The Impact of Maternal and Neonatal Intensive Care Unit Utilization on Maternal and Neonatal Health Outcomes in High-Risk Pregnancies

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The Impact of Maternal and Neonatal Intensive Care Unit Utilization on Maternal and Neonatal Health Outcomes in High-Risk Pregnancies

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ABSTRACT

The Impact of Maternal and Neonatal Intensive Care Unit Utilization on Maternal and Neonatal Health Outcomes in High-Risk Pregnancies

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Background: South Korea is facing a decline in birth rates and a rising number of high-risk pregnancies due to rising in late pregnancies. In 2022, the number of births decreased by 30.4% compared to 2017, while the proportion of mothers aged 35 and older increased to 39.3%. This shift is linked to higher risks of complications such as infertility, miscarriage, and the need for obstetric interventions. Additionally, high-risk deliveries, including preterm births, low birth weight, and multiple births, are on the rise, placing greater demand on specialized care.

In the face of these challenges, The government's efforts to address these issues include the establishment of regional integrated care centers for high-risk pregnancies and neonates since 2014. The Ministry of Health and Welfare has introduced policies to support high-risk pregnancies, including management fees and hospitalization fees for voluntary treatment. However, with the increasing number of high-risk pregnancies and decreasing birth rates, continuous development of Maternal-Fetal Intensive Care Units (MFICUs) is crucial for improving maternal and neonatal health outcomes. However, studies evaluating the related effects are scarce. Therefore, this study aims to explore the association between MFICU and Postpartum Maternal Morbidity.

Methods: This population-based cohort study used data from the National Health Insurance Service cohort database, spanning from 2011 to 2023, to investigate the relationship between MFICU admission and postpartum maternal morbidity (PMM). Propensity score matching (1:2 ratio) was applied based on maternal age, year of delivery, pregnancy-related complications, income, mode of delivery, and other factors to minimize confounding. The study focused on 21,934 pregnant women, of whom 7,962 were admitted to the MFICU and 13,972 were not.

The primary independent variable was the admission status of high-risk pregnant women to the MFICU, with the dependent variable being PMM, defined as occurrences such as sepsis, uterine hysterectomy, ICU admission, death, stillbirth, or massive transfusion within 42 days of delivery. Sociodemographic factors included maternal age, residential area, income level, and region of hospital, delivery within the same area, delivery year, while obstetric factors included mode of delivery, status of multiple births, comorbidities, parity, and anesthetic methods.

Data analysis was conducted using Generalized Estimating Equation model with a binomial distribution and logit link function to assess binary outcomes. The study also included subgroup analysis based on hospitals with or without MFICU. The results were reported as exponentiated values and presented as Exp(β) with 95% confidence intervals (CIs).

Results: Women admitted to the intensive care unit (ICU) had a significantly lower likelihood of developing postpartum maternal complications compared to those who were not admitted (Exp(β): 0.77, 95% CI 0.52–0.94). Subgroup analyses by diagnosis revealed a significant reduction in the incidence of postpartum sepsis. Other complications, such as ICU admission, stillbirth, and maternal death, showed a decreasing trend, but the results were not statistically significant. Furthermore, there were no significant differences in the length of stay, total medical costs, or out-of-pocket expenses for women admitted to the ICU. When evaluating the health outcomes of neonates born to the high-risk mothers included in the analysis, premature birth and low birth weight increased (Exp(β): 1.16, 95% CI 1.09–1.24), although there was a tendency for a reduction in infant mortality.

Conclusion: Utilization of MFICU in obstetric care has significantly reduced postpartum maternal morbidity in high-risk pregnant women. Key strategies include a multidisciplinary approach all of which are crucial for improving peripartum outcomes. These measures address current sociodemographic challenges and help ensure better care for high-risk mothers. Therefore, maintaining and enhancing obstetric care through effective MFICU utilization and continuous medical support policies is essential for improving maternal health outcomes.

Keywords : maternal-fetal intensive care unit, high risk pregnancy, postpartum maternal morbidity,low birth weight, obstetrics care

I. Introduction

1. Study Background

In South Korea, the number of births has been continuously declining, with approximately 240,000 births in 2022, representing a 30.4% decrease compared to 2017. In contrast, the proportion of mothers aged 35 and older increased to 39.3% in 2022, up from 33.4% in 2017. This rise in advanced maternal age (AMA) is closely associated with higher risks of infertility, miscarriage, and the need for obstetric interventions[1]. Additionally, according to birth statistics from 2022, 9.8% of newborns were preterm, 7.8% were low birth weight, and 5.8% were multiple births[2]. These figures represent increases of 1.3 times, 1.3 times, and 1.5 times, respectively, compared to 2017, indicating a rising share of high-risk deliveries and neonates.

The increasing prevalence of high-risk pregnancies and the declining birth rate have led to a shortage of maternity care facilities and medical personnel[3]. As of 2021, 63 local governments across South Korea lacked maternity care institutions, with particularly severe shortages in non-capital regions[3]. Furthermore, the influx of medical personnel capable of treating high-risk pregnant women and neonates has decreased[4]. For example, the average age of professors in maternal-fetal medicine, who are responsible for managing high-risk pregnancies and deliveries, increased from 45.4 years in 2010 to 50.3 years in 2020, and the number of professors in this field dropped from 144 to 124 over the same period. Although the percentage of new applicants for obstetrics residency programs increased from 66.3% in 2014 to 74% in 2022, the number of trainees still fails to meet the required positions, raising concerns about a future shortage of healthcare professionals[5,6].

Furthermore, while the population of women of childbearing age continues to decline, the number of mothers aged 35 and older and the use of infertility treatments have led to an upward trend in high-risk pregnancies[7-9]. Over the past decade, the population of women in the primary childbearing age group (ages 25-39) decreased by 550,000, and the number of births has dropped by 46.5%. The proportion of mothers aged 35 and older has increased nearly twofold, which is a major contributing factor to the rise in high-risk deliveries and neonates[10]. The proportion of preterm births and low-birth-weight infants has also increased over the past decade[11,12].

Despite these increasing challenges, the infrastructure for treating high-risk pregnant women and neonates remains inadequate. High-risk deliveries require specialized equipment, skilled medical professionals, and cooperation across multiple specialties[13,14], yet there is a lack of such facilities, equipment, and personnel[15]. The number of beds specifically designated for high-risk pregnant women and neonates is only 32.3% of the required capacity, according to a 2019 study on the development of the central maternal and child healthcare center operational model[16]. Moreover, the supply of medical resources for maternal and neonatal care continues to decrease. The shortage of obstetrics residents has made it increasingly difficult for university hospitals to operate delivery rooms. Additionally, there are regional disparities in the number of obstetric specialists available relative to the number of mothers. The lack of an integrated perinatal care system remains another significant issue. The care for pregnant women, fetuses, and deliveries is managed by obstetrics, while newborn care is managed by pediatrics, resulting in fragmented care. Specifically, a systematic and integrated perinatal care system for high-risk pregnant women and neonates is underdeveloped[17,18].

To address these issues, the South Korean government has designated regional integrated care centers for high-risk pregnant women, fetuses, and neonates since 2014, aiming to provide systematic and specialized care for healthy pregnancies and deliveries[19]. Various support programs for maternal care in birth-deprived areas have also been implemented. Each medical institution continues to handle its own patient transfers, which has led to inefficiencies in the overall emergency response system. Research has shown that the success rate for transferring high-risk pregnant women and neonates within the golden hour to hospitals capable of providing appropriate treatment is only about 69%[4]. Moreover, if high-risk pregnant women and neonates do not receive timely care at integrated treatment centers, the perinatal mortality rate increases to 53%, and the neonatal mortality rate rises to 49%[4].

In Korea, The Ministry of Health and Welfare supports intensive treatment to ensure safe delivery for pregnant women high-risk pregnancies[19]. The management of high-risk pregnant women and newborns is systematically coordinated from the period before delivery of the high-risk mother-fetus to the period after delivery of the high-risk newborn. To this end, an emergency medical system is maintained, and MFICU play a crucial role in this process. Since the second half of 2017, management fees and hospitalization fees for high-risk pregnant women have been established to expand facilities for the voluntary treatment of high-risk pregnant women. (Figure 1.) With the increasing number of high-risk pregnant women and newborns and the decreasing birth rate, continuous attention to MFICU is necessary4.

In hence, as the proportion of high-risk pregnancies and neonates increases, the need for specialized treatment and support systems is growing. Additionally, regional disparities in healthcare services and the decline in birth rates exacerbate these challenges. However, there is a lack of systematic research and proposed solutions regarding the management of high-risk pregnancies and neonates. Therefore, this study aims to analyze the effectiveness of MFICU in managing high-risk pregnancies and neonates, and to propose policy and medical responses that contribute to the improvement of South Korea's maternal and child healthcare system.

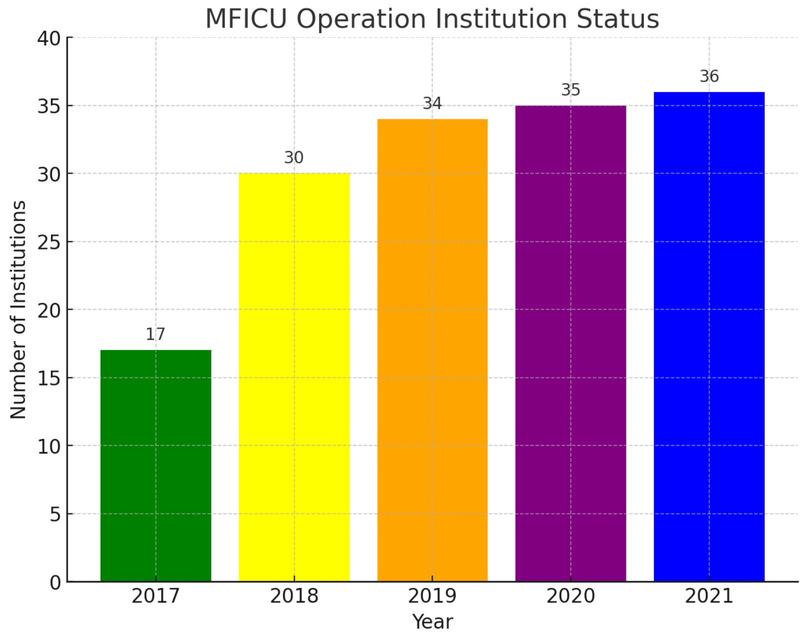

Figure 1. MFICU Institution Status

Source: Central mother& child medical center, 2024 Central mother& child medical center Statistics Report.

2. Study objectives

The objective of this study is to investigate the impact of the High-Risk Maternity Fetal Intensive Care Units on postpartum health outcomes for high-risk mothers and neonates. Furthermore, the study aims to provide a foundation for the formulation of policies regarding the management of high-risk pregnancies within an integrated care setting by analyzing the effects of the establishment of the High-Risk Maternity Integrated Care Center.

The specific objectives of the study are as follows:

1) To investigate the characteristics of individuals admitted to the MFICU
2) To investigate the effect of admission to the MFICU on the incidence of postpartum complications in mothers.
3) To investigate the effect of admission to the MFICU on the medical use and expenditure
4) To investigate the influence of maternal admission to the MFICU on the health outcomes of neonates.

II. Literature Review

1. Maternal-Fetal Intensive care unit for high risk pregnancy and neonate

As the number of high-risk pregnancies continues to rise, ensuring appropriate care is critical in preventing complications and ensuring safe deliveries. Inadequate or delayed treatment for high-risk pregnant women is directly linked to maternal mortality[25-27]. The infrastructure required for the care of high-risk pregnancies, particularly the availability of specialized delivery facilities and the involvement of qualified obstetricians, plays a crucial role in ensuring safe outcomes[28] However, the declining birth rate has contributed to a significant reduction in the number of delivery hospitals, particularly in rural areas. In 2007, there were 1,027 delivery institutions in Korea, but by 2016, the number decreased by approximately 40%, with only 607 remaining. A report in 2015 found that only 62.5% of hospitals capable of treating high-risk pregnancies were providing care, with only 309 beds available. In response, the Ministry of Health and Welfare launched the "High-Risk Maternal and Neonatal Integrated Care Center" initiative in 2014. By 2018, 17 centers had been selected, with 12 operational (Figure2). Furthermore, new management and hospitalization fees were introduced in the second half of 2017 to encourage the establishment of voluntary high-risk pregnancy care facilities.

To be recognized as a MFICU[19], hospitals must meet specific criteria and possess the necessary equipment. The designated institutions must operate both delivery rooms and neonatal intensive care units (NICUs), with at least one obstetrician and one pediatrician on staff at all times. If the nurse-to-patient ratio is below 1.04, institutions must meet additional criteria to ensure proper care levels, such as a tiered management system for the NICU with all patient care management levels rated as grade 3 or higher. Personnel requirements specify that nurses should be dedicated exclusively to high-risk pregnancy intensive care units, maintaining a nurse-to-patient ratio of less than 1.5:1 based on the average number of patients per quarter. In terms of equipment, MFICUs must be equipped with a centralized monitoring system, ECG monitors, fetal heart rate monitors, and ultrasound machines. Each bed must have access to a centralized medical gas supply system, monitoring equipment, and continuous infusion pumps. This robust infrastructure is essential for providing the necessary care for high-risk pregnant women, ultimately improving maternal and neonatal outcomes and reducing complications during childbirth.

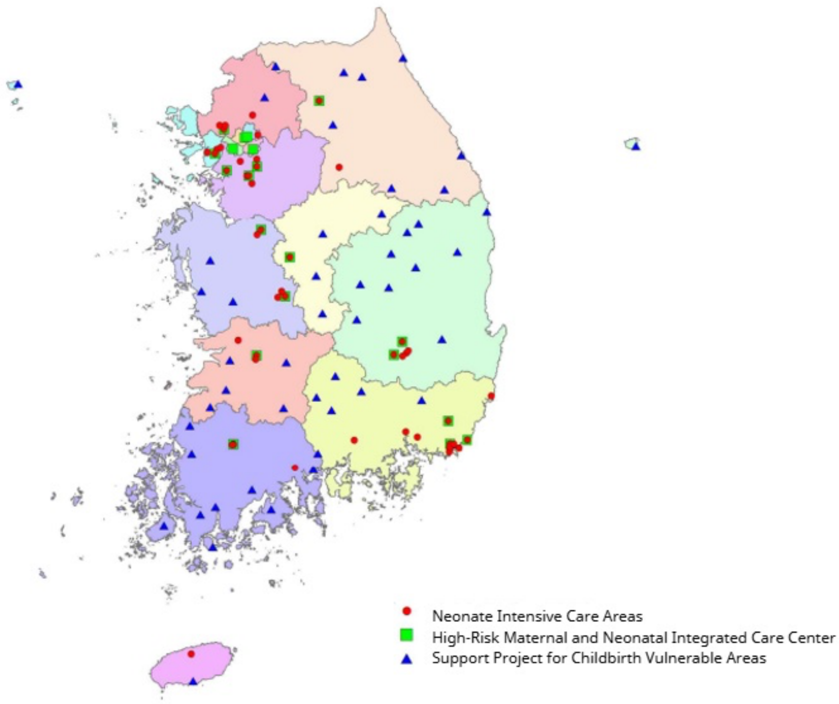

Figure 2. Maternal and Child Health Care Service Providers map

Source: Ministry of Health and Welfare. 2024 Support project guidance about Integrated care center for high risk pregnancy and neonate.

2. High risk pregnancy

The dictionary definition of high-risk pregnancy refers to a pregnancy that is likely to result in poor outcomes for both the mother and the fetus. However, in clinical practice, it refers to a pregnancy that involves risk factors that could affect pregnancy outcomes. The risk factors associated with high-risk pregnancies include the mother's age, pre-existing medical and surgical conditions, conditions that develop during pregnancy, obstetric diseases, and pregnancy-related complications[20].

