hypertensive disorders of pregnancy (32 patients), foetal growth restriction (4 patients), oligohydramnios (4 patients), nonreassuring foetal status (10 patients), or COVID-19 (1 patient) and patients who were directly transported from another hospital (5 patients). ECD was performed in 45 of these 56 patients (80.4%, Table 1).

Table 1: Excluded case list

Exclusion criteria	ECD rate (n)
HDP	75% (24/32)
NRFS	100% (10/10)
Transportation from other hospitals	80% (4/5)
Oligoamnios	100% (4/4)
FGR	50% (2/4)
COVID-19	100% (1/1)
Total	80.4% (45/56)

ECD: Emergency caesarean delivery, FGR: Foetal growth restriction, HDP: Hypertensive disorders of pregnancy, NRFS: Nonreassuring foetal status

The remaining 675 patients were classified into 1 of 3 groups according to the index of labour outcome: SVD (417 patients); ID, including vacuum delivery (VaD) (125 patients), with no forceps delivery in our hospital; and ECD (133 patients). Additionally, 846 nulliparous women aged 29 years or less were also included; among them, ECD was performed in 98 patients (11.6% of 846 patients), and VaD was performed in 97 patients (11.5% of 846 patients). Next, we classified all patients into two groups, SVD/ID and ECD, and we focused mainly on the ECD group as the main index of unfavourable labour outcomes for assessing each factor related to the characteristics of the pregnant patients. Among these indices, SVD and ID were included in the same

group, because transvaginal delivery could be achieved by performing ID. The clinical situations for selecting ID, including cases of full cervical dilation and favourable foetal head position (16, 17), were complex and dependent on the skill levels of the delivering clinicians.

To assess the influence of infertility treatments, we divided all patients into three groups according to pregnancy status, namely, no infertility treatment, ART history and non-ART history, including intrauterine insemination and ovulation-inducing agents. Timed intercourse with or without using hCG was not considered an infertility treatment. In this study, the assessment of cervical condition at the time of hospitalization was performed by using the Bishop scoring system (18), which is a well-known prediction method, and an a score of 5 or lower indicated an immature cervix based on previous studies (12, 19-21). Since the labour situation at the time of hospitalization seemed to have an important impact on the labour outcomes, we divided all patients into the following 4 groups according to the cause of hospitalization: IOL, PROM, SLP, and both PROM and SLP.

Analysis methods: We extracted data on pregnant patient characteristics, including basic personal characteristics, labour situation, maternal complications, and delivery results (Table 2).

Next, we focused on the 8 factors detected when the patients were admitted to the hospital, namely, maternal age, maternal height, maternal body mass index (maternal BMI), GW, cause for hospitalization, Bishop score, new-born birth weight and infertility treatment, to roughly evaluate their impacts on labour outcomes. Some subgroups were created to evaluate the relationship between each factor and the rate of ECD as follows: 1) maternal age, age 30 to 34 years, age 35 to 39 years and age 40 to 44 years; 2) maternal height less than 149.9 cm, 150.0 to 154.9 cm, 155.0 to 159.9 cm, 160.0 to 164.9 cm and over 165.0 cm; 3) maternal BMI, less than 24.9 kg/m^2, 25.0 to 29.9 kg/m^2 and over 30.0 kg/m^2; 4) GW at 37 weeks, 38 weeks, 39 weeks, 40 weeks, and 41 weeks; 5) cause for hospitalization, including IOL, PROM, SLP, and both PROM and SLP; 6) “Biship score”, namely, 0 to 2, 3 to 5, 6 to 8 and 9 to 13; 7) new-born birth weight of less than 2499 g, from 2500 to 2999 g, from 3000 to 3499 g and over 3500 g; and 8) infertility treatment, ART, non-ART and no infertility treatment. Then, we compared the rates of ECD among these subgroups (Figure 1). Maternal age, maternal height, maternal BMI and Bishop score were based on previous reports (6-8, 21-23). Since in many cases, the period between hospitalization and the day when the estimated foetal weight was measured was more than one week, new-born birth weight was adopted as the index of foetal size.

