

A Decade Comparison between the Years 2010-2013 and 2020-2023 of Poor Neonatal Outcomes and the Associated Factors using a Single Tertiary Hospital Birth Record: An Impact of the COVID-19 Pandemic

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ABSTRAK

Kajian ini bertujuan untuk membandingkan prevalen hasil neonatal yang buruk sebelum dan semasa pandemik COVID-19 serta faktor-faktor yang berkaitan dengannya. Kajian perbandingan keratan rentas telah dijalankan di Hospital Canselor Tuanku Muhriz (HCTM) dengan membandingkan rekod kelahiran untuk tahun 2010-2013 dan semasa pandemik COVID-19 (tahun 2020-2023). HCTM mula menggunakan telekonsultasi dan aplikasi MyMOMS digital untuk pemantauan antenatal semasa pandemik. Pemboleh ubah bersandar dalam kajian ini adalah hasil neonatal yang buruk, manakala pemboleh ubah tidak bersandar ialah demografi ibu, antropometri ibu, status risiko obstetrik dan jenis kelahiran. Rekod terpilih adalah berdasarkan warganegara Malaysia dan kehamilan tunggal manakala sebarang data yang tidak lengkap dan jantina bayi yang tidak jelas telah dikecualikan. Tiada perbezaan dalam prevalens hasil neonatal yang buruk untuk kedua-dua tempoh kajian (prevalens 3.9%). Umur ibu >35 tahun (aOR:1.26, 95%CI:1.01-1.57, $p=0.045$), kelahiran pramatang (aOR:16.95, 95%CI: 13.85-20.74, $p<0.001$), kelahiran secara pembedahan Caesarean (aOR:2.32, 95%CI 1.87-2.88, $p<0.001$), multipara (aOR: 0.73, 95%CI 0.59-0.90, $p=0.003$) dan bayi lelaki (aOR: 1.24 95% CI: 1.511-1.01, $p<0.040$) merupakan faktor risiko yang signifikan semasa pandemik. Sementara itu, dalam tempoh pra-pandemik (tempoh 2010-2013) pula, umur ibu >35 tahun (aOR:1.30, 95% CI:1.03-1.68, $p=0.032$), kelahiran pramatang (aOR: 15.97, 95 %CI: 13.22-19.29, $p<0.001$), ibu berisiko tinggi (aOR: 2.01, 95%CI: 1.47-2.73, $p<0.001$) dan kelahiran Caesarean (aOR:2.469, 95%CI 2.04-2.99, <0.001) dikaitkan dengan hasil neonatal yang buruk. Pemantapan kesihatan ibu dengan mengintegrasikan perundingan virtual atau kesihatan digital dalam memastikan kesinambungan penjagaan bagi pengesanan risiko awal semasa bencana

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akan meningkatkan jaminan kualiti dalam menyediakan penjagaan ibu.

Kata kunci: Bayi kurang berat lahir; hasil neonatal; kemasukan NICU; lahir mati; pandemik COVID-19

ABSTRACT

This study aims to compare the prevalence of adverse neonatal outcomes before and during the COVID-19 pandemic and the factors associated with it. A comparative cross-sectional study was conducted at Hospital Canselor Tuanku Muhriz (HCTM) by retrieving registered labour room records for the year 2010-2013 and during the COVID-19 pandemic (the year 2020-2023). HCTM started using teleconsultation and digital MyMOMS applications for antenatal monitoring during the pandemic. The dependent variable in this study was the adverse neonatal outcome, and the independent variables were maternal demographics, maternal anthropometry, obstetric risk status and mode of delivery. Records retrieved were based on Malaysian citizens and singleton while incomplete data and ambiguous genitalia were excluded. There was no difference in the prevalence of adverse neonatal outcomes for both study periods (3.9%). Maternal age >35 years (aOR:1.26, 95%CI:1.01-1.57, $p=0.045$), premature birth (aOR:16.95, 95%CI: 13.85-20.74, $p<0.001$), Caesarean delivery (aOR:2.32, 95%CI 1.87-2.88, $p<0.001$), multiparity (aOR: 0.73, 95%CI 0.59-0.90, $p=0.003$) and male neonates (aOR: 1.24 95% CI: 1.01-1.51, $p<0.040$) were significant risk factors during the pandemic period. Meanwhile, in the pre-pandemic (2010-2013) period, maternal age >35 years (aOR:1.30, 95% CI:1.03-1.68, $p=0.032$), premature birth (aOR: 15.97, 95%CI: 13.22-19.29, $p<0.001$), high-risk pregnancy status (aOR: 2.01, 95%CI: 1.47-2.73, $p<0.001$) and Caesarean delivery (aOR:2.469, 95%CI 2.04-2.99, $p<0.001$) were associated with adverse neonatal outcomes. Strengthening maternal health by integrating virtual consultation or digital health to ensure continuity of care for early risk identification during disasters will improve quality assurance in providing maternal care.

Keywords: COVID-19 pandemic; low birth weight; neonatal outcome; NICU admission; stillbirth

INTRODUCTION

Maternal and neonatal health care services encompass a wide variety of services including pre-pregnancy, antenatal, intrapartum, childbirth and post-partum care. The quality of maternal and neonatal care services can be monitored and assessed by the neonatal outcomes' performance. Other than quality of health

care services, the neonatal survival signified socio-demographic, economic and policy-making indicators in the country. World Health Organisation (WHO) through Sustainable Developmental Goal (SDG) 2030 number 3 (SDG3) targets, indicate population health and well-being as part of countries' development monitoring. One of the related SDG indicators is target

number 3.2, which is for all countries to end preventable causes and reduce neonatal mortality rates (WHO 2024).