In South Korea, high-risk pregnancies have been steadily increasing. In 2009, approximately 27,223 women were diagnosed with high-risk pregnancies, while by 2020, this number had risen to 139,476, marking a fivefold increase. The main cause of this rise is the increase in advanced maternal age. The number of high-risk pregnancies in women over 40 has surged, and the prevalence of chronic diseases such as hypertension and diabetes among pregnant women has also contributed to this increase.

The most common risk factors for high-risk pregnancies are advanced maternal age (35 years or older) and adolescent pregnancies (under 17 years of age). Particularly for women over the age of 40, the likelihood of miscarriage and chromosomal abnormalities is significantly higher. Additionally, the preterm birth rate has also been rising. Risk factors related to the maternal health status prior to pregnancy include obesity, hypertension, pulmonary, renal, cardiac conditions, diabetes, autoimmune diseases, sexually transmitted infections, and viral infections. Previous pregnancy history, such as miscarriage, preterm birth, preeclampsia and eclampsia, gestational diabetes, stillbirth, and neonatal death, also contribute to the risk.

Family history is also an important risk factor for high-risk pregnancies, with a family history of diabetes being a prominent example. Diseases occurring during pregnancy can be categorized into those affecting the mother and those affecting the fetus. Maternal factors include excessive weight gain, insufficient weight gain, preeclampsia and eclampsia, gestational diabetes, preterm labor, multiple pregnancies, placenta previa, oligohydramnios and polyhydramnios, cervical insufficiency, chorioamnionitis, pyelonephritis, placental abruption, uterine rupture, postpartum hemorrhage, and embolism. Fetal factors include intrauterine growth restriction, macrosomia, fetal malformations, and chromosomal abnormalities[21].

The factors that influence pregnancy outcomes are broad and varied, ranging from an individual's lifestyle habits, medical history, pregnancy history, family history, and social environmental factors before pregnancy to the current pregnancy condition. Due to this, it is practically difficult to list all specific risk factors, and therefore, high-risk pregnancy is generally used as a broad and abstract concept. In South Korea, under the guidance of academic societies, high-risk pregnancies have been classified into obstetric, medical, physical, and current pregnancy risk factors, with each risk factor being further subdivided into mild (grade I), moderate (grade II), and severe (grade III) categories[21]. (Table1)

In South Korea, the preterm birth rate increased from 5.7% in 2009 to 8.1% in 2019, indicating that preterm births[2], a major consequence of high-risk pregnancies, are occurring more frequently. This highlights the importance of managing high-risk pregnancies effectively. High-risk pregnancies contribute to increased maternal mortality rates and can have severe consequences for fetal health. In South Korea, the maternal mortality rate decreased slightly from 0.30% in 2018 to 0.27% in 2020[2], but the maternal mortality ratio (the number of maternal deaths per 100,000 live births) remains high. In 2020, the maternal mortality ratio was 11.8, significantly higher than the OECD average of 6.0[22].

The increase in high-risk pregnancies is not only a health issue but also an economic burden. The frequent prenatal checkups, hospital admissions, and intensive treatments needed for high-risk pregnancies lead to a substantial financial burden on both the individuals and the healthcare system[23]. High-risk pregnancies can lead to preterm birth, postpartum hemorrhage, disease-related complications, and even death for the mother, while the fetus may face preterm birth, low birth weight, and intrauterine fetal death[24]. This makes the management and prevention of high-risk pregnancies a critical social issue.

Table 1. Classification of High Risk Pregnancy

	Obstetrical risk factors	Medical risk factors	Physical risk factors	Current pregnancy risk factors
Mild (Grade I)	History of preeclampsia History of fetal anomalies History of cone biopsy History of GDM Procedure of ART	Family history of diabetes mellitus Rh negative women	Underweight (BMI	Anemia (Hb ≥9 g/dL) Smoking(≥1 pack/day) Psychological disease hyperemesis gravidarum Threatened Death
Moderate (Grade II)	Habitual Death history of eclampsia History of cesarean section History of uterine surgery History of Preterm birth Family Hx of abnomal karyotyping History of HIFU and myolysis	Epilepsy Heart failure by NYHA class I Serological positive results of sexually transmitted disease Pulmonary disease Thyroid disease Autoimmune disease	Maternal age (35~39 yrs, 30 kg/m 2) Multi-parous women (>3) Short cervical length (	Drug/Alcohol abuse Acute pyelonephritis Anemia (Hb
Severe (Grade III)	History of fetal demise History of neonatal death Fetal blood transfusion due to hemolytic disease History of postpartum hemorrhage including uterine rupture History of trachelectomy	Chronic HTN Heart failure by NYHA class II-IV Diabetes mellitus (pregestational DM) Moderate or severe renal disease Rh isoimmunization Others seriuous medical and surgical disease	Severe obesity (BMI ≥30 kg/m2) IIOC Uterine anomalies Maternal age (≥40 yrs)	Preterm labor (<34 weeks) PPROM (<34 weeks) IUGR Gestational HTN Multiple pregnancies IUGR SGA (<2.5 Kg) Fetal anomaly Eclampsia, preeclampsia GDM with Insulin Multiple pregnancies Placental abruptio Placental previa Uterine rupture Postpartum hemorrhage Pulmonary embolism

Abbreviations: HTN, Hypertension; IIOC, Incompetent internal os of uterine cervix; PTL. Preterm labor; PPROM, Preterm premature rupture of membranes; IUGR, Intrauterine growth restriction.

Source: Hwang JY. Reclassification of High-Risk Pregnancy for Maternal-Fetal Healthcare Providers. jksmch 2020;24:65-74.

3. Postpartum Maternal Morbidity

Maternal morbidity generally refers to physical and psychological conditions resulting from pregnancy that negatively affect the health of the mother. This includes maternal death[29](Figure3). Maternal mortality rate (MMR) has been a key indicator of maternal health, but these tragic events are often compared to the "tip of the iceberg." Governments and international organizations around the world have recognized reducing maternal mortality as an important challenge and have worked towards this goal, setting the United Nations MDG 5 (Millennium Development Goal 5)[29]. While developing countries face the greatest challenges in addressing maternal mortality, women continue to die unnecessarily during or after pregnancy in developed countries as well. In developed countries[30,31], maternal mortality rates have not decreased, and in some countries, such as the United States, the maternal mortality rate has doubled over the last 20 years[32].

Maternal near miss(MNM) refers to unintended outcomes during the labor and delivery process that result in significant short-term or long-term consequences to a woman's health, such as hemorrhage, acute myocardial infarction, and other complications[33,34]. Although MNM involves rare conditions, these conditions often lead to high direct medical costs, prolonged hospital stays during delivery, and long-term rehabilitation[34]. MNM is also a significant issue for healthcare providers involved in the care and treatment of women during and after pregnancy. Recently, there has been a call for an organized national approach to reduce maternal morbidity and mortality. Prevention and treatment for women can be challenging, but MNM provides clinically relevant measures for evaluating the quality of maternal care. Recent reports have identified two key screening criteria for MNM: 1) women admitted to intensive care units and 2) women who have received ≥ 4 units of packed red blood cells[29,35,36]. These two criteria have high sensitivity and specificity for identifying MNM cases. Recently, new gold-standard clinical guidelines have been developed to identify true cases of MNM, using a multidisciplinary committee approach to determine the incidence of MNM and identify opportunities for improving maternal care[37].

Previous studies have identified several factors contributing to MNM. These factors can be categorized into social factors (such as racism, employment status, household income[38,39] ,and obstetric history factors (such as maternal age[40], previous Death history[41], comorbidities, obstetric complications[40] , multiple births[42], cesarean section delivery[43] and the use of assisted reproductive technologies[44]). Identifying factors related to MNM is essential for a better understanding of the problem and for developing effective preventive strategies. Therefore, it is important to understand the various definitions and contributing factors of MNM.

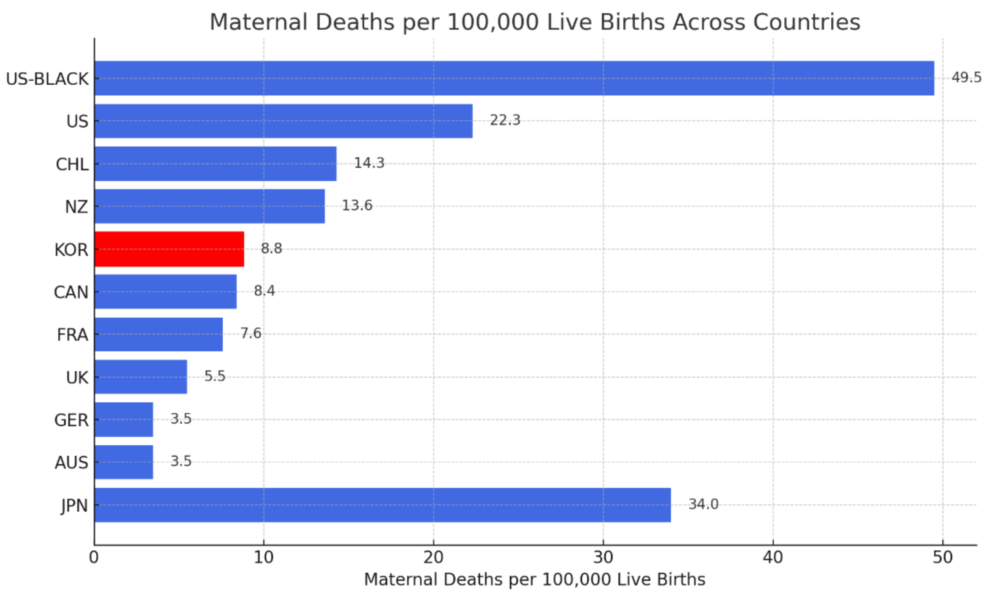

Figure 3. The maternal mortality ratio

Source: Organization for Economic Co-operation and Development, “Maternal and Infant Mortality,” in Health at a Glance 2023: OECD Indicators (OECD, 2023)

III. Material and Methods

1. Data and study population

In this population-based cohort study, data from the National Health Insurance Service (NHIS) cohort database were utilized. In 1989, universal health insurance was introduced in Korea, making it mandatory for all citizens to enroll in the NHIS. As a result, approximately 98% of the total population is covered by health insurance. The NHIS database contains health screening data, medical utilization claims data, sociodemographic data, and death data for all Koreans[45,46]. NHIS claims data, the largest database, includes medical utilization history for the entire Korean population, including International Classification of Diseases 10th revision (ICD-10) diagnostic codes, drug prescriptions, lengths of hospital stays, medical expenses, and information regarding healthcare provision[46].

The NHIS provides customized cohort data for academic research and policy-making purposes. The NHIS cohort used in this study includes data from 50% random samples of pregnant women and neonates who delivered at Korean medical institutions between January 1, 2011, and December 31, 2023. Delivery was defined based on hospital admission records with pregnancy-related diagnostic codes or procedure codes for vaginal or cesarean section[47].

Since the actual admission to the MFICU can only be investigated after the admission and management fees began to be claimed from October 1, 2017, the study was conducted on individuals for whom the relevant fees were claimed after this period. The admission criteria for the high-risk obstetric intensive care unit include the following conditions: (1) preterm labor before 37 weeks of gestation, (2) preterm premature rupture of membranes before 37 weeks of gestation, (3) uterine inertia, (4) severe preeclampsia or eclampsia, (5) oligohydramnios or polyhydramnios, (6) intrauterine growth restriction, (7) twin-to-twin transfusion syndrome, (8) antepartum hemorrhage, (9) pregnant women with a temperature of 38°C or higher, and (10) patients undergoing in utero thoracoamniotic shunting. A total of 40,212 delivery records, excluding individuals with no birth records at Korean medical institutions or missing data, formed the study population.

A total of 42,660 delivery cases did not require admission to the MFICU, while 8,377 cases were admitted. Propensity score matching was performed in a 1:2 ratio based on maternal age, year of delivery, pregnancy-related complications, criteria for intensive care unit admission, use of assisted reproductive technology, income, mode of delivery, hospital location, and anesthesia method. Among the matching variables, maternal age, year of delivery, pregnancy complications, criteria for intensive care unit admission, use of assisted reproductive technology, and income were exactly matched. After propensity score matching, a total of 21,934 individuals were included in the study, with 7,962 cases in the MFICU admission group and 13,972 cases in the control group (Figure 4).

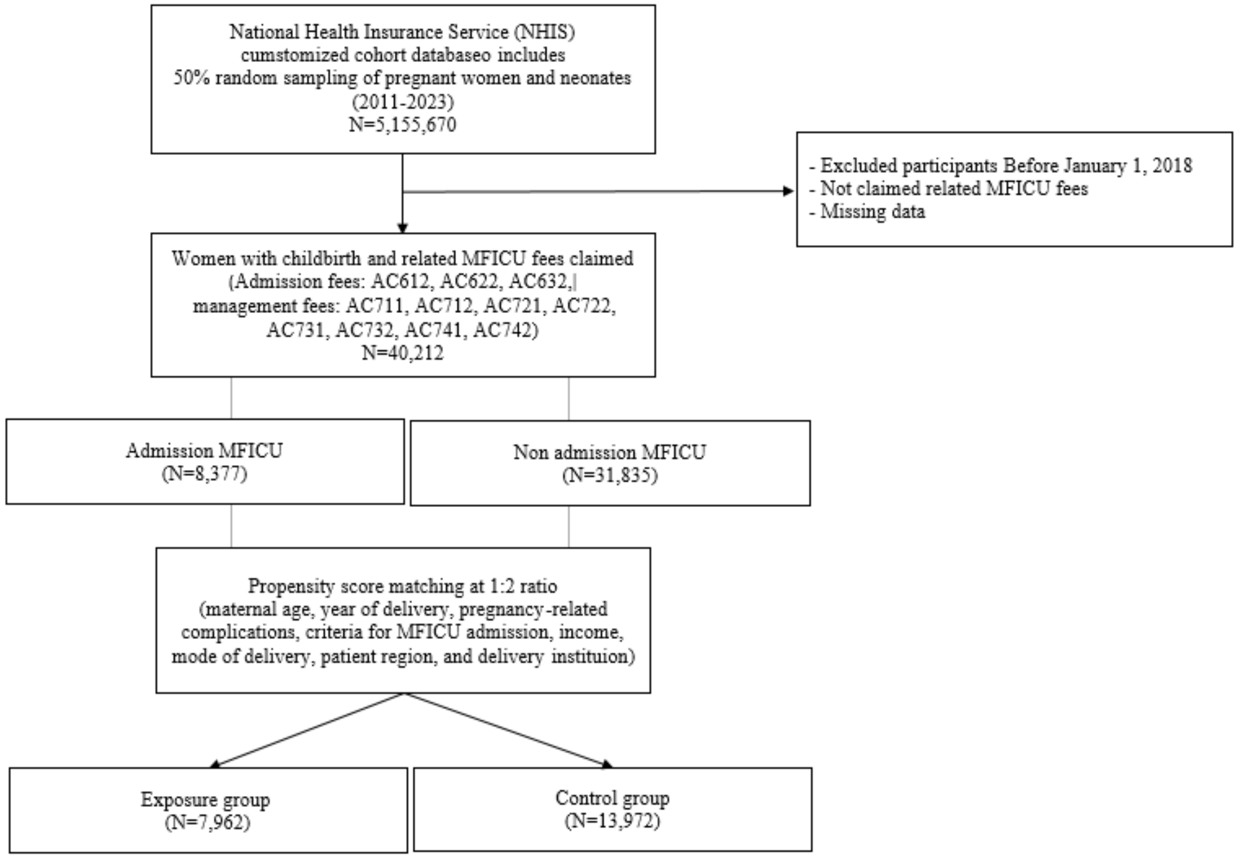

Figure 4. Flow chart of study population selection

2. Variables

1) Dependent variables

The dependent variables were Postpartum Maternal Morbidity, are defined as cases where one or more of the following conditions occurred during the perinatal period (within 42 days of delivery)[48]: sepsis, uterine hysterectomy, admitted to the ICU during delivery hospitalization[49], miscarriage, stillbirth, or massive-transfusion[50] (transfusion of ≥ 4 units of blood) (Table2).

