Causes of maternal death and late maternal mortality: from the H1N1 to COVID-19 pandemics, State of Rio de Janeiro, 2009 to 2021

Ana Lucia de Melo Bellizzi [1]
https://orcid.org/0009-0006-2948-7782

Pauline Lorena Kale [2]
https://orcid.org/0000-0001-5439-9158

Sandra Costa Fonseca [3]
https://orcid.org/0000-0001-5493-494X

Angela Maria Cascão [4]
https://orcid.org/0000-0001-5839-4688

[1,4] Subsecretaria de Vigilância em Saúde. Secretaria Estadual de Saúde do Rio de Janeiro. Rio de Janeiro, RJ, Brazil.

[2] Instituto de Estudos em Saúde Coletiva. Universidade Federal do Rio de Janeiro. Praça Jorge Machado Moreira, 100. Cidade Universitária. Ilha do Fundão. Rio de Janeiro, RJ, Brazil. CEP: 19.44-970. E-mail: pkale@iesc.ufrj.br

[3] Instituto de Saúde Coletiva. Universidade Federal Fluminense. Niterói, RJ, Brazil.

Abstract

Objectives: to analyze the causes of maternal death (MD) and maternal late death (LMD), emphasizing the H1N1 and COVID-19 pandemics.

Methods: ecological study using data from national mortality and live birth systems. Causes were described according to the WHO Maternal Causes Classification (ICD-MM). Maternal, late, and comprehensive mortality ratios were calculated per 100,000 live births with 95% confidence intervals (CI).

Results: during pandemics, comprehensive mortality was higher: 104.6 (95%CI=95.3;114.5) in 2009-2010 (H1N1), 143.9 (95%CI=132.2;156.2) in 2020-2021 (COVID-19). Between 2020 and 2021, the indicator rose 33.5%. Direct causes predominated except in 2020–2021. The leading direct causes were hypertensive disorders, other obstetric complications, abortion, and hemorrhage. During pandemics, mortality due to hypertensive disorders increased, and among indirect causes, respiratory diseases in 2009-2010 (14.5; 95%CI=11.3–18.5) and other viral infections, mainly coronavirus (55.6; 95%CI=48.5–63.4), in 2020–2021 were prominent.

Conclusion: the comprehensive indicator more accurately quantifies the risk of death. Assigning specific causes to late maternal deaths and applying the ICD-MM classification can guide targeted prevention strategies.

key words *Maternal mortality, Cause of death, Influenza A virus, H1N1 subtype, COVID-19, Hypertension*

Introduction

Maternal death is defined as the death of a woman resulting from a condition related to or aggravated by pregnancy, occurring in the pregnancy-puerperal cycle (pregnancy, childbirth, or within 42 days of termination of pregnancy).[1,2]

For 2020 and 2021, the maternal mortality ratio (MMR) per 100,000 live births (LB) in Brazil reached 74.7 and 117.4, respectively. The main causes of death showed little variation, except for COVID-19, which experienced an atypical increase in recent years.[3]

The leading causes of maternal death are from the direct obstetric group: hemorrhage and hypertensive disorders are the dominant causes, followed by infections, other obstetric causes, and unsafe abortion.[4] There are differences in distribution, and for Latin America and the Caribbean, hypertensive diseases are particularly notable.[4] In Brazil, and especially in the State of Rio de Janeiro, the main direct cause was hypertensive disease of pregnancy.[5,6] In 2012, the World Health Organization developed a classification of causes of maternal death that facilitates the interpretation of mortality statistics and directs prevention measures (WHO ICD-MM).[7]

Pregnancy can trigger cardiovascular disease, aggravate underlying disease, or cause specific diseases that can manifest from 1 to 3 months after childbirth.[8] Although most maternal deaths occur during the pregnancy-puerperal cycle, the disease burden will be underestimated when only this period is considered, excluding deaths occurring after 42 days that do not make up the maternal mortality ratio indicator.[2,8] Late maternal mortality (LMM) includes obstetric maternal deaths from 43 days to less than one year after childbirth. They are also mostly preventable, and point to the need to extend the follow-up time in the postpartum period, especially for women at higher risk.[8-13] In Brazil, an increasing trend in the LMM ratio was observed from 1999 to 2013, and a mean annual percentage variation of 9.8% from 2010 to 2019.[12] A new indicator – comprehensive maternal deaths – combines maternal deaths and late maternal deaths.[13,14]

The assignment of O96 code (International Classification of Diseases - ICD-10) as the underlying cause of late maternal death does not clarify whether the causes were direct or indirect, nor does it help define specific preventive actions.[1] Therefore, studying the associated causes of late maternal death (O96) becomes relevant.