Maternal and neonatal health care services in Malaysia are based on a two-tiered health care system, enhanced with a few written guidelines that have been developed since a few decades ago. The color-coded pregnancy risk assessment level has been employed in Malaysia for antenatal care monitoring since the year 1989 with the latest revision in year 2023 (Bahagian Pembangunan Kesihatan Keluarga 2020; Family Health Development Division 2023). The perinatal care manual (PCM) guideline, is one of the comprehensive training manuals and acts as a reference used by Malaysian healthcare providers for managing maternal and newborn cases since year 2002. Antenatal monitoring was implemented using a manual home-based maternal record called the pink book. At present there is no digital application used in public health facilities for interactive antenatal monitoring. Over two decades of PCM implementation with on disrupted of disaster, the national neonatal mortality rate and percentage of low birth weight have plateaued but premature delivery, birth asphyxia and normally formed macerated stillbirths are showing increasing trends (DOSM 2023). During the pandemic, hospital admission of neonatal morbidity cases has reported an increase (DOSM 2024). However, efforts are made by some of the tertiary hospitals to implement digital health like teleconsultation to monitor their patients to ensure continuity of care, especially during the pandemic.

During the COVID-19 pandemic, Malaysians faced multiple movement

control orders (MCO) to curb disease spread (Aziz et al. 2020), and all sectors were affected. Due to unexpected events, the quality of maternal and neonatal health care services could be affected. A study showed significant reductions in maternal and child services performance indicators in primary health care services in Malaysia (Mohd Ujang et al. 2023). Furthermore, COVID-19-related infection was the top cause of the country's deaths in the year 2021, causing more than 50% of our maternal deaths (DOSM 2021). A study in the Klang Valley identified a higher incidence of premature births and ventilatory support requirements among newborns diagnosed with COVID-19 (Lim et al. 2022).

Apart from the above factors, socio-demographic and maternal health status could also influence poor neonatal outcomes. The national census reported the mean age of women at the first live birth as 27.9 years, which was a higher mean age compared to previous decades (DOSM 2023). Among the factors are a trend of late age of marriage, delay in conceiving, and decreasing total fertility rate (DOSM 2023). Furthermore, the current population is expected to live longer, however their health status is the main concern. The latest national health survey showed an increasing prevalence of non-communicable diseases such as diabetes mellitus, hypertension and obesity among the adult population (Institute for Public Health 2024). Considering all these factors, women nowadays are more likely to be in risky pregnancies due to late age at first pregnancy and underlying comorbidities. Some studies show the effect of diabetic mellitus, obesity and advanced maternal age on poor neonatal outcomes (Frick

2021; Lewandowska 2021; Li et al. 2020), respectively.

Changes in Malaysia's demographic landscape, the COVID-19 pandemic impact, and maternal health can all affect the effort to achieve SDG 2030 targets towards reducing the neonatal mortality rate. Hence, it is imperative to identify factors associated with poor neonatal outcomes by comparing the differences across the pre- and during-pandemic periods. Variables analysed in this study were selected according to a modified conceptual framework which stated three main factors associated with neonatal outcomes, which are the distal (maternal socio-demographic factors), intermediate (pregnancy care) and proximal (neonatal characteristics factors) (de Souza et al. 2019).

The present study aimed to compare the prevalence of poor neonatal outcomes between the period 2010-2013 and 2020-2023. These periods were selected for a few reasons. Firstly, the national demographic census is updated every tenth year, with the latest two being in the years 2020 and 2010 (DOSM 2023), hence it can be related to the demographic composition comparison. Secondly, no infectious disease outbreak happened during the last decade that was similar to the COVID-19 pandemic, hence the pre and during-pandemic neonatal outcomes were compared. Thirdly, Malaysia has consistently adhered to using colour coding as pregnancy risk assessment, with several revisions in the PCM maternal and neonatal care guidelines in both periods. Finally, during the pandemic, the Hospital Canselor Tuanku Muhriz (HCTM) which is a teaching hospital, initiated a digital application (MyMOMS) in the monitoring

of their antenatal mothers to ensure continuity of care during MCO (Mesiniaga 2024). On top of that, the HCTM has been using an electronic database for labour room monitoring and record-keeping since 2010, maintaining the same provider for data entry and variables definition (Mediclink 2024).

Hence, this study's objectives were to determine the prevalence of poor neonatal outcomes in the years 2010-2013 and year 2020-2023, the latter representing pre- and COVID-19 pandemic periods, to identify the associated factors under the maternal characteristics, obstetric risk status and delivery details. The study was planned to understand the effect of demographics and maternal health in addition to the COVID-19 pandemic's impact on neonatal outcomes.

MATERIALS AND METHODS

Study Design

A comparative cross-sectional study has been conducted by retrieving registered labour room patients' records in a single delivery center, HCTM.

Study Setting

HCTM is a teaching university hospital and a tertiary referral center located in Cheras, Kuala Lumpur. HCTM has initiated a MyMOMS application during COVID-19 to improve the quality of care and early risk management. The application is aimed to replace the hard copy home-based record (the pink book) but preserve all variables collected as in the pink book and its management protocol as written in the PCM. Cheras is an urban parliament

area, populated by 135,823 at a high density of 8,489 per square km. Chinese ethnicity predominates (59.6%), followed by Bumiputera (32.2%), Indian (7.6%) and others (0.7%) (DOSM 2023).