Table 2. Classification of Postpartum Maternal Morbidity and ICD-10 codes of diagnoses

Classification	ICD-10 codes
Postpartum Maternal Morbidity	
Sepsis	O85, R65.9, R65, R65.1, A40, A41
Uterine hysterectomy	R4507, R4508, R4509, R4510, R5001, R5002, R4183, R4221
Stillbirth	Z371, Z373, Z377
Massive-transfusion	X1002, X2011, X2012, X2021, X2022, X2031, X2032, X2131, X2132, X2041, X2042, X2051, X2052, X2061, X2062, X2141, X2142, X2071, X2072, X2081, X2082, X2091, X2092, X2101, X2102, X2111, X2112, X2121, X2122, X3000, X3010
miscarriage	O02, O03, O05, O06
Admission Criteria	
Preterm labor before 37 weeks	O470, O60
premature rupture of membranes	O4220, O4221, O4290, 04291
Cervical incompetence	O343, N883, P010, O343, O3430, O3431, O3432, O3433, O3434, O3439,
preeclampsia or eclampsia	O141, O15
Hydramnios or Oligohydramnios	040, O410

Intrauterine growth retardation	O36, O360, O361, O362, O363, O364, O365, O366, O367, O368, O369, O430
Twin to twin Transfusion Syndrome	O35, O350, O351, O352, O353, O354, O355, O356, O357, O358, O359
Obstetrical Hemorrhage	O46,O460,O468 O469,
Puerperal fever	R509
thoraco-amniotic shunt patient	O67,O670,O678,O679

†ICD-10, 10th edition of the International Classification of Diseases

2) Interesting variables

The primary variable of interest is the admission of status of high-risk pregnant women to the MFICU. To identify cases of delivery the admission status of MFICU, we selected subjects with relevant procedure codes. All expectant participants who were admitted to the MFICU can be claimed admission fees, while those who meet the admission criteria but did not actually enter the MFICU can be claimed management fees. Admission fees and management fees cannot be claimed simultaneously (Table3). Since the exact gestational age could not be predicted, women who had at least one admission fee claimed during the year before delivery date were classified as the case group.

Table 3. Identification of primary variables in claims data

Variables		Claim codes [a]
Interesting Variables	Admission fees	AC612, AC622, AC632
	Management fees	AC711, AC712, AC721, AC722, AC731, AC732, AC741, AC742
Dependent variables	Admission of Intensive care unit	AJ110, AJ120, AJ100, AJ143, AJ150, AJ210, AJ220, AJ230, AJ240, AJ250, AJ260, AJ200, AJ280, AJ290, AJ310, AJ320, AJ330, AJ340, AJ350, AJ360, AJ300, AJ380, AJ390
	Admission of Neonatal Intensive care unit	AJ111, AJ121, AJ131, AJ144, AJ101, AJ161, AJ211, AJ221, AJ231, AJ244, AJ201, AJ161

[a]Procedure codes extracted from the medical history database

3) Independent variables

The independent variables of this study were sociodemographic factors and obstetric factors. Sociodemographic factors included maternal age (range: <25, 25–29, 30–34, 35–39, and ≥40 years), residential area (metropolitan, city, Obstetrics care vulnerable area), region of hospital (metropolitan, city, rural), delivery institution (tertiary hospitals, general hospital (≥500 beds and <500 beds) and hospital) whether delivery within same area, income level (divided into deciles: 1-2, 3-4, 5-6, 7-8, 9-10). Obstetric factors included mode of delivery (spontaneous vaginal delivery, cesarean section), status of multiple birth (singleton, multiple), obstetric comorbidities (0, 1+), and whether assisted reproductive technology was used (No, Yes). Additional obstetric factors included parity (1,2 and 3+), the top two most common admission criteria out of the 10 criteria, along with the remaining criteria (Preterm labor before 37 weeks, premature rupture of membranes and else) anesthetic method (general, epidural, spinal, other). Lastly, whether the maternal residence and the location of the delivering hospital were the same (yes, no) and year of delivery (2018–2023) was also adjusted for the analyses (Table 4).

Table 4. Description of covariates for the analysis

Variables		Description
Socioeconomic factors	Maternal age	<25, 25-29, 30-35, over 40 years
	Income level	Quantiles of income level, Quintile 1 represents the lowest income range and Quintile 5 represents the highest income range.(1~2, 3~4, 5~6, 7~8, 9~10)
	Residential area	Metropolitan city, City, Obstetrics care vulnerable area
	Region-Hospital	Metropolitan (Seoul), City, Rural
	Delivery institution	Tertiary hospitals, General hospital level(500 beds), General hospital level(<500 beds), Hospital level (100<beds<500)
	Delivery within same area	No, Yes
Obstetric factors	Mode of delivery	Spontaneous vaginal delivery, Cesarean section delivery
	Status of multiple birth	Singleton, Multiple
	Obstetric comorbidities	0, 1+
	Anesthetic method	General, Spinal, Epidural, Else
	Delivery within same area	No, Yes
	Parity	1(Nulliparous),2,3+
	Admission Criteria	Preterm labor before 37 weeks, premature rupture of membranes, else
	Assisted Reproductive Technology	No, Yes
	Delivery year	2018, 2019, 2020, 2021, 2022, 2023

3. Statistical methods

Chi-square tests were used to examine the distribution of the general characteristics and the distributions of the study populations according to all outcomes. General characteristics were reported as frequencies and percentages. Analysis proceeded by distinguishing between cases where admission fees and management fees were claimed for delivery, based on whether high-risk obstetric admission fees were claimed, through 1:2 propensity score matching[51] based on maternal age, year of delivery, delivery institution, pregnancy-related complications, criteria for intensive care unit admission, income, mode of delivery, patient area.

Among the matching variables, maternal age, year of delivery, criteria for MFICU admission were exactly matched. After propensity score matching, a total of 21,934 individuals were included in the study, with 7,962 cases in the MFICU admission group and 13,972 cases in the control group.

Main outcomes were analyzed using Generalized Estimating Equation(GEE) model with a binomial distribution and a logit link function for binary outcomes[52,53]. Analysis was conducted based on the hospital where delivery occurred, using codes related to MFICU.

$$g(E[Yij]) = \beta 0 + \beta 1(Case\ ij) + Xij + \epsilon ij$$

g: link function

E: Expectation

Yj: Dependent variables for the delivery cases

Case: dummy variable that assigns 1 to pregnant woman admitted to hospitalist wards (hospitalist ward, case group, management ward = control group)

Xij: covariates (maternal age, residential area, region of hospital, delivery institution, delivery within same area, income level, mode of delivery, status of multiple birth, Obstetrics comorbidities, whether assisted reproductive technology, parity, admission critieria, anesthetic method, delivery year)

ϵij: Error term for the observed value Y_{ij}

In subsequent analyses examining variations in expenditures, due to the significant concentration and uneven spread seen in the distribution of medical expenditure data[54], a Generalized Linear Model (GLM) with a Gamma distribution and a log link function was used. This method is advised to handle the right-skewed nature of the expenditure data and can be executed using the GENMOD procedure[55,56].

For the analysis of differences in length of stay, a Poisson distribution with a log link function was applied. In all analyses using the GENMOD procedure, the estimated coefficients were exponentiated and presented as Exp(β). This was done to show the trends and changes in outcomes on the original scale, with the model coefficients being interpreted multiplicatively[57]. All statistical analyses were conducted using SAS version 9.4 software (SAS Institute Inc., Cary, NC, USA), and a p-value of < 0.05 was considered statistically significant.

4. Ethics statement

This study was reviewed and approved by the International Review Board of Yonsei University's Health System (IRB number: 4-2024-0921) and adhered to the tenets of the Declaration of Helsinki. The need for informed consent was waived since the NHIS-NSC do not contain any personally identifiable information.

IV. Results

1. General characteristics of the study population

General characteristics and distribution of the study population before and after propensity score matching (Appendix 1). Before matching, the MFICU group included 8,377 (20.83%) deliveries, whereas the control group included 31,835 (79.17%) deliveries. After 1:2 propensity score matching, there were 7,962 (36.2%) deliveries in the admission MFICU group and 13,972(63.7%) in the matched control group. The balance of covariate distribution between the admission MFICU and control groups was presented as the standardized mean difference (SMD). In general, if the SMD value is less than 0.1, the covariate distribution is considered balanced[58,59].

Table 5 presents the general characteristics of the matched study participants according to postpartum maternal morbidity (PMM). Of the total 21,934 participants, 3.6% (779 individuals) experienced PMM.

In Socioeconomic factors, Maternal age the proportion of postpartum morbidity was highest among women aged 45 and older (4.8%). The lowest proportions of postpartum morbidity were found in women aged <30 years (2.4%) and those aged 30-34 years (2.8%). For Income level, the lowest income group (1~2) had a postpartum morbidity rate of 3.7%, while higher income groups had lower rates of morbidity (ranging from 3.7% to 3.3%). In terms of residential area, the postpartum maternal morbidity rate was 3.1% in metropolitan cities, 4.2% in cities, and 2.8% in obstetric care vulnerable areas. Regarding hospital region, the Capital area (Seoul) had the lowest rate at 3.1%, followed by urban areas with 4.8% and rural areas with 3.1%. In Delivery institution, Women delivering at general hospitals with ≥500 beds hospitals had the highest rate of morbidity (4.3%), compared to women delivering at smaller hospitals such as general hospitals with <500 beds (1.8%).

In Obstetric factors, regarding status of multiple birth, the morbidity rate was highest for multiple births (4.3%) compared to singleton births (3.4%). In obstetric comorbidities, Women with 1+ comorbidities had a higher morbidity rate (4.3%) compared to women with 0 comorbidities (3.5%). Regarding Anesthetic method, Women who received general anesthesia had the highest postpartum morbidity rate (8.6%). Women who had premature rupture of membranes had a higher morbidity rate (1.8%) compared to those with no such admission criteria. And Women who used ART had a postpartum morbidity rate of 26.5%, higher than those who did not use ART (3.4%). Finally, regarding delivery year The highest rate of postpartum morbidity was observed in 2019 (6.1%), with the lowest rates in 2021 (2.5%).

Table 5. General characteristics of the study population

Variables	Matched Participants, No.(%)				
		Postpartum Maternal Morbidity*			
	Total	No		Yes	
		N	%	N	%
Total (*N*=21,934)	21,934	21,155	96.4	779	3.6
Using of Maternal-Fetal Intensive Care Unit					
No	13,972	13,465	96.4	507	3.6
Yes	7,962	7,690	96.6	272	3.4
Materal age					
<30	381	372	97.6	9	2.4
30-34	2,569	2,498	97.2	71	2.8
35-39	8,995	8,727	97.0	268	3.0
40-44	7,945	7,613	95.8	332	4.2
45-	2,044	1,945	95.2	99	4.8
Type of insurance					
1Q	3,292	3,169	96.3	123	3.7
2Q	6,460	6,224	96.3	236	3.7
3Q	5,471	5,282	96.5	189	3.5
4Q	3,365	3,244	96.4	121	3.6
5Q	3346	3236	96.7	110	3.3
Region					
Metropolitan city	11,800	11,438	96.9	362	3.1
City	9,388	8,992	95.8	396	4.2
Obstetrics care vulnerable area	746	725	97.2	21	2.8
Region-Hospital					
Metropolitan (Seoul)	12,224	11843	96.9	381	3.1
City	5,659	5385	95.2	274	4.8
Rural	4051	3927	96.9	124	3.1
Delivery institution					
Tertiary hospitals	9,190	8851	96.3	339	3.7
General hospital level(≥500 beds)	8,358	8000	95.7	358	4.3
General hospital level(<500 beds)	3,241	3182	98.2	59	1.8
Hospital level (100≤beds<500)	1,145	1122	98.0	23	2.0
Mode of delivery					
Spontaneous vaginal delivery	16,697	16069	96.2	628	3.8
Cesarean section delivery	5,237	5086	97.1	151	2.9
Status of multiple birth					
Singleton	19,009	18,356	96.6	653	3.4
Multiple	2,925	2,799	95.7	126	4.3
Obstetric comorbidities					

0	20,694	19968	96.5	726	3.5
1 +	1,240	1187	95.7	53	4.3
Anesthetic method					
General	3,448	3,153	91.4	295	8.6
Epidural	6,828	6,634	97.2	194	2.8
Spinal	5,470	5,289	96.7	181	3.3
else	6,188	6,079	98.2	109	1.8
Admission Criteria					
Preterm labor before 37 weeks	12,331	12,008	97.4	323	2.6
premature rupture of membranes	2,885	2,735	94.8	150	5.2
else	6,718	6,412	95.4	306	4.6
Parity					
1 (Nulliparous)	13,735	13,264	96.6	471	3.4
2	5,631	5428	96.4	203	3.6
3+	2,568	2463	95.9	105	4.1
Assisted Reproductive Technology					
No	21,764	21030	96.6	734	3.4
Yes	170	125	73.5	45	26.5
Delivery within same area					
No	11,077	10664	96.3	413	3.7
Yes	16,392	15913	97.1	479	2.9
Delivery year					
2018	2,938	2,810	95.6	128	4.4
2019	3,038	2,854	93.9	184	6.1
2020	3,664	3,509	95.8	155	4.2
2021	4,147	4,045	97.5	102	2.5
2022	4,586	4291	93.6	195	4.3
2023	3,296	3,168	96.1	128	3.9

***Hysterectomy Massive transfusion(over 4 units), Death, Stillbirth, Sepsis**

2. Effects of Postpartum Maternal Morbidity and risk factors

Table 6 showed that women who used the MFICU had a significantly lower risk of postpartum maternal morbidity compared to those who did not (Exp(β): 0.77, 95% CI: 0.66–0.90). Maternal age was significantly associated with postpartum maternal morbidity. Women aged under 25 years had a higher risk of postpartum morbidity compared to women aged 25-29 years (Exp(β): 1.45, 95% CI: 1.10–1.91), and women aged 35-39 years also had an increased risk (Exp(β): 1.33, 95% CI: 1.06–1.68). Although women aged 40 years or older had a higher risk (Exp(β): 1.53, 95% CI: 0.99–2.38), this association was marginally significant.

Region of residence was found to be significantly associated with postpartum maternal morbidity. Women living in cities (Exp(β): 1.74, 95% CI: 1.22–2.49) and those in obstetric care vulnerable areas (Exp(β): 1.52, 95% CI: 1.11–2.07) had an increased risk of postpartum morbidity compared to those living in metropolitan areas.

The region-hospital interaction revealed that rural areas had a lower risk of postpartum morbidity (Exp(β): 0.66, 95% CI: 0.47–0.92), while the risk for those living in cities was not statistically significant (Exp(β): 1.27, 95% CI: 0.91–1.79).

Delivery institution type was significantly associated with postpartum maternal morbidity. Women delivering in general hospitals with 500 or more beds had a higher risk compared to those delivering in tertiary hospitals (Exp(β): 1.34, 95% CI: 1.15–1.56). On the other hand, women who delivered in hospitals with fewer than 500 beds (Exp(β): 0.43, 95% CI: 0.35–0.54) or hospitals with 100-499 beds (Exp(β): 0.53, 95% CI: 0.40–0.71) had a significantly lower risk of postpartum morbidity.

Regarding mode of delivery, women who underwent cesarean section delivery had a lower risk of postpartum morbidity compared to those who had spontaneous vaginal delivery (Exp(β): 0.76, 95% CI: 0.65–0.89).

The status of multiple births did not show a significant association with postpartum maternal morbidity (Exp(β): 1.01, 95% CI: 0.83–1.22). Similarly, obstetric comorbidities did not significantly affect postpartum morbidity (Exp(β): 1.05, 95% CI: 0.82–1.35).

Anesthetic methods were strongly associated with postpartum morbidity. General anesthesia (Exp(β): 4.41, 95% CI: 3.62–5.38), epidural anesthesia (Exp(β): 1.46, 95% CI: 1.19–1.80), and spinal anesthesia (Exp(β): 2.06, 95% CI: 1.67–2.54) were all associated with a higher risk of postpartum morbidity compared to other anesthesia methods.