Finally, with reference to the results of the aforementioned simple comparisons, to identify the factors influencing labour outcomes, namely, the likelihood of ECD, we extracted data on maternal age and the following 13 representative factors from among these patient characteristics (Table 3): 1) advanced maternal age, defined as an age $\geq$ 40 (years); 2) ART history; 3) short height, defined as a height < 150 (cm); 4) high BMI, defined as a BMI > 30 (kg/m^2); 5) low Bishop score, defined as a Bishop score $\leq$ 5; 6) late-term delivery, defined as hospitalization at 41 GW; 7) large infant, defined as a new-born birth weight $\geq$ 3500 (g); 8) IOL, defined as undergoing treatment for IOL; 9) threatened preterm labour history, defined as the presence of threatened preterm labour before 37 GW; 10) gestational diabetes mellitus (GDM), defined as patients with GDM; 11) GBS positivity, defined as positivity for vaginal group B streptococcus (GBS); 12) Gynaecological operation history, defined as patients who had previously undergone a gynaecological operation; and 13) uterine leiomyoma, defined as patients who had been diagnosed with uterine leiomyoma. From the viewpoint of infertility treatments, 42 years of age was one option for the borderline of advanced age (10, 24). However, we could not adopt this value because the number of patients 41 years of age or older was extremely small (41 years old: 10 patients; 42 years old: 10 patients; 43 years old: 5 patients; and 44 years old: 2 patients).

Statistical analyses were performed using Microsoft Excel (Microsoft Corporation, Redmond, WA) and JMP version 12 for Windows (SAS Institute, Inc., Tokyo, Japan) to determine the correlations between patient characteristics and the failure of laparoscopic surgery. The odds ratios (ORs) and 95% confidence intervals (CIs) were estimated to determine the strengths of the correlations. $P < 0.05$ was considered to indicate statistical significance.

Results

Simple comparison of patient characteristics of the SVD/ID and ECD groups

The patient characteristics are summarized in Table 2.