Data Collection

The recorded data for 2010-2013 and 2020-2023 were retrieved retrospectively for analysis. The recorded data was obtained from the ObsCentral digital database maintained by the provider Mediclink System Malaysia. ObsCentral is the system that provides labour room data management monitoring by the healthcare provider during delivery (Mediclink 2024). The labour room management and birth data are routinely entered into the database by the labour room health staff and verified by the senior medical officer in charge of the maternal and fetal unit.

Study Variables

The dependent variable in this study was poor neonatal outcomes, which were defined based on a previous study (Beyuo et al. 2023) as any 'Yes' to (i) stillbirth or birthweight <1500 grams, or (ii) Apgar score at 5 minutes of life < 7, or (iii) NICU admission or live birth with death before discharge. The neonatal outcomes that did not fulfil any of the criteria was considered good neonatal outcomes in this study.

The independent variables in this study were maternal demographics (age in years, ethnicity, marital status), maternal anthropometrics (height in cm, body mass index (BMI) kg/m²), obstetric status (gravida, parity, gestational period in weeks, risk level) and delivery details (mode of delivery, neonatal gender and

maternal status either alive or death).

Inclusion and Exclusion Criteria

Data from mothers who were Malaysian citizens with singleton pregnancies delivered during both study periods were included in this study. Any incomplete data variables were excluded. Ambiguous genitalia were excluded.

Data Analysis

Data were entered into Microsoft Excel and were cleaned before analysis. There were 29,900 sets of data originally retrieved from the Mediclink Obscentral database. However, only 29,380 cases of Malaysian mothers with singleton pregnancies were included. A total of 4,078 (13.67 %) cases were excluded: 3,196 for incomplete data and 27 cases for ambiguous genitalia. Finally, 25,302 cases remained. The total number of eligible cases for 2010-2013 was 13,535 cases while for 2020-2023 was 11,767 cases (Figure 1).

Data were analysed using IBM Statistical Package for the Social Science (SPSS) version 26.0. All variables were presented as counts and percentages for categorical variables and as means and standard deviation (SD) for continuous variables. Data normality was checked. Simple logistic regression was used to determine the associations between potential independent variables and poor neonatal outcomes. Variables with *p*-values <0.05 in the bivariate analysis were selected for multivariate analysis using multivariate binary logistic regression to control the selected independent variables. Results were presented as adjusted odds ratios (aOR) with a 95% confidence interval (CI).

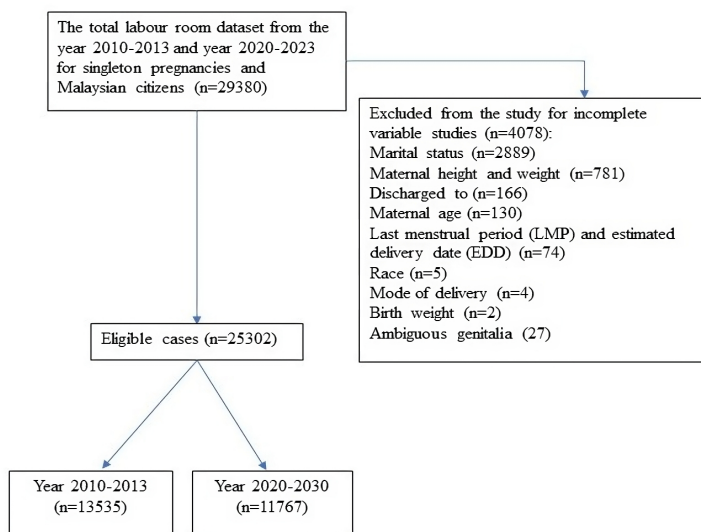


FIGURE 1: Data sampling

Statistical significance was set at $p < 0.05$.

Sample Size

The sample size was calculated using a two-proportion formula, utilising the Epitools software calculator (Sergeant ESG 2018). Using the assumption of 95% CI, 80% desired power, 0.43% proportion of annual neonatal death in the year 2010, and 0.39% in the year 2020 (DOSM 2024), the calculated minimum sample size was 2422 for each study population. Hence, the minimum total sample size for both populations was 4,844 cases.

Ethical Consideration

Ethical approval for this study was obtained from the University Kebangsaan Malaysia (UKM) Research Ethics Committee (FF-2020-510). ObsCentral database was managed by MedicLink System Malaysia Private Limited which had been granted permission to retrieve the database.

RESULTS

The prevalence of poor neonatal outcomes for the year 2020-2023 was 3.9% (n=463), which was similar to the prevalence in the year 2010-2013, 3.9% (n=529). The composites for poor neonatal outcomes, i.e. stillbirth, birth weight <1,500 grams Apgar score <7 at 5 minutes of life, or required NICU or mortuary admission were almost similar in proportion for both periods (Table 1).

For comparison of independent variables between the years 2020-2023 and 2010-2013, the mean maternal age was 31.49 (SD ±4.67), 2 years higher for the year 2020-2023 compared to the previous mean of 29.57 (±4.44 SD) age. The proportion of mothers aged >35 years old was 27.4% (n=3,229) in the year 2020-2023, which was higher compared to 13.5% (n=1,856) in the previous period. In both periods, the majority of mothers were Malay, constituting more than 70% of all ethnicities, followed by Chinese, Indian and others. More than 90% of mothers

TABLE 1: Prevalence and composite of poor neonatal outcomes for years 2010-2013 (n=13535) and 2020-2023 (n=11767)