Admission criteria also played a role in postpartum morbidity. Women admitted due to premature rupture of membranes had a higher risk of postpartum morbidity (Exp(β): 2.11, 95% CI: 1.85–2.42), while other admission criteria such as preterm labor before 37 weeks were not significantly associated with increased risk.

Parity did not significantly affect postpartum morbidity. Women with two or more children had similar risks to nulliparous women (Exp(β): 0.98, 95% CI: 0.84–1.14), suggesting that parity is not a major factor in determining postpartum morbidity.

Assisted reproductive technology (ART) use was strongly associated with an increased risk of postpartum morbidity (Exp(β): 5.23, 95% CI: 3.79–7.22). Women who underwent ART had a significantly higher risk of complications compared to those who did not.

Finally, delivering within the same area was associated with a lower risk of postpartum morbidity (Exp(β): 0.46, 95% CI: 0.22–0.93), indicating that local delivery may reduce the risk of complications. Delivery year did not show any significant temporal trends, as all p-values for the years 2019–2023 were above 0.05, suggesting no significant differences in outcomes over time (Table 6).

Table 6. Results of association between Using of Maternal-Fetal Intensive Care Unit and Postpartum Maternal Morbidity*

Variables	Postpartum Maternal Morbidity*		
	Exp(β)[a]	95% CI	p-value
Using of Maternal-Fetal Intensive Care Unit			
No	1.00		
Yes	0.77	(0.66 - 0.90)	0.001
Materal age			
<25	1.45	(1.10 - 1.91)	0.009
25-29	1.00		
30-34	1.02	(0.81 - 1.28)	0.889
35-39	1.33	(1.06 - 1.68)	0.015
40-	1.53	(0.99 - 2.38)	0.057
Income level			
1Q	1.00		
2Q	1.05	(0.86 - 1.28)	0.663
3Q	0.97	(0.79 - 1.20)	0.776
4Q	1.02	(0.81 - 1.29)	0.871
5Q	0.91	(0.72 - 1.15)	0.414
Region			
Metropolitan city	1.00		
City	1.74	(1.22 - 2.49)	0.002
Obstetrics care vulnerable area	1.52	(1.11 - 2.07)	0.009
Region-Hospital			
Metropolitan (Seoul)	1.00		
City	1.27	(0.91 - 1.79)	0.162
Rural	0.66	(0.47 - 0.92)	0.016
Delivery institution			
Tertiary hospitals	1.00		
General hospital level(≥500 beds)	1.34	(1.15 - 1.56)	0.000
General hospital level(<500 beds)	0.43	(0.35 - 0.54)	<.0001
Hospital level (100≤beds<500)	0.53	(0.40 - 0.71)	<.0001
Mode of delivery			
Spontaneous vaginal delivery	1.00		
Cesarean section delivery	0.76	(0.65 - 0.89)	0.001
Status of multiple birth			
Singleton	1.00		
Multiple	1.01	(0.83 - 1.22)	0.940
Obstetric comorbidities			
0	1.00		
1 +	1.05	(0.82 - 1.35)	0.688
Anesthetic method			
General	4.41	(3.62 - 5.38)	<.0001
Epidural	1.46	(1.19 - 1.80)	<.0001
Spinal	2.06	(1.67 - 2.54)	<.0001
else	1.00		
Admission Criteria			
Preterm labor before 37 weeks	1.00		
premature rupture of membranes	2.11	(1.85 - 2.42)	0.866
else	1.31	(1.11 - 1.55)	<0.001

Parity					
1 (Nulliparous)	1.00				
2	0.98	(0.84	-	1.14)	0.786
3+	1.00	(0.80	-	1.25)	0.973
Assisted Reproductive Technology					
No	1.00				
Yes	5.23	(3.79	-	7.22)	<.0001
Delivery within same area					
No	1.00				
Yes	0.46	(0.22	-	0.93)	0.031
Delivery year					
2018	1.00				
2019	0.78	(0.61	-	1.01)	0.056
2020	0.97	(0.76	-	1.23)	0.807
2021	1.03	(0.82	-	1.30)	0.784
2022	0.98	(0.78	-	1.23)	0.866
2023	0.90	(0.71	-	1.14)	0.367

*Hysterectomy Massive transfusion(over 4 units), Death, Stillbirth, Sepsis

3. Subgroup analysis

3.1. Independent subgroup analysis

Table 7 shows that subgroup analysis utilization of MFICU and Socio-demographic and Obstetrics factor. Regarding socioeconomic factors, maternal age had a significant impact on the risk of maternal morbidity after MFICU admission. Women aged 40-44 years had a significantly lower risk of maternal morbidity. However, other age groups, including those aged 30-34, 35-39, and 45 years or older, did not show significant differences in risk compared to the reference group ($p > 0.05$). Income levels also played a role in maternal morbidity. Women in the second and fourth income quartiles had significantly lower risks of maternal morbidity (Exp(β): 0.75, 95% CI: 0.56–0.99 and Exp(β): 0.60, 95% CI: 0.40–0.92, respectively). However, no significant association was observed for women in the first and fifth income quintiles.

As for region of residence, women living in cities had a significantly lower risk of maternal morbidity after MFICU admission (Exp(β): 0.57, 95% CI: 0.41–0.80). Conversely, women from metropolitan areas and obstetric care vulnerable regions did not show significant differences in morbidity risk compared to those in the reference group. Additionally, women residing in rural areas had a significantly higher risk of maternal morbidity (Exp(β): 1.67, 95% CI: 1.10–2.53). This suggests that geographic location plays a crucial role in determining maternal health outcomes.

Delivery institution type was another factor that influenced maternal morbidity. Women who delivered in general hospitals with 500 or more beds had a significantly lower risk of maternal morbidity (Exp(β): 0.52, 95% CI: 0.40–0.67) compared to those delivering in tertiary hospitals. However, women delivering in hospitals with fewer than 500 beds had a higher risk (Exp(β): 1.75, 95% CI: 1.03–1.19), and those who delivered in hospitals with 100-499 beds showed a significantly higher risk (Exp(β): 3.29, 95% CI: 1.83–5.83). These findings suggest that the size and type of delivery institution are significant determinants of maternal morbidity after MFICU admission.

In terms of obstetric factors, mode of delivery had a significant association with maternal morbidity. Women who underwent spontaneous vaginal delivery had a significantly lower risk of maternal morbidity after MFICU admission (Exp(β): 0.72, 95% CI: 0.61–0.86), while those who underwent cesarean section did not show significant differences (Exp(β): 0.96, 95% CI: 0.69–1.35). Regarding multiple births, women with singleton pregnancies had a significantly lower risk of maternal morbidity (Exp(β): 0.78, 95% CI: 0.66–0.92), while women with multiple pregnancies did not show significant differences in risk (Exp(β): 0.77, 95% CI: 0.53–1.12). Obstetric comorbidities were also an important factor. Women without obstetric comorbidities had a significantly lower risk of maternal morbidity (Exp(β): 0.81, 95% CI: 0.69–0.95), while those with one or more obstetric comorbidities had a much lower risk as well (Exp(β): 0.44, 95% CI: 0.24–0.80).

Anesthetic methods significantly influenced maternal morbidity. Women who underwent spinal anesthesia had a significantly lower risk of maternal morbidity after MFICU admission (Exp(β): 0.55, 95% CI: 0.40–0.74). However, other anesthetic methods, including general and epidural anesthesia, did not show significant associations with maternal morbidity.

In terms of admission criteria, women admitted due to premature rupture of membranes had a significantly lower risk of maternal morbidity (Exp(β): 0.88, 95% CI: 0.73–1.06). Other admission criteria, such as preterm labor before 37 weeks, did not show significant effects on the risk of maternal morbidity.

Regarding parity, women with three or more children had a significantly lower risk of maternal morbidity after MFICU admission (Exp(β): 0.44, 95% CI: 0.28–0.71), while women with one or two children did not show significant differences in risk.

The use of ART also influenced maternal morbidity. Women who used ART had a significantly lower risk of maternal morbidity after MFICU admission (Exp(β): 0.39, 95%

CI: 0.16–0.96). Women who did not use ART also showed a moderate reduction in risk (Exp(β): 0.80, 95% CI: 0.68–0.93).

Finally, delivery within the same area was associated with a lower risk of maternal morbidity after MFICU admission (Exp(β): 0.47, 95% CI: 0.16–0.96), while those who delivered in a different area had a slightly lower risk (Exp(β): 0.77, 95% CI: 0.66–0.90).

Delivery year also influenced maternal morbidity. Women who delivered in 2021 (Exp(β): 0.69, 95% CI: 0.48–0.98), 2022 (Exp(β): 0.72, 95% CI: 0.52–0.99), and 2023 (Exp(β): 0.67, 95% CI: 0.47–0.96) showed a significantly lower risk of maternal morbidity after MFICU admission compared to those who delivered in 2018. Women who delivered in 2019 and 2020 did not show significant differences in maternal morbidity.

Table 7. Subgroup analysis utilization of MFICU and Socio-demographic and Obstetrics factor

Variables	No	Admission MFICU				
	Ref	Exp(β)	95% CI			p-value
Socioeconomic factors						
Maternal age						
<30	1.00	0.60	(0.17	-	2.05)	0.412
30-34	1.00	0.78	(0.45	-	1.33)	0.356
35-39	1.00	1.00	(0.78	-	1.30)	0.975
40-44	1.00	0.69	(0.54	-	0.88)	0.003
45-	1.00	0.76	(0.50	-	1.17)	0.844
Income level						
1Q	1.00	0.99	(0.68	-	1.44)	0.951
2Q	1.00	0.75	(0.56	-	0.99)	0.040
3Q	1.00	0.88	(0.65	-	1.20)	0.417
4Q	1.00	0.60	(0.40	-	0.92)	0.018
5Q	1.00	0.68	(0.45	-	1.03)	0.068
Region						
Metropolitan city	1.00	0.89	(0.72	-	1.10)	0.291
City	1.00	0.57	(0.41	-	0.80)	0.001
Obstetrics care vulnerable area	1.00	0.97	(0.71	-	1.33)	0.868
Region-Hospital						
Metropolitan (Seoul)	1.00	0.90	(0.73	-	1.10)	0.305
City	1.00	0.59	(0.45	-	0.79)	0.000
Rural	1.00	1.67	(1.10	-	2.53)	0.015
Delivery institution						
Tertiary hospitals	1.00	0.81	(0.65	-	1.02)	0.070
General hospital level (≥500 beds)	1.00	0.52	(0.40	-	0.67)	<.0001
General hospital level (<500 beds)	1.00	1.75	(1.03	-	1.19)	0.017
Hospital level (100≤beds<500)	1.00	3.29	(1.83	-	-	<.0001
Obstetric factors						
Mode of delivery						
Spontaneous vaginal delivery	1.00	0.72	(0.61	-	0.86)	0.000
Cesarean section delivery	1.00	0.96	(0.69	-	1.35)	0.822
Status of multiple birth						
Singleton	1.00	0.78	(0.66	-	0.92)	0.004
Multiple	1.00	0.77	(0.53	-	1.12)	0.174
Obstetric comorbidities						

0	1.00	0.81	(0.69	-	0.95)	0.010
1 +	1.00	0.44	(0.24	-	0.80)	0.007
Anesthetic method						
General	1.00	0.80	(0.51	-	1.24)	0.316
Epidural	1.00	1.02	(0.80	-	1.30)	0.873
Spinal	1.00	0.55	(0.40	-	0.74)	0.000
else	1.00	0.87	(0.62	-	1.21)	0.402
Admission Criteria						
Preterm labor before 37 weeks	1.00	0.61	(0.47	-	0.79)	0.116
premature rupture of membranes	1.00	0.88	(0.73	-	1.06)	0.043
else	1.00	0.92	(0.60	-	1.38)	0.675
Parity						
1 (Nulliparous)	1.00	0.84	(0.69	-	1.02)	0.078
2	1.00	0.82	(0.61	-	1.11)	0.195
3+	1.00	0.44	(0.28	-	0.71)	0.001
Assisted Reproductive Technology						
No	1.00	0.80	(0.68	-	0.93)	0.004
Yes	1.00	0.39	(0.16	-	0.96)	0.040
Delivery within same area						
No	1.00	0.77	(0.66	-	0.90)	0.004
Yes	1.00	0.47	(0.24	-	0.81)	0.080
Delivery year						
2018	1.00	0.72	(0.44	-	1.18)	0.194
2019	1.00	1.14	(0.73	-	1.77)	0.562
2020	1.00	0.73	(0.50	-	1.07)	0.110
2021	1.00	0.69	(0.48	-	0.98)	0.038
2022	1.00	0.72	(0.52	-	0.99)	0.042
2023	1.00	0.67	(0.47	-	0.96)	0.028

*Hysterectomy Massive transfusion(over 4 units), Death, Stillbirth, Sepsis

3.2. Subgroup analysis by Diagnosis-based PMM

Table 8 presents the association between the use of the MFICU and various maternal complications, including admission to the ICU, sepsis, massive transfusion, stillbirth, death, and hysterectomy. For admission to the ICU (N=275), the use of MFICU was not significantly associated with the risk of ICU admission, with an adjusted relative risk of 0.94 (95% CI: 0.73–1.21), suggesting no significant effect of MFICU use on ICU admissions. In the case of sepsis (N=240), MFICU use showed a significant reduction in the risk of sepsis, with an adjusted relative risk of 0.41 (95% CI: 0.30–0.58) indicating that the use of MFICU was associated with a lower risk of developing sepsis. For massive transfusion (N=356), there was no significant association between MFICU use and the need for massive transfusion. The adjusted relative risk was 1.04 (95% CI: 0.83–0.00), with a p-value of 0.718, indicating that MFICU use did not significantly impact the risk of massive transfusion.

Regarding stillbirth (N=23), the use of MFICU did not show a significant effect, with an adjusted relative risk of 0.47 (95% CI: 0.17–1.33) and a p-value of 0.154, suggesting no strong association between MFICU use and the risk of stillbirth. For death (N=10), the adjusted relative risk was 0.74 (95% CI: 0.19–2.92) with a p-value of 0.668, indicating that MFICU use was not significantly associated with maternal death in this study. Finally, for hysterectomy (N=57), there was a trend suggesting an increased risk of hysterectomy among women who used MFICU, with an adjusted relative risk of 1.70 (95% CI: 0.99–2.91) (Appendix 2).