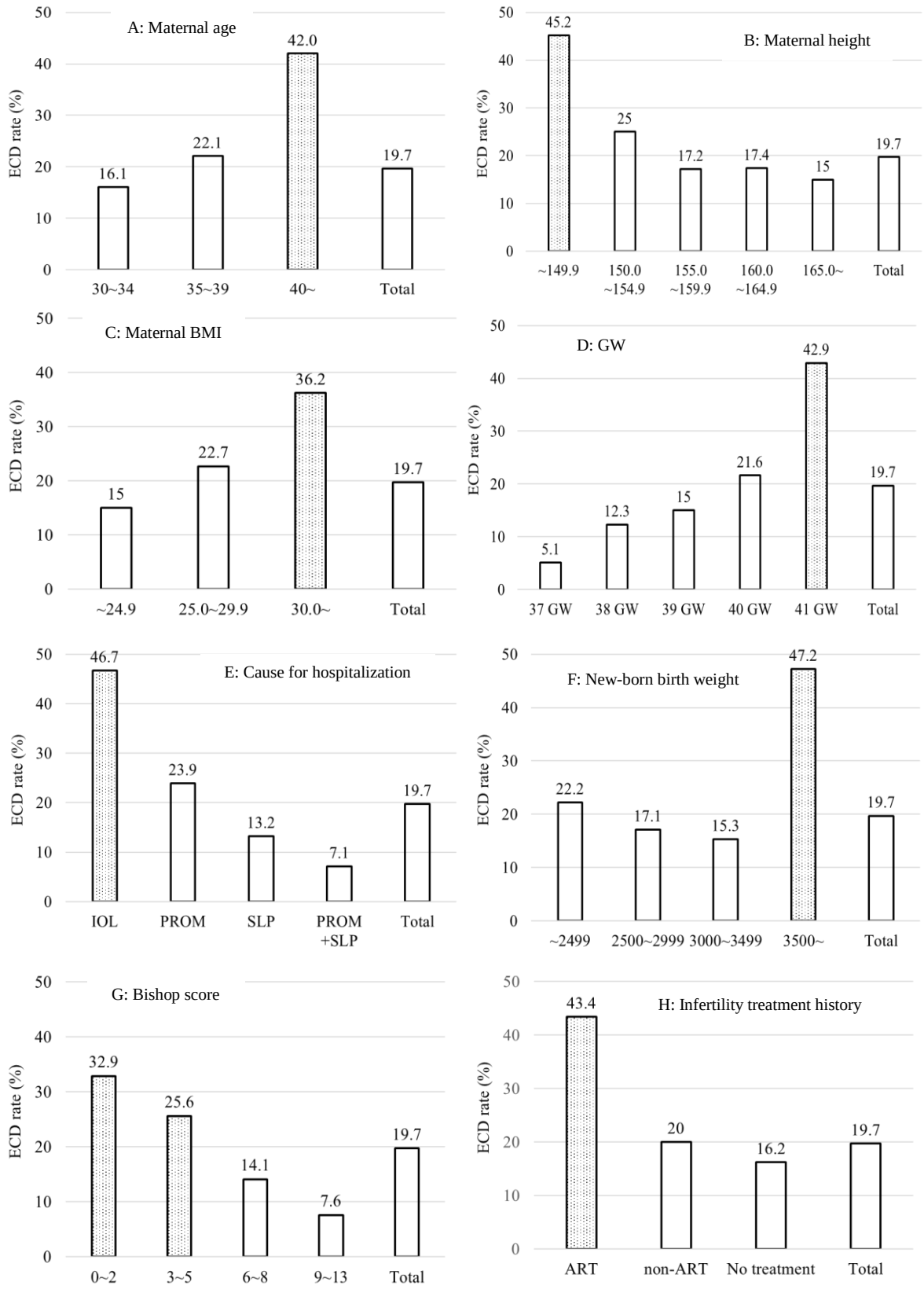

Figure 1: Relationship between each factor and ECD possibility

ART: Assisted reproductive technology, BMI: Body mass index, ECD: Emergency caesarean delivery, GW: Gestational week, IOL: Induction of labour, PROM: Premature rupture of membranes, SLP: Spontaneous labour pain

Table 2: Patient characteristics

	Total (mean ± SD, Min – Max, n)	ECD (mean ± SD, Min – Max, n)	SVD/ID (mean ± SD, Min – Max, n)	P value
Maternal age (year old)	33.9 ± 3.2, 30 - 44, n=675	35.0 ± 3.6, 30 - 44 n=133	33.6 ± 3.0, 30 - 43, n=542	<0.01
Maternal height (cm)	158.3 ± 5.2, 142.0 - 175.0, n=675	157.2 ± 5.5, 146.0 - 169.0, n=133	158.6 ± 5.1, 142.0 - 175.0, n=542	<0.01
Maternal weight (kg)	63.4 ± 8.9, 41.0 - 97.6, n=675	65.1 ± 9.7, 45.3 - 90.7, n=133	63.0 ± 8.7, 41.0 - 97.6, n=542	0.019
Maternal BMI (kg/m^2)	25.3 ± 3.3, 17.6 - 40.2, n=675	26.3 ± 3.8, 18.9 - 35.5, n=133	25.0 ± 3.1, 17.6 - 40.2, n=542	<0.01
Bishop score	5.7 ± 3.3, 0 - 13, n=675	4.0 ± 2.9, 0 - 12, n=133	6.1 ± 3.3, 0 - 13, n=542	<0.01
Gestational week (week)	39.7 ± 1.0, 37.0 - 41.9, n=675	40.2 ± 1.0, 37.0 - 41.9 n=133	39.6 ± 1.0, 37.0 - 41.7, n=542	<0.01
New-born birth weight (g)	3071.3 ± 344.9, 2194 - 4106, n=675	3179.3 ± 399.2, 2312 - 4089, n=133	3044.8 ± 325.2, 2194 - 4106, n=542	<0.01
Blood loss amount (ml)	432.5 ± 329.2, 46 - 2556, n=675	556.9 ± 317.5, 98 - 1793, n=133	402.0 ± 325.1, 46 - 2556, n=542	<0.01
Apgar score (1min)	8.6 ± 0.9, 1 - 10, n=675	8.2 ± 1.2, 1 - 10, n=133	8.6 ± 0.8, 4 - 10, n=542	<0.01
Apgar score (5min)	9.6 ± 0.7, 1 - 10, n=675	9.4 ± 1.0, 1 - 10, n=133	9.6 ± 0.7, 4 - 10, n=542	<0.01
ART history	n=83/675	n=36/133	n=47/542	<0.01
Non-ART history	n=35/675	n=7/133	n=28/542	1.00
SLP	n=357/675	n=47/133	n=310/542	<0.01
PROM	n=201/675	n=48/133	n=153/542	0.10
PROM+SLP	n=42/675	n=3/133	n=39/542	0.05
IOL	n=75/675	n=35/133	n=40/542	<0.01
GBS positive	n=86/675	n=16/133	n=70/542	0.87
GDM	n=18/675	n=3/133	n=15/542	0.97
Threatened preterm labour history	n=150/675	n=18/133	n=132/542	<0.01
Gynaecological operation history	n=13/675	n=1/133	n=12/542	0.45
Uterine leiomyoma	n=27/675	n=7/133	n=20/542	0.57