Variables	2010 to 2013	2020 to 2023
	n (%)	n (%)
Poor neonatal outcomes		
Yes	526 (3.9)	463 (3.9)
No	13009 (96.1)	11304 (96.1)
Neonatal status		
Stillbirth*	77 (0.6)	63 (0.5)
Live birth	13458 (99.4)	11704 (99.5)
Birth weight (grams)		
<1500*	139 (1.0)	101 (0.9)
≥1500 -2499	1066 (7.9)	908 (7.7)
≥2500	12330 (91.1)	10,686 (90.8)
Apgar score at 5 minutes of life		
<7*	147 (1.1)	136 (1.2)
≥7	13388(98.9)	11631 (98.8)
Discharged to		
NICU*	387 (2.9)	354 (3.0)
Mortuary*	86 (0.6)	66 (0.6)
Mother	13080 (96.5)	11347 (96.4)

*Composite of poor neonatal outcomes was defined as any 'Yes' to stillbirth or birth weight <1500 grams or Apgar score <7 at 5 minutes of life or discharged to neonatal intensive care unit (NICU) or live birth with death before discharge.

were legally married in both periods, with a slight increment in unmarried mothers from 6.8% in the year 2010-2013 to 7.5% in 2020-2023.

The proportion of multiparous mothers was 63.4% (n=7,464), which was higher than nulliparous mothers for the year 2020-2023. In contrast, the proportion of nulliparous mothers was 79.5% (n=10,764) higher compared to multiparous mothers in the years 2010-2013. The multiparous mother has experienced at least one live birth while a nullipara is a mother who may have had a miscarriage, stillbirth, or elective abortion but has never given birth to a live newborn.

The mean gravida, which indicates a mean number of maternal pregnancies regardless of outcomes of the previous pregnancy was almost similar in both

periods, which was 2.58 (\pm SD1.59) and 2.31 (\pm SD1.43) for years 2020- 2023 and 2010-2013 respectively. The proportion of mothers with gestational periods <37 weeks was similar (8.4%) in both periods. This might indicate the proportion of babies born <37 weeks was similar in both periods.

The mean maternal height was 157.02 (\pm SD5.74) in the year 2020-2023, 1 cm higher compared to the previous mean 156.73 (\pm SD 5.80) height. However, both periods had a similar proportion of mothers with height <145 cm which was 1.9%. For BMI, the proportion of mothers with BMI 25 kg/m² was higher compared to <18.5 and 18.5 to 24.9 kg/m² for both periods. There was an increasing proportion of overweight mothers with BMI 25 kg/m², 51.7% (n= 7,003) in the year 2010 to 2013

to 74.0% (n= 8,710) for the year 2020 to 2023.

Antenatally, the pregnancy risk is continually assessed from having no risk to high risk, which is colour-coded white, green, yellow, and red respectively according to the perinatal care manual (PCM) guideline. For both periods, white code mothers were higher in proportion compared to other risk levels. As per colour code, there was an increasing proportion of green code, from 1.9% (n=503) in 2010-2013 to 6.1% (n =776) for 2020-2023. This was in contrast with the yellow and red codes which decreased in proportion from the previous period.

Non-Caesarean delivery including spontaneous vaginal and instrumental assisted delivery was higher in proportion compared to Caesarean delivery in both periods. There was an increasing proportion of Caesarean delivery from 24.7% (n=3,348) in the year 2010-2013 to 43.0% (n=5,061) for the year 2020-2023. The proportion of male neonates was higher than females in both periods. Lastly, there was a decreasing proportion of maternal deaths, from 0.03% (n=4) in the years 2010-2013 to 0.02% (n=2) for the years 2020-2023 (Table 2).

For the years 2010-2013, simple logistic regression analysis resulted in

TABLE 2: Maternal demographic, anthropometric, obstetric status, and delivery for years 2010-2013 and 2020-2023

Variables	2010-2013 (n=13535), n (%)	2020-2023 (n=11767), n (%)
Maternal Demographic		
Age (years)	29.57 ± 4.44*	31.49 ± 4.67*
Age group (years)		
≤35	11679 (86.3)	8538 (72.6)
>35	1856 (13.7)	3229 (27.4)
Ethnic		
Others	192 (1.4)	330 (2.8)
Indian	340 (2.5)	387 (3.3)
Chinese	2494 (18.4)	1213 (10.3)
Malay	10509 (77.6)	9837(83.6)
Marital status		
Married	12615 (93.2)	10888 (92.5)
Unmarried	920 (6.8)	879 (7.5)
Maternal Anthropometric		
Mean Height (cm)	156.73 ± 5.80*	157.02 ± 5.74*
Height group (cm)		
≤145	258 (1.9)	227 (1.9)
>145	13277 (98.1)	11540 (98.1)
BMI (kg/m ²)		
<18.5	655 (4.8)	165 (1.4)
18.5 to 24.9	5877 (43.4)	2892 (24.6)
≥25	7003 (51.7)	8710 (74.0)

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Obstetric Status		
Gravida	2.31 ± 1.43*	2.58 ± 1.59*
Parity		
Nulliparous	10764 (79.5)	4303 (36.6)
Multiparous	2771 (20.5)	7464 (63.4)
Gestational period		
<37 weeks	1216 (9.0)	994 (8.4)
≥37 weeks	12319 (91.0)	10773 (91.6)
Risk level		
White	12439 (91.9)	10646 (90.5)
Green	503 (1.9)	715 (6.1)
Yellow	258 (3.7)	236 (2.0)
Red	335 (2.5)	170 (1.4)
Delivery Details		
Mode of delivery		
Non-Cesarean delivery	10187 (75.3)	6706 (57.0)
Cesarean delivery	3348 (24.7)	5061 (43.0)
Neonatal gender		
Female	6529 (48.2)	5666 (48.2)
Male	7006 (51.8)	6101 (51.8)
Maternal status		
Alive	13531 (100.0)	11765 (100.0)
Death	4 (0.03)	2 (0.02)

*Mean, standard deviation (SD)

five significant factors associated with poor neonatal outcomes. There were mothers aged >35 years old (cOR: 1.64, 95%CI:1.32,2.05, p<0.001), gestational period <37 weeks (cOR: 17.52, 95%CI: 14.56-21.09, p<0.001), high-risk mothers (cOR: 3.46, 95%CI: 2.64-4.54, p<0.001), Cesarean delivery mode (cOR:0.36, 95% CI:0.30-0.43, p<0.001) and male neonates (cOR:1.22, 95%CI: 1.02-1.45, p<0.001).