Table 8 . Dependent subgroup Results of Postpartum Maternal Morbidity

Variables	Admission of ICU(N=275)			Sepsis(N=240)			Massive transfussion(N=356)		
	Exp(β)	95% CI	p-value	Exp(β)	95% CI	p-value	Exp(β)	95% CI	p-value
Using of Maternal-Fetal Intensive Care Unit									
No	1.00			1.00			1.00		
Yes	0.94	(0.73 - 1.21)	0.651	0.41	(0.30 - 0.58)	<0.001	1.04	(0.83 - 0.00)	0.718
Materal age									
<25	1.44	(0.91 - 2.27)	0.119	1.01	(0.59 - 1.75)	0.964	0.56	(0.20 - 1.58)	0.272
25-29	1.00			1.00			1.00		
30-34	1.00	(0.67 - 1.48)	0.991	0.88	(0.58 - 1.35)	0.557	1.35	(0.94 - 1.95)	0.102
35-39	1.35	(0.92 - 2.00)	0.127	1.00	(0.65 - 1.54)	0.986	1.84	(1.29 - 2.64)	0.001
40-	2.03	(1.05 - 3.92)	0.035	1.86	(0.89 - 3.92)	0.100	2.13	(1.40 - 3.23)	0.000
Type of insurance									
1Q	1.00			1.00			1.00		
2Q	1.35	(0.97 - 1.88)	0.079	0.76	(0.51 - 1.12)	0.165	1.17	(0.88 - 1.56)	0.268
3Q	1.12	(0.78 - 1.59)	0.549	0.85	(0.57 - 1.25)	0.403	1.04	(0.77 - 1.40)	0.792
4Q	1.33	(0.91 - 1.95)	0.141	0.72	(0.45 - 1.13)	0.153	1.03	(0.73 - 1.45)	0.867
5Q	1.05	(0.71 - 1.56)	0.810	0.82	(0.53 - 1.26)	0.358	1.00	(0.72 - 1.40)	0.987
Region									
Metropolitan city	1.00			1.00			1.00		
City	0.95	(0.51 - 1.77)	0.871	3.10	(1.52 - 6.30)	0.002	1.07	(0.64 - 1.79)	0.792
Obstetrics care vulnerable area	0.95	(0.56 - 1.59)	0.835	2.51	(1.31 - 4.81)	0.005	1.26	(0.80 - 1.97)	0.317
Region-Hospital									
Metropolitan (Seoul)	1.00			1.00			1.00		
City	0.84	(0.47 - 1.50)	0.550	2.41	(1.22 - 4.76)	0.011	1.52	(0.94 - 2.47)	0.089
Rural	0.43	(0.24 - 0.78)	0.006	0.35	(0.16 - 0.74)	0.007	1.09	(0.68 - 1.74)	0.728
Delivery institution									
Tertiary hospitals	1.00			1.00			1.00		
General hospital level(≥500 beds)	1.01	(0.80 - 1.28)	0.933	5.64	(4.06 - 7.84)	<.0001	0.49	(0.38 - 0.62)	<.0001
General hospital level(<500 beds)	0.31	(0.21 - 0.45)	<.0001	0.51	(0.33 - 0.81)	0.004	0.48	(0.36 - 0.63)	<.0001
Hospital level (100≤beds<500)	0.44	(0.27 - 0.71)	0.001	0.75	(0.38 - 1.47)	0.397	0.58	(0.40 - 0.83)	0.003
Mode of delivery									

Spontaneous vaginal delivery	1.00			1.00			1.00		
Cesarean section delivery	0.73	(0.56 - 0.94)	0.016	0.67	(0.48 - 0.93)	0.018	0.85	(0.68 - 1.06)	0.148
Status of multiple birth									
Singleton	1.00			1.00			1.00		
Multiple	0.64	(0.45 - 0.92)	0.015	1.20	(0.84 - 1.71)	0.325	1.03	(0.78 - 1.36)	0.814
Obstetric comorbidities									
0	1.00			1.00			1.00		
1 +	1.48	(1.06 - 2.06)	0.021	1.20	(0.72 - 1.98)	0.487	0.71	(0.47 - 1.06)	0.094
Anesthetic method									
General	2.81	(4.00 - 5.37)	<.0001	1.17	(1.85 - 1.34)	0.486	0.13	(0.10 - 0.18)	<.0001
Epidural	1.33	(1.01 - 1.74)	<.0001	1.01	(1.49 - 1.45)	0.945	0.20	(0.15 - 0.25)	<.0001
Spinal	1.24	(1.68 - 2.48)	<.0001	1.29	(0.85 - 1.94)	0.228	0.39	(0.30 - 0.51)	<.0001
else	1.00			1.00			1.00		
Admission Criteria									
Preterm labor before 37 weeks	1.00			1.00			1.00		
premature rupture of membranes	2.43	(1.93 - 3.06)	<.0001	0.73	(0.56 - 0.97)	0.028	4.41	(3.54 - 5.48)	<.0001
else	1.31	(1.11 - 1.55)	<0.001	1.57	(0.57 - 4.31)	0.379	0.38	(0.12 - 1.20)	0.098
Parity									
1 (Nulliparous)	1.00			1.00			1.00		
2	0.98	(0.84 - 1.14)	0.786	1.45	(1.05 - 2.01)	0.024	0.82	(0.66 - 1.01)	0.056
3+	1.00	(0.80 - 1.25)	0.973	1.16	(0.72 - 1.88)	0.539	0.97	(0.72 - 1.31)	0.866
Assisted Reproductive Technology									
No	1.00			1.00			1.00		
Yes	-	- - -	-	-	- - -	-	0.19	(0.03 - 1.37)	0.099
Delivery within same area									
No	1.00			1.00			1.00		
Yes	0.55	(0.20 - 1.50)	0.246	0.32	(0.04 - 2.31)	0.257	0.44	(0.14 - 1.40)	0.166
Delivery year									
2018	1.00			1.00			1.00		
2019	0.68	(0.46 - 1.01)	0.054	1.10	(0.59 - 2.04)	0.768	0.76	(0.55 - 1.05)	0.093
2020	0.79	(0.55 - 1.15)	0.223	1.04	(0.55 - 1.99)	0.901	0.97	(0.71 - 1.31)	0.826
2021	0.89	(0.63 - 1.26)	0.509	3.65	(2.11 - 6.30)	<.0001	0.59	(0.43 - 0.81)	0.001
2022	0.56	(0.39 - 0.82)	0.003	5.58	(3.24 - 9.61)	<.0001	0.50	(0.36 - 0.69)	<.0001
2023	0.61	(0.42 - 0.89)	0.010	4.65	(2.66 - 8.12)	<.0001	0.46	(0.33 - 0.64)	<.0001

4. Effects use of MFICU on neonatal health outcomes

Table 9 and 10 presents the association between the use of the MFICU and neonatal health outcomes, including miscarriage, neonatal health outcomes, Neonatal Intensive Care Unit (NICU) admission, and infant mortality.

The use of the MFICU was associated with a 9% reduction in the risk of miscarriage (Exp(β) = 0.91, 95% CI: 0.78-0.98) compared to not using the unit. For neonatal health outcomes (N=3910), the use of MFICU was associated with a higher risk of negative outcomes. The adjusted relative risk for MFICU use was 1.16 (95% CI: 1.09–1.24), with a p-value less than 0.05, indicating that the use of MFICU increased the risk of poor neonatal health outcomes compared to non-use.

However, for NICU admission (N=88), MFICU use did not show a significant association. The adjusted relative risk was 1.00 (95% CI: 0.63–1.60) suggesting no significant effect of MFICU use on the likelihood of NICU admission. Regarding infant mortality (N=20), MFICU use did not significantly affect the risk. The adjusted relative risk was 0.58 (95% CI: 0.19–1.81), indicating no significant relationship between MFICU use and infant mortality.

Table 9. The association between the use of the MFICU and Abortion

Variables	Miscarriage (N=1101)		
	Exp(β)	95% CI	P-value
Using of Maternal-Fetal Integrated Care Unit			
No	1.00		
Yes	0.91	(0.78 - 0.98)	0.025
Materal age (years)			
<25	0.89	(0.56 - 1.40)	0.613
25-29	1.00		
30-34	1.07	(0.86 - 1.32)	0.541
35-39	0.90	(0.72 - 1.12)	0.356
40-	1.01	(0.77 - 1.32)	0.947
Type of insurance			
1Q	1.00		
2Q	0.98	(0.80 - 1.21)	0.882
3Q	1.13	(0.91 - 1.40)	0.262
4Q	1.20	(0.95 - 1.51)	0.129
5Q	1.33	(1.06 - 1.67)	0.013
Region			
Metropolitan city	1.00		
City	1.21	(0.85 - 1.74)	0.289
Obstetrics care vulnerable area	1.06	(0.78 - 1.44)	0.716
Region-Hospital			
Metropolitan (Seoul)	1.00		
City	1.06	(0.75 - 1.49)	0.757
Rural	1.00	(0.73 - 1.38)	0.983
Delivery institution			
Tertiary hospitals	1.00		
General hospital level(≥500 beds)	1.56	(1.33 - 1.83)	<.0001
General hospital level(<500 beds)	1.03	(0.86 - 1.24)	0.713
Hospital level (100≤beds<500)	0.80	(0.62 - 1.02)	0.076
Mode of delivery			
Spontaneous vaginal delivery	1.00		
Cesarean section delivery	0.19	(0.15 - 0.23)	<.0001
Status of multiple birth			
Singleton	1.00		
Multiple	0.56	(0.44 - 0.72)	<.0001
Obstetric comorbidities			
0	1.00		
1			
2+	1.37	(1.15 - 1.63)	0.000
Anesthetic method			
General	1.96	(1.63 - 2.35)	<.0001
Spinal	0.42	(0.34 - 0.52)	<.0001
Epidural	0.19	(0.15 - 0.25)	<.0001

else	1.00				
Admission Criteria					
Preterm labor before 37 weeks	1.00				
premature rupture of membranes	1.49	(1.01	-	2.20)	0.043
else	7.87	(6.69	-	9.26)	<.0001
Parity					
1 (Nulliparous)	1.00				
2	1.07	(1.01	-	1.14)	0.019
3+	0.92	(0.84	-	1.01)	0.067
Assisted Reproductive Technology					
No	1.00				
Yes	1.46	(0.71	-	2.98)	0.302
Delivery within same area					
No	1.00				
Yes	0.85	(0.47	-	1.53)	0.590
Delivery year					
2018	1.00				
2019	1.04	(0.84	-	1.30)	0.697
2020	1.04	(0.83	-	1.31)	0.703
2021	1.04	(0.83	-	1.31)	0.708
2022	1.32	(1.05	-	1.66)	0.017
2023	1.22	(0.96	-	1.54)	0.104

Table 10. The association between the use of the MFICU and neonatal health outcomes

Variables	Neonatal Health Outcomes* (N=3910)			Neonatal Intensive Care Unit (NICU) (N=88)			Infant Mortality (N=20)		
	Exp(β)[a]	95% CI	P-value	Exp(β)[a]	95% CI	P-value	Exp(β)[a]	95% CI	P-value
Using of Maternal-Fetal Intensive Care Unit									
No	1.00						1.00		
Yes	1.16	(1.09 - 1.24)		1.00	(0.63 - 1.60)	0.994	0.58	(0.19 - 1.81)	0.351
Maternal age									
<25	0.98	(0.83 - 1.15)	0.772	0.54	(0.07 - 4.29)	0.560	0.00	- - -	-
25-29	1.00			1.00			1.00		
30-34	0.94	(0.87 - 1.01)	0.095	1.03	(0.49 - 2.17)	0.946	1.63	(0.19 - 14.14)	0.657
35-39	0.86	(0.79 - 0.93)	0.000	1.14	(0.54 - 2.42)	0.734	3.62	(0.46 - 28.69)	0.223
40-	0.78	(0.70 - 0.87)	<.0001	1.34	(0.55 - 3.28)	0.516	1.80	(0.16 - 20.74)	0.638
Type of insurance									
1Q	1.00			1.00			1.00		
2Q	1.01	(0.93 - 1.09)	0.801	1.97	(0.89 - 4.36)	0.093	1.38	(0.27 - 7.19)	0.700
3Q	1.11	(1.03 - 1.21)	0.008	1.69	(0.73 - 3.89)	0.218	1.06	(0.17 - 6.45)	0.949
4Q	1.09	(1.00 - 1.20)	0.047	2.53	(1.08 - 5.94)	0.033	2.44	(0.44 - 13.55)	0.308
5Q	1.19	(1.09 - 1.30)	0.000	2.50	(1.07 - 5.85)	0.034	3.40	(0.67 - 17.22)	0.139
Region									
Metropolitan city	1.00			1.00			1.00		
City	0.95	(0.83 - 1.10)	0.504	0.65	(0.19 - 2.22)	0.489	0.50	(0.03 - 8.78)	0.633
Obstetrics care vulnerable area	1.01	(0.90 - 1.14)	0.827	0.90	(0.34 - 2.42)	0.839	2.20	(0.25 - 19.07)	0.476
Region-Hospital									
Metropolitan (Seoul)	1.00			1.00			1.00		
City	0.98	(0.86 - 1.12)	0.780	0.91	(0.29 - 2.81)	0.870	1.43	(0.08 - 24.69)	0.806
Rural	0.91	(0.80 - 1.04)	0.158	0.77	(0.26 - 2.26)	0.636	0.49	(0.06 - 4.33)	0.523
Delivery institution									

Tertiary hospitals	1.00			1.00			1.00		
General hospital level(≥500 beds)	0.66	(0.62 - 0.70)	<.0001	0.76	(0.48 - 1.21)	0.246	1.18	(0.44 - 3.13)	0.746
General hospital level(<500 beds)	0.25	(0.23 - 0.27)	<.0001	0.13	(0.05 - 0.31)	<.0001	0.48	(0.11 - 2.11)	0.334
Hospital level (100≤beds<500)	0.16	(0.14 - 0.17)	<.0001	0.14	(0.04 - 0.47)	0.002	-	- - -	-
Mode of delivery									
Spontaneous vaginal delivery	1.00			1.00			1.00		
Cesarean section delivery	0.24	(0.23 - 0.26)	<.0001	0.56	(0.31 - 1.03)	0.061	0.16	(0.02 - 1.20)	0.075
Status of multiple birth									
Singleton	1.00			1.00			1.00		
Multiple	1.97	(1.83 - 2.13)	<.0001	1.04	(0.56 - 1.91)	0.907	1.23	(0.34 - 4.38)	0.752
Obstetric comorbidities									
0	1.00			1.00			1.00		
1 +	0.58	(0.51 - 0.64)	<.0001	1.33	(0.66 - 2.69)	0.426	1.83	(0.51 - 6.52)	0.351
Anesthetic method									
General	1.16	(0.79 - 0.93)	0.000	1.22	(2.32 - 1.56)	0.544	1.83	(6.74 - 2.01)	0.364
Epidural	1.10	(0.84 - 0.98)	0.017	1.60	(2.95 - 1.15)	0.132	1.83	(6.42 - 1.92)	0.346
Spinal	1.23	(0.75 - 0.89)	<.0001	1.05	(0.56 - 2.00)	0.871	1.45	(5.64 - 2.68)	0.590
else	1.00			1.00			1.00		
Admission Criteria									
Preterm labor before 37 weeks	1.00			1.00			1.00		
premature rupture of membranes	0.67	(0.64 - 0.71)	<.0001	1.99	(1.27 - 3.12)	0.003	5.92	(1.69 - 20.67)	0.005
else	0.86	(0.67 - 1.10)	0.231	1.40	(10.20 - 5.22)	0.741	2.17	(0.28 - 16.71)	0.456

Parity									
1 (Nulliparous)	1.00			1.00			1.00		
2	1.07	(1.01 - 1.14)	0.019	1.04	(1.73 - 1.61)	0.888	1.10	(0.35 - 3.48)	0.875
3+	0.92	(0.84 - 1.01)	0.067	1.41	(0.71 - 2.79)	0.323	2.55	(0.68 - 9.63)	0.167
Assisted Reproductive Technology									
No	1.00			1.00			1.00		
Yes	1.01	(0.75 - 1.36)	0.940	2.79	(0.66 - 11.70)	0.162	-	- - -	-
Delivery within same area									
No	1.00			1.00			1.00		
Yes	0.86	(0.67 - 1.10)	0.231	0.72	(0.10 - 5.22)	0.741	0.45	(0.27 - 17.58)	0.458
Delivery year									
2018	1.00			1.00			1.00		
2019	0.93	(0.85 - 1.01)	0.084	0.63	(0.28 - 1.40)	0.252	0.18	(0.02 - 1.59)	0.124
2020	0.93	(0.85 - 1.02)	0.118	0.59	(0.25 - 1.35)	0.211	1.12	(0.33 - 3.79)	0.850
2021	0.92	(0.85 - 1.00)	0.064	1.01	(0.50 - 2.04)	0.985	0.49	(0.11 - 2.11)	0.334
2022	0.98	(0.90 - 1.07)	0.609	1.32	(0.67 - 2.61)	0.429	0.44	(0.10 - 1.97)	0.282
2023	0.98	(0.89 - 1.07)	0.633	0.62	(0.27 - 1.40)	0.252	0.32	(0.06 - 1.74)	0.186

*Preterm birth and Low birth weight

5. Differences in Medical use and Expenditures according to the use of MFICU

Table 11 and Table 12 shows descriptive statistics on the length of stay and expenditures during the pregnancy period were compared between women who used the MFICU and those who did not.

For the length of stay, women who used the MFICU had a slightly shorter stay (5.16 ± 2.34 days) compared to those who did not use MFICU (5.25 ± 1.92 days).