ART: Assisted reproductive technology, BMI: Body mass index, ECD: Emergency caesarean delivery, GBS: Group B Streptococcus, GDM: Gestational diabetes mellitus, GW: Gestational week, ID: Instrumental delivery, IOL: Induction of labour, Min.: Minimum, Max.: Maximum, No.: Number, PROM: Premature rupture of membranes, SLP: Spontaneous labour pain, SD: Standard deviation, SVD: Spontaneous vaginal delivery

Table 3: Identification of influencing factors for emergency caesarean delivery

Factor	OR (95% CI, n)	P value
Advanced maternal age ≥ 40 years old	2.8 (1.4 - 5.6, n=21/50)	<0.01
ART history	2.9 (1.6 - 5.0, n=36/83)	<0.01
Short height <150	4.2 (1.8 - 9.6, n=14/31)	<0.01
High BMI >30	2.1 (1.1 - 4.1, n=20/57)	0.030
Low Bishop score ≤ 5	2.3 (1.4 - 3.6, n=94/326)	<0.01
Late-term delivery ≥ 41 GW	2.8 (1.5 - 5.2, n=39/91)	<0.01
Large infant > 3500	3.3 (1.8 - 5.9, n=34/71)	<0.01
IOL	1.2 (0.6 - 2.4, n=35/75)	0.64
Threatened preterm labour history	0.7 (0.4 - 1.3, n=18/150)	0.25
GDM	0.7 (0.2 - 2.7, n=3/18)	0.55
GBS positivity	0.9 (0.4 - 1.6, n=16/86)	0.63
Gynaecological operation history	0.5 (0.1 - 4.3, n=1/13)	0.47
Uterine leiomyoma	0.7 (0.2 - 2.1, n=7/27)	0.53

ART: Assisted reproductive technology, BMI: Body mass index, CI: Confidence interval, GBS: Group B Streptococcus, GDM: Gestational diabetes mellitus, GW: Gestational week, IOL: Induction of labour, OR: Odds ratio

When the data of the SVD/ID and ECD groups were compared, we detected significant differences in various factors related to both maternal characteristics and the labour situation. In this analysis, differences in the amount of blood loss and Apgar score were also detected. These results may support the definition of ECD as an unfavourable labour outcome.

Relationships between eight factors and delivery method

As shown in Figure 1, when simply comparing the rates of ECD in the respective subgroups, we could macroscopically observe a general tendency towards a constant increase with the increase in maternal age, maternal BMI and GW, and a decrease of Bishop score. Similarly, there were subgroups in which a remarkably high rate of ECD was detected for the other 4 factors. From these results, we extracted the following 8 indices as candidates for the prediction model: 1) advanced maternal age, 2) ART history, 3) short height, 4) high BMI, 5) low Bishop score, 6) late-term delivery, 7) large infant; and 8) IOL.

Factors influencing labour outcome

To identify significant factors affecting the likelihood of ECD, multivariate analysis of 14 representative factors was performed (Table 3). Among the 13 factors, the following 7 were associated with a significantly increased rate of ECD: advanced maternal age; ART history; small height; High BMI; low Bishop score; late-term delivery; and large infant, and the results for all of these factors were roughly similar to those of various previous reports (1, 9, 12, 25, 26). However, unexpectedly, IOL was not significant. This may be because the effects of "late-term delivery" and "large infant" were superior to those of "IOL", although in some cases, IOL was performed to treat patients who had reached 41 GWs or had a high foetal weight.

New scoring system for predicting emergency caesarean delivery

Next, based on the results of the multivariate analysis, we investigated the relationships between the scores of the aforementioned 7 factors and the likelihood of ECD. The indices of the prediction model included advanced maternal age; ART history; small height; High BMI; low Bishop score; late-term delivery; and large infant (each 1 point). After the scores of the 7 factors was determined, 675 patients were divided into 5 groups, in which the points ranged from 0 to 5. Although the highest score was theoretically 7, among the 675 patients, the maximal point value was 5. Then, the rates of ECD were calculated for these 5 groups, because the number of patients with 5 points was only 2. This analysis revealed a consistent increase in the rate of ECD with an increasing number of applicable factors (Figure 2).

Discussion

First, together with well-known factors, such as the Bishop score, foetal weight and maternal height, advanced maternal age and ART history also significantly increased the likelihood of ECD. As expected in this study, even when the borderline age was set to 30 years, there was a clear difference in the rates of ECD (11.6%, n=98/846 vs. 19.9%, n=133/675, p<0.0001).