Meanwhile, for 2020-2023, there were seven significant associations, which were mothers aged >35 years old (cOR: 1.47, 95%CI:1.21-1.79, p<0.001), BMI beyond 18.5-24.9 kg/m² (cOR: 0.75, 95%CI: 0.61-0.92, p=0.006), multiparous mothers (cOR:0.642, 95%CI:0.53-0.77, p<0.001), gestational period <37weeks (cOR: 18.63, 95%CI: 15.28-22.72, p<0.001),

Caesarean birth (cOR:2.94, 95% CI:2.41-3.59 p<0.001), male neonates (cOR:1.25, 95%CI: 1.04-1.51, p=0.018) and maternal death (cOR 24.47, 95%CI: 1.53-391.75, p=0.024). Variables with p-value < 0.05 were considered to be included in multiple logistic regression (Table 3).

After controlling selected variables using multivariate binary logistic regression, the statistical analysis showed four significant factors associated with poor neonatal outcomes in the years 2010-2013. These were mothers aged >35 years old (aOR:1.30, 95% CI:1.03-1.68, p=0.032), mothers with gestational periods <37weeks (aOR: 15.97, 95%CI: 13.22-19.29, p<0.001), high-risk level mothers (aOR: 2.01, 95%CI: 1.47-2.73, p<0.001) and Cesarean delivery (aOR:2.469, 95%CI

TABLE 3: Simple logistic regression for associated factors with poor neonatal outcomes for the years 2010-2013 (n=13535) and 2020-2023 (n=11767)

Independent variables	2010-2013					2020-2023				
	Poor neonatal outcome n (%)		cOR	95% CI	p-value*	Poor neonatal outcome n (%)		cOR	95% CI	p-value*
	Yes	No				Yes	No			
Age group (years)										
≤35	419 (79.7)	11260 (86.6)	1			299 (64.6)	8239 (72.9)	1		
>35	107 (20.3)	1749 (13.4)	1.64	1.32-2.05	<0.001	164 (35.4)	3065 (27.1)	1.47	1.21-1.79	<0.001
Ethnic										
Non-Malay**	111 (21.1)	2915 (22.4)	1			89 (19.2)	1841 (16.3)	1		
Malay	415 (78.9)	10094 (77.6)	1.08	0.87-1.34	0.481	37 (80.8)	9463 (83.7)	0.81	0.65-1.04	0.095
Marital status										
Married	485 (92.2)	12130 (93.2)	1			424 (91.6)	10464 (92.6)	1		
Unmarried	41 (7.8)	879 (6.8)	1.17	0.84-1.62	0.354	39 (8.4)	840 (7.4)	1.15	0.82-1.60	0.426
Height group (cm):										
>145	517 (98.3)	12760(98.1)	1			450(3.8)	11090 (98.1)	1		
≤145	9 (1.7)	249(1.9)	0.89	0.46-1.75	0.739	13(0.1)	214 (1.9)	1.50	0.85-2.64	0.164
BMI (kg/m ²)										
18.5 to 24.9	249 (47.3)	5628 (43.3)	1			139 (30.0)	2753 (24.4)	1		
Beyond 18.5 to 24.9	277 (52.7)	7381 (56.7)	0.85	0.71-1.01	0.065	324 (70.0)	8551 (75.6)	0.75	0.61-0.92	0.006
Gravida										
			1.05	0.99-1.11	0.124			0.95	0.89-1.01	0.086
Parity										
Nulliparous	408 (77.6)	10356 (79.6)	1			217 (46.9)	4086 (36.1)	1		
Multiparous	118 (22.4)	2653 (20.4)	1.13	0.92-1.39	0.256	246 (53.1)	7218 (63.9)	0.64	0.53-0.77	<0.001
Gestational period										
≥37 weeks	226 (43.0)	12093 (93.0)	1			202 (43.6)	10571 (93.5)	1	15.28-22.72	<0.001
<37 weeks	300 (57.0)	916 (7.0)	17.53	14.56-21.09	<0.001	261 (56.4)	733 (6.5)	18.63		
Risk level***										
Low-risk	459 (87.3)	12483 (96.0)	1			441(95.2)	10920(96.6)	1		
High-risk	67 (12.7)	526 (4.0)	3.46	2.64-4.54	<0.001	22(4.8)	384 (3.4)	1.42	0.91-2.20	0.119

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Mode of delivery										
Non-Caesarean delivery	280 (53.2)	9907 (76.2)	1	0.30-0.43	<0.001	148(32.0)	6558(58.0)	1	2.41-3.59	<0.001
Cesarean delivery	246 (46.8)	3102 (23.8)	0.36	1.02-1.45		315(68.0)	4746 (42.0)	2.94		
Neonatal gender										
Female	229 (43.5)	6300 (46.5)	1		0.028	198 (42.8)	5468 (48.4)	1	1.04-1.51	0.018
Male	297 (56.5)	6709 (51.6)	1.21			265 (57.2)	5836 (51.6)	1.25		
Maternal status										
Alive	522 (99.2)	13009 (100.0)	1	0.0	0.999	462 (99.8)	11303(100.0)	24.47	1.53-391.75	0.024
Death	4 (0.8)	0 (0.00)	4.03e+12			1 (0.2)	1(0.0)			

*p-value <0.05 indicated significant result
 **Non-Malays included Chinese, Indian and others
 ***Low-risk level included white and green code; high-risk level included yellow and red code (Yeoh et al. 2016)

2.04-2.99, p<0.001).