Regarding total medical expenses, women who used the MFICU had higher medical expenses, with an average of 3,007,397 KRW (± 1,461,851 KRW), compared to 2,642,736 KRW (± 1,157,485 KRW) for women who did not use MFICU.

In terms of out-of-pocket expenses, MFICU users also had higher out-of-pocket costs, with an average of 173,581 KRW (± 142,983 KRW), while non-users had an average of 156,538 KRW (± 142,306 KRW).

Table 13 and Table 14 presents the association between the use of the MFICU and medical use, including the length of stay, total medical expenses, and out-of-pocket costs, was examined. Regarding length of stay, there was no significant difference between the MFICU users and non-users.

The adjusted relative risk for length of stay was 0.99 (95% CI: 0.98–1.01) with a p-value of 0.389, indicating no significant effect of MFICU use on the length of stay. For total medical expenses, MFICU use was associated with a statistically significant increase in expenses. The adjusted relative risk was 1.03 (95% CI: 1.01–1.04) with a p-value of <0.0001, indicating that MFICU use was associated with higher total medical expenses. In terms of out-of-pocket expenses, MFICU use did not significantly affect out-of-pocket costs. The adjusted relative risk was 0.99 (95% CI: 0.97–1.01) with a p-value of 0.389, suggesting no significant difference in out-of-pocket expenses between MFICU users and non-users.

Table 11. Descriptive statistics on length of stay during the pregnancy period

Variables	Length of stay during the pregnancy period (Days, Mean±SD)		
	Length of stay		
Using of Maternal-Fetal Intensive Care Unit			
No	5.25	±	1.92
Yes	5.16	±	2.34
Materal age			
<25	5.09	±	1.97
25-29	5.07	±	1.92
30-34	5.35	±	2.23
35-39	5.69	±	2.30
40-	5.74	±	1.14
Region			
Metropolitan city	5.19	±	2.17
City	5.24	±	2.00
Obstetrics care vulnerable area	5.30	±	1.73
Region-Hospital			
Metropolitan (Seoul)	5.00	±	1.95
City	5.39	±	2.34
Rural	5.40	±	1.85
Delivery institution			
Tertiary hospitals	5.04	±	2.13
General hospital level(≥500 beds)	5.38	±	2.27
General hospital level(<500 beds)	5.84	±	1.95
Hospital level (100≤beds<500)	5.33	±	1.77
Mode of delivery			
Spontaneous vaginal delivery	5.20	±	2.09
Cesarean section delivery	5.75	±	1.51
Status of multiple birth			
Singleton	4.74	±	2.06
Multiple	5.77	±	1.96
Obstetric comorbidities			
0	5.18	±	2.08
1 +	5.59	±	2.06
Anesthetic method			
General	5.71	±	2.19
Spinal	5.64	±	2.00
Epidural	4.97	±	1.90
else	4.18	±	1.88

Admission Criteria			
Preterm labor before 37 weeks	5.16	±	2.03
premature rupture of membranes	5.15	±	2.58
else	5.58	±	1.88
Parity			
1 (Nulliparous)	5.25	±	2.07
2	5.09	±	2.13
3+	5.02	±	2.01
Assisted Reproductive Technology			
No	5.22	±	2.08
Yes	5.08	±	1.64
Delivery within same area			
No	5.21	±	2.06
Yes	5.23	±	2.09
Delivery year			
2018	5.08	±	2.05
2019	5.11	±	2.16
2020	5.20	±	0.00
2021	4.98	±	2.01
2022	5.39	±	2.23
2023	5.50	±	1.96

Table 12. Descriptive statistics on expenditures during the pregnancy period

Variables	Expenditures during the pregnancy period (KRW, Mean±SD)					
	Total medical expenses			Out-of-pocket		
Using of Maternal-Fetal Intensive Care Unit						
No	2,642,736	±	1,157,485	156,538	±	142,306
Yes	3,007,397	±	1,461,851	173,581	±	142,983
Maternal age						
<25	2,539,828	±	1,063,817	143,356	±	149,829
25-29	2,628,531	±	1,166,390	149,836	±	131,713
30-34	2,944,189	±	1,292,934	175,632	±	141,996
35-39	3,187,447	±	1,907,798	207,432	±	174,048
40-	3,024,556	±	839,853	201,743	±	98,030
Region						
Metropolitan city	2,757,015	±	1,291,510	157,825	±	132,335
City	2,788,225	±	1,280,485	168,104	±	152,885
Obstetrics care vulnerable area	2,702,588	±	1,242,959	139,802	±	116,159
Region-Hospital						
Metropolitan (Seoul)	2,789,190	±	1,336,646	158,525	±	149,124
City	2,771,758	±	1,312,636	164,791	±	136,594
Rural	2,733,277	±	1,118,222	167,423	±	138,538
Delivery institution						
Tertiary hospitals	3,291,194	±	1,541,647	201,035	±	173,650
General hospital level(≥500 beds)	2,705,202	±	1,008,338	156,272	±	113,108
General hospital level(<500 beds)	2,613,010	±	728,683	166,422	±	126,499
Hospital level (100≤beds<500)	1,970,476	±	429,549	114,501	±	82,137
Mode of delivery						
Spontaneous vaginal delivery	2,767,328	±	1,286,917	160,786	±	142,733
Cesarean section delivery	2,898,294	±	1,217,967	217,979	±	132,704
Status of multiple birth						
Singleton	2,619,680	±	1,289,681	133,231	±	143,765
Multiple	2,947,643	±	1,256,848	196,621	±	133,778
Obstetric comorbidities						
0	2,730,539	±	1,248,230	159,309	±	142,903
1 +	3,188,950	±	1,554,154	195,768	±	137,137

Anesthetic method						
General	3,330,247	±	1,819,010	226,061	±	176,119
Spinal	2,940,787	±	1,092,237	188,078	±	121,678
Epidural	2,440,471	±	877,864	138,305	±	126,182
else	2,223,577	±	856,473	69,670	±	87,462
Admission Criteria						
Preterm labor before 37 weeks	2,674,233	±	1,185,296	153,896	±	138,192
premature rupture of membranes	2,991,041	±	1,345,882	181,036	±	162,094
else	3,138,311	±	1,356,594	199,109	±	140,622
Parity						
1 (Nulliparous)	2,753,958	±	1,231,444	162,924	±	139,025
2	2,848,022	±	1,541,170	159,928	±	159,978
3+	2,862,263	±	1,064,753	163,889	±	146,093
Assisted Reproductive Technology						
No	2,770,532	±	1,286,119	162,500	±	142,849
Yes	2,960,431	±	993,188	173,827	±	124,866
Delivery within same area						
No	2,901,840	±	1,393,610	178,189	±	165,711
Yes	2,690,858	±	1,206,202	152,899	±	125,602
Delivery year						
2018	2,292,996	±	1,137,049	129,577	±	135,301
2019	2,473,913	±	1,016,944	147,101	±	130,584
2020	2,661,198	±	1,220,998	160,417	±	153,447
2021	279,553	±	1,327,649	158,722	±	145,903
2022	3,032,393	±	1,319,039	180,957	±	109,870
2023	3,158,762	±	1,380,545	184,696	±	133,166

Table 13. Association between the use of the MFICU and Length of stay

Variables	Length of stay				
	Exp(β)[a]	95% CI			P-value
Using of Maternal-Fetal Intensive Care Unit					
No	1.00				
Yes	0.99	(0.98	-	1.01)	0.389
Materal age					
<25	0.98	(0.96	-	0.99)	0.008
25-29	1.00				
30-34	1.02	(0.98	-	1.03)	0.078
35-39	1.04	(1.02	-	1.07)	0.178
40-	1.07	(0.97	-	1.08)	0.259
Region					
Metropolitan city	1.00				
City	1.00	(0.99	-	1.00)	0.990
Obstetrics care vulnerable area	0.98	(0.99	-	0.98)	0.285
Region-Hospital					
Metropolitan (Seoul)	1.00				
City	1.08	(1.07	-	1.09)	<.0001
Rural	1.08	(1.07	-	1.09)	<.0001
Delivery institution					
Tertiary hospitals	1.00				
General hospital level(≥500 beds)	1.21	(1.11	-	1.17)	<.0001
General hospital level(<500 beds)	1.14	(1.11	-	1.17)	0.000
Hospital level (100≤beds<500)	1.17	(1.10	-	1.16)	<.0001
Mode of delivery					
Spontaneous vaginal delivery	1.00				
Cesarean section delivery	1.06	(1.03	-	1.10)	<.0001
Status of multiple birth					
Singleton	1.00				
Multiple	1.16	(1.14	-	1.16)	<.0001
Obstetric comorbidities					
0	1.00				
1 +	1.08	(1.06	-	1.10)	0.061
Anesthetic method					
General	1.16	(0.79	-	0.93)	0.000
Epidural	1.10	(0.84	-	0.98)	0.017
Spinal	1.23	(0.75	-	0.89)	<.0001
else	1.00				
Admission Criteria					
Preterm labor before 37 weeks	1.00				
premature rupture of membranes	1.04	(1.06	-	1.10)	0.007
else	0.89	(0.95	-	0.91)	0.001
Parity					
1 (Nulliparous)	1.00				
2	0.94	(0.93	-	0.96)	<.0001
3+	0.92	(0.84	-	1.01)	0.067
Assisted Reproductive Technology					
No	1.00				
Yes	0.96	(0.89	-	1.04)	0.354

Delivery within same area					
No	1.00				
Yes	1.00	(0.98	-	1.01)	0.652
Delivery year					
2018	1.00				
2019	0.99	(0.97	-	1.02)	0.559
2020	1.01	(0.98	-	1.02)	0.118
2021	0.96	(0.94	-	0.98)	0.000
2022	1.02	(0.99	-	1.04)	0.609
2023	1.02	(1.00	-	1.04)	0.086

Table 14. Association between the use of the MFICU and medical use.

Variables	Total medical expenses			Out-of-pocket		
	Exp(β)	95% CI	P-value	Exp(β)	95% CI	P-value
Using of Maternal-Fetal Intensive Care Unit						
No	1.00			1.00		
Yes	1.03	(1.01 - 1.04)	<.0001	0.99	(0.97 - 1.01)	0.389
Maternal age						
<25	0.98	(0.97 - 1.00)	0.023	0.94	(0.91 - 0.73)	<.0001
25-29	1.00			1.00		
30-34	1.07	(1.05 - 1.09)	<.0001	1.08	(1.05 - 1.11)	<.0001
35-39	1.09	(1.06 - 1.12)	<.0001	1.13	(1.08 - 1.18)	<.0001
40-	1.16	(1.00 - 1.35)	0.046	1.36	(1.04 - 1.78)	0.024
Region						
Metropolitan city	1.00			1.00		
City	1.02	(0.97 - 0.99)	0.008	0.98	(0.96 - 1.01)	0.267
Obstetrics care vulnerable area	0.97	(0.97 - 0.97)	0.093	0.79	(0.79 - 0.85)	<.0001
Region-Hospital						
Metropolitan (Seoul)	1.00			1.00		
City	1.00	(0.99 - 1.01)	0.808	1.05	(1.03 - 1.08)	<.0001
Rural	0.99	(0.98 - 1.01)	0.390	1.09	(1.06 - 1.12)	<.0001
Delivery institution						
Tertiary hospitals	1.00			1.00		
General hospital level(≥500 beds)	0.85	(0.83 - 0.86)	<.0001	0.84	(0.81 - 0.86)	<.0001
General hospital level(<500 beds)	0.82	(0.80 - 0.84)	<.0001	0.87	(0.84 - 0.91)	<.0001
Hospital level (100≤beds<500)	0.65	(0.63 - 0.67)	<.0001	0.72	(0.69 - 0.76)	<.0001
Mode of delivery						
Spontaneous vaginal delivery	1.00			1.00		
Cesarean section delivery	1.09	(1.06 - 1.12)	<.0001	1.38	(1.31 - 1.46)	<.0001
Status of multiple birth						
Singleton	1.00			1.00		
Multiple	1.09	(1.08 - 1.10)	<.0001	1.45	(1.42 - 1.46)	<.0001
Obstetric comorbidities						
0	1.00			1.00		
1 +	1.08	(1.06 - 1.10)	<.0001	1.16	(1.13 - 1.21)	<.0001
Anesthetic method						
General	1.19	(1.17 - 1.21)	<.0001	1.44	(1.40 - 1.49)	<.0001
Epidural	1.06	(1.04 - 1.08)	<.0001	1.18	(1.15 - 1.22)	<.0001
Spinal	0.98	(0.96 - 1.00)	0.025	0.54	(0.52 - 0.56)	<.0001
else	1.00			1.00		

Admission Criteria										
Preterm labor before 37 weeks	1.00					1.00				
premature rupture of membranes	0.97	(0.96	-	0.99)	0.004	0.93	(0.90	-	0.96)	<.0001
else	0.96	(0.94	-	0.98)	0.000	0.80	(0.77	-	0.84)	<.0001
Parity										
1 (Nulliparous)	1.00					1.00				
2	0.96	(0.95	-	0.98)	<.0001	0.92	(0.92	-	0.92)	<.0001
3+	0.99	(0.98	-	1.04)	0.427	0.90	(0.90	-	0.90)	<.0001
Assisted Reproductive Technology										
No	1.00					1.00				
Yes	0.99	(0.92	-	1.07)	0.843	0.96	(0.83	-	1.11)	0.549
Delivery within same area										
No	1.00					1.00				
Yes	0.97	(0.96	-	0.98)	<.0001	0.92	(0.90	-	0.94)	<.0001
Delivery year										
2018	1.00					1.00				
2019	1.07	(1.05	-	1.09)	<.0001	1.14	(1.10	-	1.18)	<.0001
2020	1.15	(1.13	-	1.17)	<.0001	1.27	(1.22	-	1.32)	<.0001
2021	1.19	(1.17	-	1.22)	<.0001	1.22	(1.17	-	1.26)	<.0001
2022	1.26	(1.23	-	1.29)	<.0001	1.38	(1.32	-	1.43)	<.0001
2023	1.31	(1.28	-	1.34)	<.0001	1.42	(1.36	-	1.48)	<.0001

V. Discussion

1. Discussion of the study method

This study was conducted to evaluate the effect of Maternal-Fetal Intensive Care Unit (MFICU) admission on high-risk pregnant women who meet the MFICU admission criteria. The results showed that mothers admitted to the MFICU, equipped with multidisciplinary care and effective equipment, had a lower risk of postpartum maternal morbidity. The methodology used in this study has several noteworthy features.

First, the NHIS Cohort database, which contains health information on mothers, is a large national dataset. The study subjects were mothers whose claims were submitted for MFICU-related fees after the introduction of these charges in October 2017. The MFICU group consisted of mothers for whom intensive care unit admission fees were claimed. To minimize confounding variables, the control group was selected from mothers who met the same admission criteria but did not have hospitalization fees billed, and propensity score matching was used to select them. Variables such as maternal age, year of delivery, pregnancy complications, criteria for intensive care unit admission, use of assisted reproductive technology, and income were exactly matched, while hospital location, anesthesia method, and mode of delivery were matched based on adjacent propensity scores. Propensity score matching is a statistical technique used to match subjects with similar characteristics.

Second, this study employed a Generalized Estimating Equation (GEE) model with a logit link and an autoregressive correlation structure to account for repeated measures. Unlike many previous studies, where data on parity was collected only once to determine whether a woman was nulliparous, this study tracked women's parity over a 12-year period and examined whether they had multiple deliveries. This approach allowed for the estimation of correlations between a woman's first and subsequent births, as well as the relationship between parity and individual characteristics.

The strength of this study is that it comprehensively analyzed the effect and performance of MFICU using real-world data. Most of the findings presented in previous literature were derived from subjects who did not meet the MFICU admission criteria or were based on limited observations. Therefore, the results of this study provide valuable insights into the effectiveness of the Maternal-Fetal Integrated Care Center.