There are a few studies on the causes of death associated with late postpartum. In Brazil, in 2002, among the 239 cases of maternal death studied, 13.8% were late deaths (n=33), mainly due to postpartum complications, with emphasis on cardiomyopathy, followed by hypertension complicating pregnancy or hypertensive diseases of pregnancy, and circulatory diseases complicating pregnancy.[2] In other countries, the study of late maternal death causes has made progress.[15-18]

The pandemics of influenza (H1N1) in 2009 and 2010, and COVID-19 (SARS-CoV-2) ten years later, impacted the magnitude and distribution of causes of maternal mortality worldwide and in Brazil.[3,19-27] In the USA, 12% of pregnancy-related deaths were attributed to influenza A (H1N1 pdm09) during the 2009–2010 pandemic season, and, among these deaths, 13.7% occurred 42 or more days after delivery.[19] In 2009, the incidence of influenza in Brazil was 28.0/100,000, with a rate of 97/100,000 among pregnant women, and a case-fatality rate of 6.9%.[20] In a Brazilian multicentric study, those who presented severe respiratory disease and tested positive for H1N1 had a worse outcome, with 28.6% dying.[21] As to COVID-19, many studies showed a substantial risk of maternal mortality.[22-27]

This study analyzed the causes of maternal deaths and the causes associated with late maternal deaths in the State of Rio de Janeiro from 2009 to 2021, with an emphasis on the H1N1 and COVID-19 pandemic periods.

Methods

This is a descriptive ecological study of maternal mortality, with an emphasis on late mortality and causes of death, among women living in the State of Rio de Janeiro, from 2009 to 2021.

The data sources were the Mortality Information System - State and Federal SIM (Maternal Death Investigation Module) and the Live Birth Information System (Sinasc). The Rio de Janeiro State Health Department provided databases in June 2022.

The causes of maternal death (during pregnancy or up to the 42nd day after its end) correspond to the codes in chapter XV of the ICD-10, plus codes A34, B20 to B24, D39.2, E23.0, F53, and M83.0 outside chapter XV, when these causes have led to death during the pregnancy-puerperal cycle.[1] Since 2013, the World Health Organization has attributed the code O98.7 to maternal deaths related to HIV/aids. We consider this for the entire analysis period. Deaths due to direct obstetric causes correspond to the ICD 10 codes O00.0 to O08.9, O11 to O23.9, O24.4, O26.0 to O92.7, D39.2, E23.0, F53 and M83.0.), indirect to codes O10.0 to O10.9, O24.0 to O24.3, O24.9, O25, O98.0 to O99.8, A34, B20 to B24), and unspecified to code O95. The underlying cause of late maternal death corresponds to code O96 from chapter XV of ICD-10, without specifying the direct or indirect obstetric causes.

Two authors of this study, who are employees of the State Health Department, have expertise in coding causes of death and reviewing the connections among them. They accessed the Mortality Information System (SIM) and identified late maternal deaths (from 42 to 364 days after the delivery). For each of late maternal deaths, they analyzed all the coded causes declared on parts I and II of the Death Certificate, disregarded the O96 code, and reconstructed the sequence of events leading to death. The automated selection rules of the SIM were applied, which allowed for the assignment of an associated cause of late maternal death as the underlying cause. These selection rules are used in routine analyses by the State Health Department through SIM, helping to reduce the risk of misclassifying the deaths under study. Those deaths for which the associated cause was external (Chapter XX) were excluded from this analysis due to the inability to associate them, either directly or indirectly, with the pregnancy-puerperal cycle. These deaths were classified as "deaths due to external causes occurring in the late postpartum period.