Meanwhile, for 2020-2023, five significant factors remained after controlling selected variables in an analysis. These were mothers aged >35 years (aOR:1.26, 95% CI:1.01-1.57, p=0.045), multiparous mothers (aOR: 0.73, 95%CI 0.59-0.90, p=0.003), mothers with a gestational period < 37 (aOR:16.95, 95%CI: 13.85-20.74, p<0.001), Cesarean delivery (aOR:2.31, 95%CI 1.87-2.88, p<0.001) and being male neonates (aOR: 1.24 95% CI: 1.01-1.51, p=0.04) (Table 4).

DISCUSSION

The present study was conducted at a single academic medical center and found no significant difference in the prevalence of poor neonatal outcomes between pre-pandemic and during the pandemic. However, these findings differ slightly from the national neonatal mortality rate trends, which showed a decrease from 4.3 per 1,000 live births in the year 2010 to 3.9 per 1,000 live births in the year 2020 (DOSM 2023). Other studies in Alabama also reported lower neonatal mortality rates during the pandemic, 3.6 per 1,000 live births compared to baseline 4.4 per 1,000 live births (Shukla et al. 2023). In contrast, Nepal documented a rise in neonatal mortality after the pandemic lockdown, from 13 per 1,000 live births to 40 per 1,000 live births (Kc et al. 2020). This showed that the pandemic's impact on neonatal outcomes varies depending on location and healthcare systems (Di Toro et al 2021).

The possible explanation for the unchanged prevalence of poor neonatal outcomes in this study could be the implementation of a digital pregnancy

TABLE 4: Multivariate binary logistic regression of poor neonatal outcomes for years 2010-2013 (n=13535) and 2020-2023 (n=11767)

Independent Variables	2010-2013a				2020-2023b					
	Wald	aOR	(95% CI)	X ² stat (df)	p-value*	Wald	aOR	(95% CI)	X ² stat (df)	p-value*
Age group (years)										
≤35	Ref.	1				Ref.	1			
>35	19.95	1.30	1.02-1.66	4.60 (1)	0.032	15.24	1.26	1.01-1.57	4.02 (1)	0.045
Parity										
Nulliparous	Ref.					Ref.	1			
Multiparous	1.29					21.73	0.73	0.59-0.90	8.91 (1)	0.003
Gestational period										
≥37 weeks	Ref.	1				Ref.	1			
<37 weeks	918.03	15.97	13.22-19.29	825.65 (1)	<0.001	835.43	16.95	13.8-20.74	755.26 (1)	<0.001
Risk level**										
Low-risk	Ref.	1				Ref.				
High -risk	80.89	2.01	1.47-2.73	19.53(1)	<0.001	2.43				
Mode of delivery										
Non-Cesarean delivery	Ref.	1				Ref.	1			
Cesarean delivery	132.07	2.47	2.04-2.99	85.97(1)	<0.001	113.04	2.32	1.87-2.88	58.98 (1)	<0.001
Neonatal gender										
Female	Ref.					Ref.	1			
Male	4.83					5.58	1.24	1.01-1.51	4.19 (1)	0.040

*p-value <0.05 indicated significant result; **Low-risk level included white and green code; high-risk level included yellow and red code (Yeoh et al. 2016)
 Ref. = Reference; †No interaction between variables, no multicollinearity, no influential outlier; Hosmer-Lemeshow goodness-of-fit test was not significant (p=0.296);
 Specificity (99.8%), sensitivity (3.8%), accuracy (96%) of model prediction; R2 = 0.242; ††No interaction between variables, no multicollinearity, no influential outlier;
 Hosmer-Lemeshow goodness-of-fit test was not significant (p=0.265); Specificity (100%), sensitivity (0%), and accuracy (96.1%) of model prediction; R2 = 0.246

record system in HCM in 2022 called the MyMOMS application. This digital app may improve maternal health record data collection, hence facilitating communication between mothers and health care providers through the digital platform. This also enhances maternal engagement, in which mothers can document their pregnancy details, such as fetal movement within the app. Real-time assessment of maternal and fetal well-being is facilitated, enabling healthcare providers to intervene promptly if any concerns are detected. There was a study that assessed the availability and utilisation of teleconsultation services across 249 public primary care clinics in Malaysia in which about 60.5% have been offered phone consultations, while a smaller portion, 14.9% solely provided video consultations (Ng et al. 2022). The teleconsultations primarily focused on managing chronic diseases like diabetes mellitus and hypertension. While there have been initial attempts by the Malaysian Ministry of Health (MOH) to integrate virtual postnatal care for low-risk mothers and newborns since the pandemic (Bahagian Pembangunan Kesihatan Keluarga 2020), these services are still limited by clinic resources and availability.

A study on China's use of health teleconsultation during the pandemic emphasises several key factors for success such as building strong infrastructure including reliable internet connectivity, robust government support with clear regulations and sufficient funding, and tailoring teleconsultation services to address the specific needs of marginalised populations and considering socio-cultural factors (Ye et al. 2023). Malaysia's

experience with teleconsultation also can benefit from lessons learned in India. The early stages of adopting teleconsultation before the pandemic were hampered by limited infrastructure and a lack of comprehensive guidelines (Bhaskar et al. 2020; Ng et al. 2022). However, the COVID-19 crisis accelerated India's teleconsultation rollout, prompting the introduction of new practice guidelines in March 2020, that gives further guidance to the practice of teleconsultation in India.