There are some limitations in this study. First, to evaluate postpartum maternal morbidity (PMM), we used administrative data (ICD-10), which does not include important clinical data such as disease severity, and thus we were unable to define the severity of the diseases. Likewise, diagnostic codes may not always accurately represent the patient's true disease status. Second, we were unable to adjust for potential confounders such as maternal education level, body mass index, and behavioral risk factors (smoking or alcohol consumption), as these variables were not included in the data. Third, the data did not include the exact date of pregnancy commencement, so we could not calculate the exact pregnancy duration. However, because the data includes accurate birth dates, we were able to estimate the first pregnancy period by calculating the gestation period.

2. Discussion of the results

In our analysis, we found that high-risk pregnant women who met the admission criteria for the MFICU and were admitted had a significantly lower likelihood of experiencing postpartum maternal morbidity. Specifically, we observed a trend toward a reduction in ICU admissions, sepsis, stillbirth, and death, with the exception of massive transfusions and hysterectomy. However, aside from sepsis, the differences were not statistically significant, and thus caution is needed in interpreting these findings.

In this study, we also found that the use of the MFICU was associated with a reduced likelihood of postpartum maternal morbidity and was linked to better neonatal health outcomes. Notably, in cases where the mother was admitted to the intensive care unit, there was a significant increase in the number of low birth weight and preterm infants. This is likely due to the fact that most ICU admissions were related to preterm labor, and future studies should explore whether ICU admission influenced the gestational age of the mother.

Additionally, while there was a trend toward a reduced likelihood of infant mortality, the incidence was very low, so it is uncertain whether this represents a meaningful difference, and further research is needed to confirm this. In terms of healthcare utilization, women admitted to the MFICU had higher total medical expenses and out-of-pocket costs. The total medical expenses for MFICU users were 3,007,397 KRW (± 1,461,851 KRW), which was significantly higher than the 2,642,736 KRW for non-users. Additionally, out-of-pocket costs for MFICU users were 173,581 KRW (± 142,983), compared to 156,538 KRW for non-users. However, statistical analysis revealed that admission to the MFICU did not have a significant effect on healthcare costs.

As highlighted in previous studies, South Korea is facing a decline in birth rates due to increasing mExp(β)iage age and lower mExp(β)iage rates[60-62]. Concerns about pregnancy complications and maternal health conditions, including severe maternal morbidity, have grown with the increase in maternal age[60].

Childbirth and maternity care are critical healthcare areas that require appropriate government intervention[63]. The infrastructure for treating high-risk mothers and newborns constitutes a high-cost, low-profit sector, and there is a lack of voluntary private investment. Therefore, proactive government support is essential. In Korea, the Ministry of Health and Welfare aims to support healthy childbirth by establishing an integrated and systematic maternity care system for high-risk mothers and newborns[19]. This includes the introduction of relevant compensation fees to fund the development of specialized personnel, facilities, and equipment. Advanced economies are increasingly strengthening and establishing integrated maternity care systems and support mechanisms[64]. Japan, for example, has been actively promoting integrated maternity center projects since 1996, operating as a comprehensive care system. This approach has helped Japan maintain a low infant mortality rate of 1.9 deaths per 1,000 births, compared to the OECD average of 4.2 deaths per 1,000 births[65].

According to previous studies, efficient care delivery and timely intervention for complications have the potential to reduce maternal mortality[66]. In developed countries, maternal mortality rates have steadily decreased, and such cases are becoming increasingly rare. Consequently, there is a growing focus on severe obstetric morbidity, particularly cases classified as near misses for maternal mortality[67].According to WHO guidelines, severe complications such as massive transfusion and hysterectomy are considered critical indicators of maternal death and are classified as near misses[68]. Furthermore, we expanded our monitoring to include patients requiring ICU admission, as this is suitable for identifying potentially life-threatening complications that could progress to an almost fatal state[68]. Previous studies have suggested that providing intermediate care between ICU and general wards, which includes obstetric and anesthesia services, has advantages in overall treatment accessibility[69].

In conclusion, this study emphasizes that MFICU use significantly benefits both maternal and neonatal health. The MFICU plays a crucial role in reducing postpartum maternal morbidity and improving neonatal health outcomes. However, since some of the neonatal health results were not statistically significant, further studies are needed to clarify whether these differences are meaningful. While MFICU use did not significantly impact healthcare costs, it is evident that MFICU's role in the management of high-risk pregnancies is crucial.

3. Policy implication

The findings from this study emphasize the critical need for continued policy efforts aimed at improving maternal and neonatal health outcomes, particularly for high-risk pregnancies. The importance of specialized care systems, such as the Maternal-Fetal Integrated Care Unit (MFICU), cannot be overstated. Such systems provide comprehensive, specialized treatment for high-risk mothers and newborns, significantly improving health outcomes. However, as high-risk pregnancies continue to rise, there is a growing need for ongoing investment in and expansion of such healthcare systems to ensure that these services remain accessible and effective.

Given the challenges posed by declining birth rates and the aging maternal population in South Korea, policy approaches need to focus not only on encouraging childbirth but also on establishing robust systems for managing high-risk pregnancies and ensuring the health of both mothers and infants. For instance, policies like postpartum compensation for high-risk deliveries are critical in supporting healthcare infrastructure and ensuring that medical losses incurred during this process are mitigated. These measures help maintain the necessary medical infrastructure, especially considering the decline in demand for certain healthcare services, such as obstetric and pediatric care. The government must continue to provide efficient support for human resources and facilities to strengthen the healthcare system through appropriate compensation policies.

Furthermore, the shortage of obstetricians and specialized medical personnel remains a significant challenge. The growing problem of maternal bottlenecks, where pregnant women face difficulty accessing appropriate care and are shuffled between emergency departments, points to the urgent need for better allocation of resources. As the number of high-risk pregnancies rises, the demand for specialized facilities and personnel capable of providing the necessary care will only increase. To address this, the government must invest in medical training for obstetricians, offer incentives for working in underserved areas, and provide financial support to improve the capacity of delivery facilities.

Additionally, the government's efforts to expand postpartum care and implement policies that encourage the development of specialized maternity care centers should be prioritized. Countries with advanced economies, such as Japan, have effectively implemented integrated maternity care systems, which has helped reduce infant mortality and improve maternal health. South Korea can learn from such models and integrate similar approaches to improve healthcare accessibility and quality for high-risk pregnancies.

In conclusion, integrated and systematic care systems for high-risk pregnancies are crucial to improving maternal and neonatal health outcomes in South Korea. However, to meet the growing demand, the government must increase its investment in healthcare infrastructure and specialized personnel, and implement policies that ensure sustainable and efficient support for high-risk maternal and neonatal care.

VI. Conclusion

In conclusion, the utilization of the MFICU has demonstrated a crucial role in reducing postpartum maternal morbidity for high-risk pregnant women. Adopting a multidisciplinary approach, conducting thorough risk assessments before conception, and ensuring early admission for delivery are key components of contemporary obstetric care strategies[70]. These measures are vital for addressing the evolving sociodemographic trends and improving peripartum outcomes. Additionally, the expansion of specialized care systems and continuous policy support for high-risk pregnancies are essential.

Ensuring accessibility to healthcare and providing timely interventions are critical to improving both maternal and neonatal health outcomes. Therefore, effectively managing high-risk mothers requires the efficient utilization of units like the MFICU and continuous improvements in healthcare policies to enhance the quality of obstetric care. This approach is essential in addressing the increase in high-risk pregnancies and will form a significant foundation for creating a healthier childbirth environment in the future.

Abbreviations

MFICU –Maternal Fetal Intensive Care Unit

ICU – Intensive Care Unit

PMM - Postpartum Maternal Morbidity

NHIS – National Health Insurance Service

ICD-10 - International Classification of Diseases 10th revision

GEE – Generalized Estimating Equation

CI –Confidence Interval

GLM- Generalized Linear Model

Q – Quintile

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Appendix

Appendix 1. General characteristics of study population before and after propensity score matching

Variables	Before matching					After matching				
	MFICU		Control		SMD	MFICU		Control		SMD
	N	%	N	%		N	%	N	%	
Exact matching										
Materal age					0.183					0.007
<25	146	1.7	984	3.1		138	1.7	242	1.7	
25-29	981	11.7	4,780	15.0		932	11.7	1,636	11.7	
30-34	3,435	41.0	13,387	42.1		3,266	41.0	5,731	41.0	
35-39	2,920	34.9	10,291	32.3		2,884	36.2	5,061	36.2	
40-	781	9.3	2,507	7.9		742	9.3	1,302	9.3	
Delivery year					0.065					0.048
2018	1,122	13.4	4,799	15.1		1,080	13.6	1,896	13.6	
2019	1,160	13.9	5,504	17.3		1,116	14.0	1,959	14.0	
2020	1,399	16.7	5,099	16.0		1,346	16.9	2,363	16.9	
2021	1,584	18.9	6,185	19.4		1,524	19.1	2,674	19.1	
2022	1,751	20.9	5,511	17.3		1,683	21.1	2,954	21.1	
2023	1,259	15.0	5,315	16.7		1,212	15.2	2,126	15.2	
Admission Criteria					0.017					0.012
Preterm labor before 37 weeks	4,709	56.2	19,115	60.0		4,475	56.2	7,852	56.2	
premature rupture of membranes	1,102	13.2	3,086	9.7		1,059	13.3	1,837	13.2	
else	2,566	30.6	9,634	30.3		2,428	30.5	4,241	30.4	
Propensity score matching										
Income					0.063					0.020
1Q	1,257	15.0	4,637	14.6		1,223	15.4	2,146	15.4	
2Q	2,467	29.5	8,944	28.1		2,321	29.2	4,073	29.2	
3Q	2,089	24.9	8,155	25.6		1,979	24.9	3,472	24.9	
4Q	1,285	15.3	5,078	16.0		1,245	15.6	2,185	15.6	
5Q	1,278	15.3	5,022	15.8		1,194	15.0	2,096	15.0	
Mode of delivery					0.145					0.013

Spontaneous vaginal delivery	6,377	76.1	21,696	68.2		6,059	76.1	10,619	76.0	
Cesarean section delivery	2,000	23.9	10,139	31.8		1,903	23.9	3,353	24.0	
Region					0.286					0.007
Metropolitan city	4,669	55.7	17,767	55.8		4,276	53.7	7,503	53.7	
City	2,161	25.8	5,335	16.8		3,408	42.8	5,980	42.8	
Obstetrics care vulnerable area	1,547	18.5	8,733	27.4		279	3.5	489	3.5	
Obstetric comorbidities					0.258					0.031
0	7,903	94.3	30,384	95.4		7,512	94.4	13,183	94.4	
1 +	474	5.7	1,451	5.1		450	5.7	789	5.7	
Delivery institution					0.056					0.019
Tertiary hospitals	3,510	41.9	7,554	23.7		3,323	41.7	5,776	41.3	
General hospital level(≥500 beds)	3,192	38.1	7,215	22.7		3,053	38.4	5,413	38.8	
General hospital level(<500 beds)	1,238	14.8	11,675	36.7		1,170	14.7	1,998	14.3	
Hospital level (100≤beds<500)	437	5.2	5,391	16.9		416	5.2	785	5.6	
	8,377	100	31,835	100		7,962	100	13,972	100	

Appendix 2. Results of association between Using of Maternal-Fetal Integrated Care Unit and Neonatal Health Outcomes

Variables	Stillbirth(N=23)					Death(N=10)					Hysterectomy(N=57)				
	Exp(β)[a]	95% CI			p-value	Exp(β)[a]	95% CI			p-value	Exp(β)[a]	95% CI			p-value
Using of Maternal-Fetal Intensive Care Unit															
No	1.00					1.00					1.00				
Yes	0.47	(0.17	-	1.33)	0.154	0.74	(0.19	-	2.92)	0.668	1.70	(0.99	-	2.91)	0.054
Maternal age															
<25	0.53	(0.05	-	6.04)	0.431	-	-	-	-	-	1.66	(0.17	-	16.48)	0.667
25-29	1.00					1.00					1.00				
30-34	1.26	(0.27	-	5.90)	0.772	1.03	(0.10	-	10.00)	0.982	1.55	(0.45	-	5.35)	0.484
35-39	1.60	(0.35	-	7.41)	0.545	3.14	(0.39	-	25.44)	0.285	2.92	(0.88	-	9.65)	0.080
40-	2.65	(0.24	-	29.77)	0.607	-	-	-	-	-	2.50	(0.68	-	9.21)	0.168
Type of insurance															
1Q	1.00					1.00					1.00				
2Q	1.00	(0.32	-	3.10)	0.996	1.98	(0.22	-	17.86)	0.544	0.94	(0.41	-	2.14)	0.888
3Q	0.86	(0.25	-	2.91)	0.811	1.80	(0.18	-	17.67)	0.612	1.54	(0.69	-	3.43)	0.295
4Q	0.73	(0.17	-	3.13)	0.670	2.17	(0.19	-	24.43)	0.529	2.68	(1.20	-	5.99)	0.016
5Q	0.69	(0.16	-	2.98)	0.623	3.84	(0.42	-	35.57)	0.236	1.61	(0.69	-	3.73)	0.271

Region															
Metropolitan city	1.00					1.00					1.00				
City	6.69	(1.09	-	40.98)	0.040	1.89	(0.07	-	52.51)	0.707	1.16	(0.33	-	4.13)	0.814
Obstetrics care vulnerable area	4.38	(1.14	-	16.76)	0.031	0.62	(0.04	-	9.64)	0.734	1.43	(0.49	-	4.19)	0.516
Region-Hospital															
Metropolitan (Seoul)	1.00					1.00					1.00				
City	0.17	(0.03	-	1.01)	0.052	0.73	(0.03	-	20.79)	0.856	1.09	(0.34	-	3.52)	0.888
Rural	0.29	(0.06	-	1.38)	0.121	3.40	(0.22	-	52.12)	0.379	0.84	(0.27	-	2.66)	0.771
Delivery institution															
Tertiary hospitals	1.00					1.00					1.00				
General hospital level(≥500 beds)	1.35	(0.56	-	3.25)	0.506	1.62	(0.50	-	5.31)	0.423	0.64	(0.38	-	1.07)	0.088
General hospital level(<500 beds)	0.43	(0.12	-	1.54)	0.196	0.85	(0.14	-	5.32)	0.863	0.05	(0.01	-	0.35)	0.003
Hospital level (100≤beds<500)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mode of delivery															
Spontaneous vaginal delivery	1.00					1.00					1.00				
Cesarean section delivery	-	-	-	-	-	-	-	-	-	-	0.74	(0.42	-	1.32)	0.314
Status of multiple birth															
Singleton	1.00					1.00					1.00				
Multiple	1.19	(0.38	-	3.69)	0.761	1.05	(0.22	-	4.95)	0.949	0.21	(0.07	-	0.69)	0.010
Obstetric comorbidities															

0	1.00					1.00					1.00				
1 +	-	-	-	-	-	1.58	(0.34	-	7.39)	0.560	0.45	(0.14	-	1.45)	0.179
Anesthetic method															
General	2.84	(0.79	-	10.30)	0.111	0.28	(0.06	-	1.27)	0.100	-	-	-	-	-
Epidural	0.39	(0.06	-	2.42)	0.315	0.41	(0.11	-	1.55)	0.187	0.07	(0.03	-	0.15)	<.0001
Spinal	1.20	(0.28	-	5.21)	0.805	0.20	(0.03	-	1.24)	0.085	0.08	(0.03	-	0.21)	<.0001
else	1.00					1.00					1.00				
Admission Criteria															
Preterm labor before 37 weeks	1.00					1.00					1.00				
premature rupture of membranes	3.34	(1.42	-	7.84)	0.006	6.24	(1.36	-	28.57)	0.018	2.27	(1.35	-	3.81)	0.002
else	-	-	-	-	-	2.95	(0.37	-	23.44)	0.307	-	-	-	-	-
Parity															
1 (Nulliparous)	1.00					1.00					1.00				
2	0.57	(0.24	-	1.36)	0.203	0.84	(0.25	-	2.85)	0.786	0.28	(0.16	-	0.49)	<.0001
3+	0.68	(0.17	-	2.67)	0.582	1.01	(0.18	-	5.63)	0.991	1.16	(0.63	-	2.11)	0.636
Assisted Reproductive Technology															
No	1.00					1.00					1.00				
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Delivery within same area															
No	1.00					1.00					1.00				