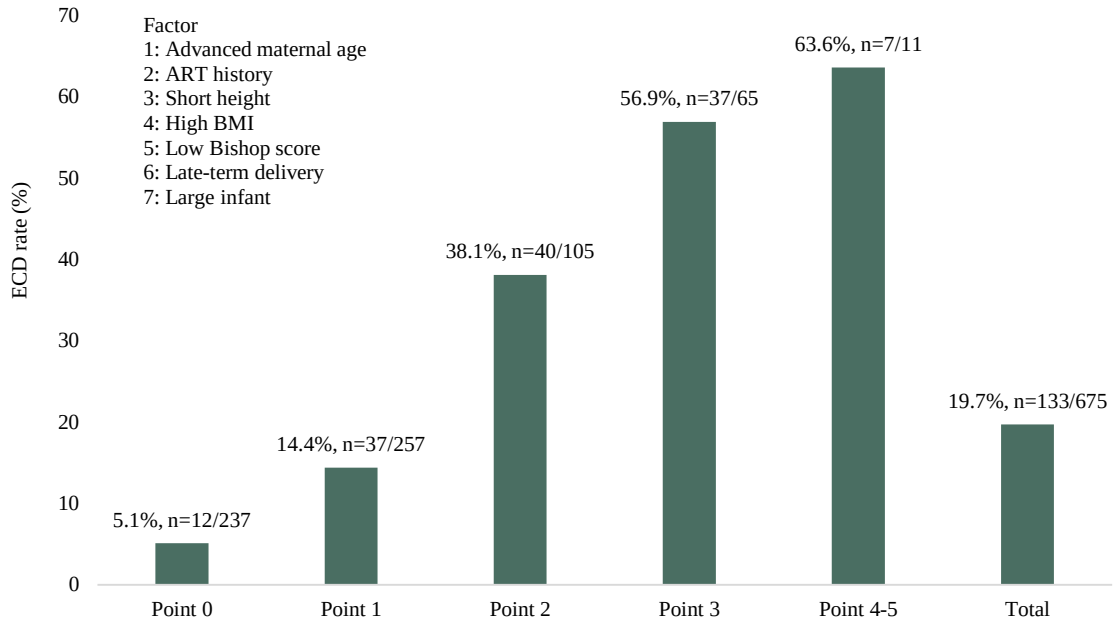

Figure 2: Relationships between the number of factors and the likelihood of emergency caesarean delivery

ART: assisted reproductive technology, BMI: body mass index, ECD: emergency caesarean delivery

Moreover, over 40% of the nulliparous pregnant women over 40 years old had an ECD. Considering the existence of a certain number of ID cases, namely, approximately 20% in this study, some problems may occur during labour in more than 60% of nulliparous pregnant women aged 40 years or older. Interestingly, ART history also had a negative impact on labour outcomes independent of maternal age. This might indicate a direct relationship between reproductive ability and labour-related ability. Because the number of pregnant women of advanced age who conceive after ART treatment is expected to increase, the management of labour will become more difficult in the future. Finally, by adding the other 5 significant factors shown in Table 3 for predicting the risk of needing an ECD, a new prediction model, in which the score ranged theoretically from 0 to 7, was constructed. By using this model, patients who had an extremely high risk of ECD, namely, more than 80%, were identified. When encountering nulliparous pregnant women with scores of 3 or 4, relatively early preparation for ECD may be needed, or in extreme cases, caesarean delivery may be selected without trying to achieve SVD. In the future, it would be desirable to generalize this model after accumulating more cases of advanced-age nulliparous pregnant women and performing larger-scale analyses.

However, there were some limitations in this study. Unfortunately, since in most of the patients with HDP, FGR and oligohydramnios, ECD was determined almost entirely before starting IOL in our hospital, probably due to limited medical resources, so these factors were unavoidably excluded from the analyses. To perform sufficient analyses of these factors, large-scale facilities may be needed for the use of abundant medical resources.

Finally, when considering other gynaecological complications, unlike in previous reports (27), GDM and other factors were not significant. This result indicated that we could manage the labour process without considering various gynaecological complications.

Conclusion

We detected the clear impact of maternal age and ART history on labour outcomes in addition to other labour-related factors. Based on these results, an effective scoring system for predicting the possibility of ECD could be established. Therefore, in the future, it might become more important to consider factors related to maternal age and infertility treatment when managing the labour process.

Conflict of Interests

Authors declare no conflict of interests.

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