For the significant factors associated with poor neonatal outcomes during the COVID-19 pandemic, this study found that multiparous mothers were less likely (aOR: 0.73, 95%CI 0.59-0.90, $p=0.003$) to have poor neonatal outcomes compared to nulliparous mothers during a pandemic. This finding is similar to other studies that showed that multiparous mothers had a lower risk of poor neonatal outcomes (Lin et al. 2021). However, other studies did not find any association between parity and neonatal outcomes (Tadesse 2020). A piece of evidence found that grand multiparous mothers might have a higher risk of having poor neonatal outcomes (Dasa et al. 2022). This suggested that parity might be an important contributing factor for neonatal outcomes, however, care needs to be tailored based on maternal pregnancy risk assessment.

Male neonates born during the pandemic were at slightly higher odds of having poor outcomes (aOR: 1.24 95% CI: 1.01-1.51, $p=0.04$) compared to females. This is similar to other studies that showed male neonates had a higher odds ratio of death (aOR1.07, 95% CI 1.05-1.10) compared to females (Garfinkle et al. 2020). For example, a study of twins found that male-male twins had worse

outcomes compared to other twin-paired combinations (Funaki et al. 2023). It is important to note that there was no difference in management and approach towards pregnant mothers irrespective of fetal gender. Some supported genetic theories suggest that the genes on the Y chromosomes, which determine the male sex, might play a role in causing more health problems compared to females (Nielsen et al. 2023). This could be a factor to consider during fetal assessment procedures in the future.

Mothers who underwent Cesarean births were twice more likely to develop poor neonatal outcomes before and during the pandemic period (aOR:2.469, 95%CI 2.04-2.99, $p<0.001$; aOR:2.31, 95%CI 1.87-2.88, $p<0.001$), respectively. This study also showed that Cesarean birth became more common with a prevalence of 43.0% ($n=5,061$) during the pandemic compared to 24.7% ($n=3,348$) pre-pandemic. This was similar to other studies demonstrating rises in Cesarean birth rates during the COVID-19 pandemic (Di Toro et al. 2021). The surge in Cesarean births during the pandemic could be due to more complications arising from the mothers initially considered as low-risk. It may also be due to an opt-out cesarean birth policy for all COVID-19 mothers, as was practiced in Malaysia, where an increasing Cesarean birth rate was reported among relatively low-risk maternal groups during the pandemic (Karalasingam et al. 2020). Another study suggests that the main reason for planned Cesarean birth was maternal request due to secondary fear of vaginal delivery and the main reason for urgent Cesarean birth was prolonged labour (da Silva Charvalho et al. 2019). Hence, increasing the proportion of

low-risk level mothers from 95.6% pre-pandemic to 96.5% during the pandemic could explain the rise in Cesarean birth rate in this study.

Our study found that mothers with gestational periods <37 weeks have 15-16 times higher odds (aOR: 15.97, 95%CI: 13.22-19.29, $p<0.001$; aOR:16.95, 95%CI: 13.85-20.74, $p<0.001$) of ending with poor neonatal outcomes, regardless of whether they gave birth before or during the pandemic. There was a slight drop in the overall rate of preterm births from 9.0% ($n=1216$) pre-pandemic to 8.4% ($n=994$) during the pandemic. This aligns with reports from other hospitals, which reported an 8% preterm birth rate in 2010 (Jeganathan 2010) and 6.63% in 2020 (Jeganathan & Karalasingam 2020). Other studies have shown a higher rate of preterm deliveries among mothers with COVID-19 compared to the general population (Smith et al. 2020). However, despite a decrease in preterm births, the prevalence of poor neonatal outcomes remained the same. This suggests a potential need for increased support for preterm-related care during a pandemic.

Mothers aged >35 years old had 1.3 times higher odds of having poor neonatal outcomes (aOR:1.26, 95% CI:1.01-1.57, $p=0.045$; aOR:1.30, 95% CI:1.03-1.68, $p=0.032$) compared to younger mothers, regardless of whether they delivered pre or during the pandemic. This aligns with other studies showing an association between advanced maternal age and various poor neonatal outcomes (Correa-de-Araujo & Yoon 2021; Frick 2021; Yeoh et al. 2016). Of concern is the significant increase in the number of older mothers giving birth during the pandemic, i.e. 27.4% ($n=3229$) compared to 13.5%

(n=1856) pre-pandemic. The average maternal age also rose by 2 years from a mean of 29.57 (± 4.44 SD) pre-pandemic to 31.49 (± 4.67 SD) during the pandemic. The trend coincides with national statistics which reported mean age of mothers to have their first child is currently 27.9, which is higher than in previous years (DOSM 2023).

This study found that high-risk mothers pre-pandemic were twice as likely (aOR: 2.01, 95%CI: 1.47-2.73, $p < 0.001$) to have poor neonatal outcomes compared to low-risk mothers. However, this factor was not significant during the COVID-19 pandemic (Yahaya et al 2022). A study found that babies born to mothers with high-risk conditions, such as preeclampsia, were more likely to experience poorer outcomes (Kalok et al. 2022; Sutan et al. 2022). Despite an increase in low-risk mothers' proportions during the pandemic, the prevalence of poor neonatal outcomes remained the same, suggesting another potential factor. The disruption of antenatal care services during the pandemic might be a contributing factor. A study by Mohd Ujang et al. (2023) found a decrease in visits to ANC at primary healthcare clinics during the COVID-19 pandemic. Studies from other countries also suggest that COVID-19 impacted access to and utilisation of ANC services (Landrian et al. 2022; Tadesse 2020). This lack of access to ANC during the pandemic could have prevented healthcare providers from properly identifying and managing risks in expecting mothers, possibly leading to poor neonatal outcomes.