Yes	0.00	-	-	-	-	3.35	(0.40	-	27.96)	0.263	0.58	(0.08	-	4.44)	0.603
Delivery year															
2018	1.00					1.00					1.00				
2019	1.56	(0.26	-	9.46)	0.626	0.31	(0.03	-	3.03)	0.315	0.48	(0.23	-	0.98)	0.045
2020	7.43	(1.60	-	34.41)	0.010	1.22	(0.26	-	5.66)	0.801	0.30	(0.14	-	0.67)	0.003
2021	3.22	(0.61	-	17.10)	0.170	0.80	(0.15	-	4.15)	0.791	0.38	(0.19	-	0.75)	0.005

Appendix method
- Statistical analysis for Difference in difference analysis

$$g(E[Yit])=\beta 0 + \beta 1(Timeit) + \beta 2(Caseit) + \beta 3(Interventionit) + \beta 4(Caseit\times Interventionit)+Xit$$

g: link function

E: Expectation

Y: Dependent variables

i: high-risk pregnancy delivery cases (i=1, 2, 3 …, i)

t: time period

Time: time variable before and after the newly operating of the MFICU in hospital (continuous variable in units of Quarter)

Treat: dummy variable that assigns 1 to pregnant woman admitted to a newly operated MFICU after 2 years later a established admission fee (pregnant women who admitted to a hospital newly operating on hospitalist wards, treat=1: case group, treat =0: control group)

Intervention: dummy variable that is assigned 1 if time is after the first time charged the admission fee, and depends on the hospitals (intervention=1: The point in time when the admission fee charges were first billed at the hospital, intervention=0: before 2 years when first filled time) -

Xij: covariates (maternal age, residential area, region of hospital, delivery institution, delivery within same area, income level, mode of delivery, status of multiple birth, Obstetrics comorbidities, whether assisted reproductive technology, parity, admission critieria, anesthetic method, delivery year)

Additionally, to evaluate changes in health outcomes in hospitals that newly introduced the high-risk maternity care fee after its implementation, relative to the control group, a difference-in-differences (DID) analytical approach was applied. The DID method is commonly used to assess policy effects in the healthcare sector and has been widely adopted in prior similar studies. Accordingly, the effect of the establishment of the intensive care unit was assessed by comparing the pre- and post-implementation differences between the case and control groups using the DID method. Since the related MFICU fee was introduced in hospitals in October 2017, a 2-year washout period was applied, and the hospitals introduced in 2019 were selected as the target group. To find an appropriate control hospital, matching was conducted based on the hospital's delivery volume, hospital region, cesarean section rate relative to the number of deliveries, and hospital type for the two years prior to the opening (from January 2017 to December 31, 2018), using the exact matching.

Appendix 3. General characteristics of the study population for the Difference in difference analysis

Variables	Matched Participants, No.(%)				
		Postpartum Maternal Morbidity*			
	Total	No		Yes	
		N	%	N	%
Total (*N*=3,083)	3,083	2,979	96.6	104	3.4
MFICU Hospital (Treat)					
Control	1,782	1,735	97.4	47	2.6
Treat	1,301	1,268	97.5	33	2.5
Post-Implementation Period (Post)					
Pre-imprementation	1,054	1,015	96.3	39	3.7
Post-imprementation	2,029	1,964	96.8	65	3.2
Maternal age (years)					
<30	512	501	97.9	11	2.1
30-34	1,256	1,222	97.3	34	2.7
35-39	1,084	1,037	95.7	47	4.3
40-	231	219	94.8	12	5.2
Region-Hospital					
City	2,495	2,426	97.2	69	2.8
Rural	588	553	97.7	35	2.3
Delivery institution					
General hospital level(≥500beds)	2,178	2,081	95.5	97	4.5
General hospital level(<500beds)	774	768	99.2	6	0.8
Hospital level(100≤beds<500)	131	130	99.2	1	0.8
Status of multiple birth					
Singleton	1,675	1606	95.9	69	4.1
Multiple	1,408	1373	97.5	35	2.5
Mode of delivery					
Spontaneous vaginal delivery	5,177	4987	96.3	190	3.7
Cesarean section delivery	2,083	2049	98.4	34	1.6
Obstetric comorbidities					
0	2,851	2760	96.8	91	3.2
1 +	232	219	94.4	13	5.6
Anesthetic method					
General	444	392	88.3	52	11.7
Epidural	685	676	98.7	9	1.3
Spinal	577	570	98.8	7	1.2
else	1,377	1,341	97.4	36	2.6
Admission Criteria					

Preterm labor before 37 weeks	2,370	2316	97.7	54	2.3
premature rupture of membranes	293	286	97.6	7	2.4
else	182	162	89.0	20	11.0
Parity					
1	5,190	5,137	99.0	53	1.0
2 +	6,772	6,534	96.5	238	3.5
Delivery within same area					
No	1,563	1,513	96.8	50	3.2
Yes	1,520	1,466	96.4	54	3.6
Delivery year					
2018	571	546	95.6	25	4.4
2019	679	654	96.3	25	3.7
2020	780	749	96.0	31	4.0
2021	737	723	98.1	14	1.9
2022	263	255	97.0	8	3.0
2023	53	52	98.1	1	1.9

*Hysterectomy Massive transfusion(over 4 units), Death, Stillbirth, Sepsis

Appendix 4. Distribution of study population by time based on before and after intervention

Variables	Total		MFICU		Control	
	N	%	N	%	N	%
Time before and after intervention (Quarters)						
-8	24	0.78	17	0.95	7	0.54
-7	83	2.69	50	2.81	33	2.54
-6	86	2.79	41	2.30	45	3.46
-5	108	3.50	62	3.48	46	3.54
-4	221	7.17	169	9.48	52	4.00
-3	235	7.62	162	9.09	73	5.61
-2	163	5.29	94	5.27	69	5.30
-1	134	4.35	86	4.83	48	3.69
0	286	9.28	194	10.89	92	7.07
1	275	8.92	161	9.03	114	8.76
2	166	5.38	72	4.04	94	7.23
3	178	5.77	91	5.11	87	6.69
4	285	9.24	161	9.03	124	9.53
5	304	9.86	156	8.75	148	11.38
6	176	5.71	76	4.26	100	7.69
7	181	5.87	83	4.66	98	7.53
8	178	5.77	107	6.00	71	5.46
	3,083	100	1,782	33.9	1,301	66.1

Appendix 5. Difference-in-Differences Estimates of Postpartum Maternal Morbidity Before and After MFICU Established

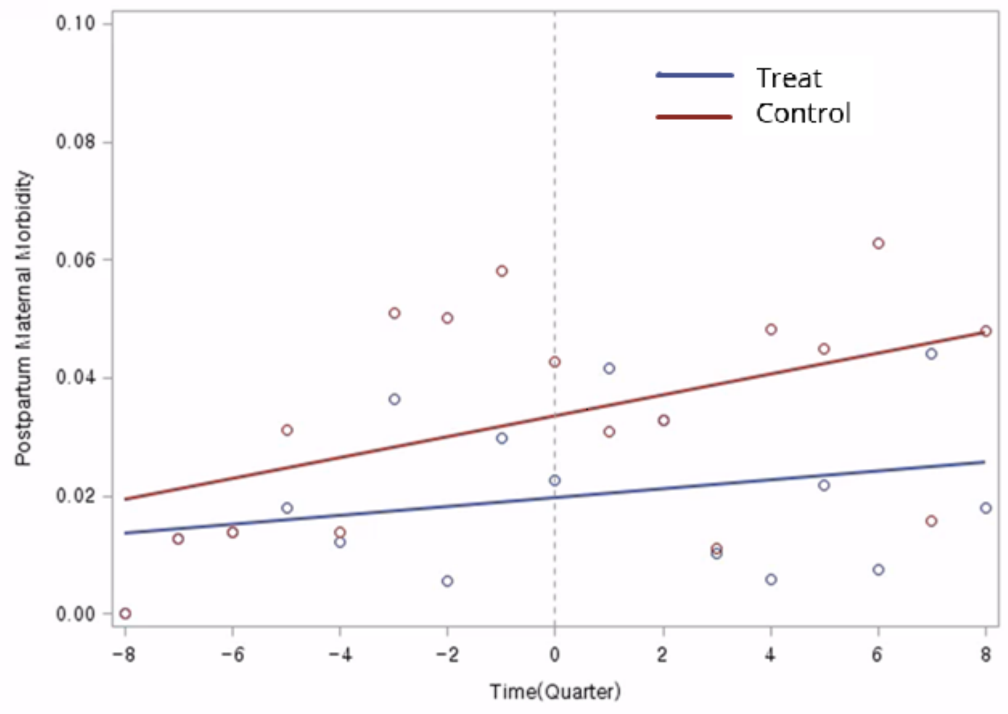
Variables	Postpartum Maternal Morbidity*			
	Exp(β)[a]	95% CI		
MFICU Hospital (Treat)				
Control	1.00			
Treat	0.97	(0.49	-	2.07)
Post-Implementation Period (Post)				
Pre-imprementation	1.00			
Post-imprementation	1.05	(1.02	-	2.70)
Treatment × Post (DID Estimate)	0.94	(0.49	-	0.99)
Materal age (years)				
<30	1.00			
30-34	1.05	(0.44	-	2.54)
35-39	1.89	(0.81	-	4.44)
40-	1.76	(0.51	-	6.10)
Region-Hospital				
City	1.00			
Rural	2.08	(1.28	-	3.37)
Delivery institution				
General hospital level(≥500 beds)	1.00			
General hospital level(<500 beds)	0.85	(0.29	-	2.46)
Hospital level (100≤beds<500)	0.43	(0.14	-	1.32)
Status of multiple birth				
Singleton	1.00			
Multiple	0.62	(0.44	-	0.89)
Mode of delivery				
Spontaneous vaginal delivery	1.00			
Cesarean section delivery	1.19	(1.11	-	1.37)
Obstetric comorbidities				
0	1.00			
1 +	1.09	(0.47	-	2.48)
Anesthetic method				
General	5.16	(1.79	-	14.85)
Epidural	0.64	(0.23	-	1.80)
Spinal	0.64	(0.20	-	2.05)
else	1.00			
Admission Criteria				
Preterm labor before 37 weeks	0.27	(0.10	-	0.70)

premature rupture of membranes	0.31	(0.10	-	1.01)
Cervical incompetence	1.06	(0.54	-	2.09)
else	1.00			
Parity				
1	1.00			
2 +	1.57	(0.99	-	2.52)
Delivery within same area				
No	1.00			
Yes	0.95	(0.64	-	1.40)
Delivery year				
2018	1.00			
2019	0.66	(0.25	-	1.78)
2020	0.75	(0.28	-	2.03)
2021	0.49	(0.14	-	1.66)
2022	0.72	(0.17	-	3.16)
2023	0.49	(0.11	-	2.19)

*Hysterectomy Massive transfusion(over 4 units), Admission of ICU, Stillbirth, Sepsis,Death

**The interaction term "Treatment × Post" represents the difference-in-differences (DID) estimate. MFICU Hospital indicates whether the hospital had an MFICU installed. Post-Implementation Period refers to observations after MFICU introduction.

Appendix 6. Trends in Postpartum maternal morbidity according to establishment of the MFICU



고위험산모-신생아 집중치료실 이용이 고위험 산모의 산후 모성질환과 신생아에 미치는 영향

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장예슬

서론: 한국은 산모의 출산 연령 지연으로 인해 지속적인 출산율 감소와 고위험 임신의 증가에 직면해 있다. 2022 년에는 출생아 수가 2017 년 대비 약 30% 감소한 반면, 35 세 이상 산모의 비율은 약 40%로 증가했다. 이는 불임, 유산, 산과적 개입의 증가로 이어질 가능성이 있다. 또한 저체중 출생아, 다태아 등의 고위험 출산이 증가하고 있으며, 이는 전문 치료에 대한 수요를 늘리고 있는 반면, 산과 병원 및 의료 인력 부족 문제가 지속적으로 대두되고 있다. 이러한 문제에 직면하여 정부는 2014 년부터 고위험 임산부와 신생아를 위한 통합 치료센터를 시범 도입하여 운영 중이며, 2017 년 10 월부터 고위험 임산부를 위한 관리 수가와 입원료를 신설하였다. 고위험 임산부와 신생아 수가 증가하고, 출산율이 감소하는 상황에서, 고위험 산모-태아 집중치료실의 지속적인 발전은 필수적이다. 그러나 이와 관련하여 효과를 평가한 연구는 부족한 상황이다. 이에 따라 이 연구는 산모-태아 집중치료실의 효과를 실증적으로 평가하며, 고위험 산모의 산후 모성질환 및 신생아의 건강결과와의 연관성을 탐구하고자 하였다.

연구방법: 이 연구는 2018 년부터 2023 년까지의 국민건건강보험공단 맞춤형 코호트 자료를 활용하였으며, 해당 기간 동안 출산한 산모 중 고위험산모 집중치료실 입실 조건을 만족하는 산모를 대상으로 분석하였다. 두 군 간의 중증도 보정을 위해 나이, 출산 연도, 집중치료실 입실 기준 등을 정확하게 매칭하였으며, 추가로 제왕절개여부, 거주 지역, 합병증 여부, 병원 유형, 소득수준 등을 매칭변수로 사용하였다. 성향점수 매칭법(Propensity score matching)을 사용하여 출산 전 임신 기간 동안 집중치료실 입원료를 한번 이상 청구한 산모를 실험군으로, 관리료를 청구한 환자를 대조군으로 하여 1:2 비율로 매칭하였다. 주요 종속변수는 출산 후 42일 내에 발생한 산후 패혈증,

자궁 적출술 시행, 중환자실 입원, 대량 수혈, 사망을 포함한 산후 모성질환이었으며 고위험산모에게서 태어난 아이의 경우 조산과 저출생아를 고위험 신생아로 정의하였고, 추가적으로 영아 사망 등을 분석하였다. 주요 분석방법은 일반화 선형 방정식(Generalized Estimating Equation model)을 사용하였다.

연구결과: 집중치료실에 입원한 산모는 입원하지 않은 산모에 비해 산후 모성질환 발생 확률이 유의하게 낮았으며(Exp(β) 0.77, 95% CI 0.52-0.94). 진단별 하위 분석에서는 산후 패혈증 발생 확률이 유의하게 감소하였다. 이 외 중환자실 입원, 사산, 사망 등은 감소하는 추세를 보였으나 통계적으로 유의하지 않았다. 추가적으로 집중치료실에 입원했을 때, 산모의 재원일수나 총 의료비, 본인부담금에서는 큰 차이를 보이지 않았으며, 분석에 포함된 고위험 산모들에게서 태어난 신생아들의 건강결과를 확인하였을 때, 조산이나 저출생아는 증가하였으나(Exp(β) 1.16, 95% CI 1.09-1.24) 유산 확률은 유의하게 감소하였으며 (Exp(β):0.91, 95% CI: 0.78-0.98), 영아 사망 확률은 감소하는 경향을 보였으나 유의하지 않았다.

결론: 결론적으로, 고위험산모-신생아 집중치료실(MFICU)의 활용은 고위험 임산부의 산후 모성질환 발생 확률을 줄이고, 태아의 유산 확률을 감소시키는 데 중요한 역할을 할 수 있음을 시사한다. 이는 고위험산모 집중치료실과 같은 전문 치료 인프라를 갖춘 구조적 개입이 산모의 건강 결과에 긍정적인 영향을 미친다는 점에서 의의가 있다. 고위험 임산부의 지속적인 증가와 출산율 감소라는 현재의 상황을 고려할 때, 집중치료실의 효과적인 활용은 물론, 향후 산모와 태아를 위한 지속적이고 체계적인 의료 지원 정책의 시행이 필요할 것이다..

핵심되는 말: 고위험산모, 고위험신생아, 고위험산모 신생아 집중치료실, 산후 모성질환,