During the pandemic, maternal death was a significant contributory factor (cOR 24.47, 95%CI: 1.53-391.75, $p = 0.024$) for the poor neonatal outcome, however, this

factor was not significant afterward when other factors were considered. There were fewer maternal deaths overall during the pandemic. The proportion of maternal deaths decreased from 0.03% (n=4) pre-pandemic to 0.02% (n=2) during the pandemic. This aligns with the national trend of a decreasing maternal mortality rate (MMR), except for a spike in 2021 due to COVID-19 infection (DOSM 2023). Other studies around the world have shown a link between COVID-19 infection and maternal death (Hantoushzadeh et al. 2020; Takemoto et al. 2022). This study did not investigate the specific causes of maternal deaths, but the initial result does suggest maternal deaths were more likely to be associated with poor neonatal outcomes.

In the present study, while not directly linked to poor neonatal outcomes, there was a difference in proportions of BMI between mothers who delivered pre- and during a pandemic. The proportion of mothers with BMI ≥ 25 kg/m² increased significantly during the pandemic, 74.0% (n=8710) compared to pre-pandemic 51.7% (n=7003). This rise aligns with data showing increasing obesity prevalence among the Malaysian population (Institute for Public Health 2024). Although BMI in this study was based on weight upon admission to the labour room, it suggests a trend of mothers gaining more weight during pregnancy, or starting pregnancy with a larger weight, compared to pre-pandemic. This is concerning because other studies have shown an association between maternal obesity and poor neonatal outcomes (Correa-de-Araujo & Yoon 2021; Frick 2021; Institute for Public Health 2024).

The present study found a similar

proportion of maternal height <145 cm, which was 1.9 %, in both the pre-pandemic and during the pandemic periods. While this factor was not statistically significant for poor neonatal outcomes in this study, other research suggests an association between short maternal stature and poor neonatal outcomes (Skåren et al. 2020; Teoh et al. 2024; Zeegers et al. 2022). Interestingly, the average maternal height increases slightly during the pandemic. The mean maternal height was 157.02 (± 5.74 SD) cm, 1 cm higher compared to the pre-pandemic period. However, concern remains due to national data reporting that 20% of young Malaysians are at risk of stunting (Institute for Public Health 2023). This could potentially impact future generations of mothers and their newborn's health. Paternal height plays a role in neonatal outcomes too (Takagi et al. 2019), but it was not explored in this study.

More than 90% of mothers in both the pre-pandemic and during-pandemic periods were found married in this study. There was a slight increase in the proportion of unmarried mothers, from 6.8% pre-pandemic to 7.5% during pandemic. While marital status was not directly associated with poor neonatal outcomes in this study, the rising proportion of unmarried mothers is a potential concern. Studies suggested that being a single mother can negatively impact pregnancy outcomes (Barr & Marugg 2019; Correa-de-Araujo & Yoon 2021; Frick 2021). The data also showed that half of pregnant teenagers in both periods remained unmarried. This is concerning because teenage pregnancy itself is a risk factor for various poor pregnancy outcomes (Eliner et al. 2022).

The present study revealed similar

gravidity for mothers delivering in both periods. Mothers delivering in pre-pandemic had an average of 2.31 (± 1.43 SD), while those delivering during the pandemic had an average of 2.58 (± 1.59 SD). This suggests most mothers were having their second or third child, which is generally considered a low-risk pregnancy without considering other risk factors. Lin et al. (2021) conducted a study in China and also noted similar findings of no correlation of parity with adverse birth outcomes.

The ethnic make-up of mothers giving birth mirrored our Malaysian population (DOSM 2023). Over 70% were Malay, followed by Chinese, Indian and others in both periods. This is consistent with the three major ethnic compositions in Malaysia. This study only includes Malaysian citizens; it is recommended to include non-citizens in future studies to understand how migration might affect health outcomes.

Strength

The strength of this study is that it uses an electronic database with consistent data entry and collection since the year 2010. Furthermore, this study includes the recent four years of data with a large sample size. This allows a better understanding of the study variables in the current period and to compare them to the previous period. This study only includes singleton pregnancy, which helps in controlling the influence of multiple pregnancies on poor neonatal outcomes. Only Malaysian citizens are included in this study, considering the opportunity to utilise optimum maternal and neonatal health care services in Malaysia.

Limitation

The limitation of this study is the use of data from a single birthing center only, hence affecting the generalisation of study results. Non-citizen was excluded, which left out vulnerable populations and immigration health impact in this study. This study did not consider other demographic variables influencing poor neonatal outcomes, such as family economic status and paternal height. It is known that low socio-economic status (Sullivan et al. 2023) and short paternal height (Takagi et al. 2019) are associated with poor neonatal outcomes. However, no data regarding income and paternal height was available from the database. Future studies should be done with the inclusion of those variables.

CONCLUSION

No difference in the prevalence of poor neonatal outcomes in both study periods pre- and during the COVID-19 pandemic was found in this study. However, advanced maternal age, multiparity, Cesarean birth, preterm delivery, and the male neonate were at risk of poor neonatal outcomes during the pandemic. To strengthen maternal health and ensure continuity of care during major infectious disease outbreaks, it is recommended to integrate virtual consultation or digital health services into pregnancy care. This approach can help identify early risks and provide a safe pregnancy journey for both the mother and her newborn.

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