Obstetric causes (chapter XV) of maternal (underlying cause) and late deaths (cause associated with O96, which corresponds to the underlying cause in its absence) were analyzed according to an adapted ICD-MM classification.[6] The ICD-MM classification of maternal death causes groups obstetric causes into direct, indirect, and unknown.[7] The direct causes are grouped into six categories: 1- Abortion (O00-O07), 2- Hypertension (O11-O16), 3- Hemorrhages (O20; O43-O46; O67; O71.0; O71.1, O71.3, O71.4, O71.7; O72), 4- Infections (O23; O41.1; O75.3; O85-O86; O91), 5- Other obstetric complications (O21.1, O21.2; O22; O24.4; O26.6, O26.9; O41.0, O41.8, O71.2, O71.5, O71.6, O71.8, O71.9; O73; O75.0-O75.2, O75.4-O75.9; O87.1, O87.3, O87.9; O88; O90); 6- Unanticipated complications, generally related to anesthetic procedures (O29; O74; O89). The indirect causes are represented by group 7, consisting of all non-obstetric complications (O10; O24.0, O24.2, O24.3, O24.9; O98 [including B20-24, recoded as O98.7], O99), and the unknown causes, group 8, by the ICD O95 code. Group 9, corresponding to causes of death occurred during pregnancy, childbirth, and the postpartum period due to external causes (coincident causes) was not analyzed. Mendonça et al.[6] adapted the original ICD-MM,[7] including the codes O30-O36, O40, O41.9, O42; O60-061 and O63-066 in group 5.[6] Since 2012, the WHO has suggested the use of code O98.7 to classify indirect obstetric maternal deaths from HIV/aids.[7] In Brazil, the SIM began to classify HIV/aids outside Chapter I (B20-B24) as code O98.7 (Chapter XV) from 2020. We adopted the code O98.7 for maternal and late maternal deaths to the entire analysis period.

The absolute and percentage distributions of maternal, late maternal, and comprehensive maternal deaths (sum of the two previous ones) were described. The maternal mortality ratio (MMR) and late maternal mortality ratio (LMMR) were calculated accordingly (quotient between maternal and late maternal deaths, respectively, and LB, multiplied by 100,000), and the comprehensive maternal mortality ratio (CMMR) (quotient between the sum of the number of maternal and late maternal deaths and the number of LB, multiplied by 100,000), along with their respective 95% confidence intervals (CI95%). Proportional mortality according to the ICD-10 chapter was described for maternal deaths (underlying cause) and late maternal deaths (associated/underlying cause). MMR, LMMR and CMMR were calculated according to the adapted ICD-MM classification (obstetric causes from Chapter XV and main groupings and specific causes up to 4 digits). Relative differences in CMMR between each pandemic period (H1N1 and COVID-19) and the interpandemic period were calculated.

The analyses were conducted annually and, in an aggregated form, in two-year periods during the H1N1 and COVID-19 pandemic years – 2009/10 and 2020/21 – and in order to characterize the pandemic periods (H1N1 and COVID-19) and no pandemic period, the following three-year periods between the two pandemics -2011 to 2013; 2014 to 2016; and 2017 to 2019, as well as the total interpandemic period, from 2011 to 2019.

This study was approved by the Research Ethics Committee of the *Universidade Federal Fluminense* (CAAE: 71323023.0.0000.5243; n° 6.592.725). The public workers and authors of the study accessed the SIM (Mortality Information System) at the Rio de Janeiro State Health Department, using data not identified by name, preserving privacy and confidentiality.

Results

There were 2,778 maternal deaths from gestation to 364 days after delivery (comprehensive maternal deaths), in the State of Rio de Janeiro, from 2009 to 2021. The MMR in the H1N1 (2009/2010) and COVID-19 (2020/2021) pandemic years was higher than in the period from 2011 to 2019. LMMR was high in 2011, shortly after the H1N1 pandemic, in the 2017/2019 period (contributing to 17.6% of total deaths), and rose more sharply in the two years of the COVID-19 pandemic. The behavior of the CMMR was strongly influenced by that of the MMR (Table 1). From 2020 to 2021, the CMMR increased by 33.5%, mainly due to maternal deaths, with no overlap between the respective 95% CI. The same behavior is observed by comparing the COVID-19 pandemic CMMR with all other periods, including the H1N1 pandemic. On the other

Table 1

Live births, maternal mortality (deaths and MMR), late maternal mortality (deaths and LMMR), comprehensive maternal mortality (deaths and CMMR), State of Rio de Janeiro, 2009 to 2021.

Year/ period	Live Births (n)	Maternal Mortality			Late maternal mortality			Comprehensive maternal mortality	
		deaths (n)	%	MMR (IC95%)	deaths (n)	%	LMMR (95%CI)	deaths (n)	CMMR (95%CI)
2009	217280	224	92.6	103.1 (90.2;117.3)	18	7.4	8.3 (5.1;12.8)	242	111.4 (98.0; 126.1)
2010	215916	189	89.6	87.5 (75.7;100.7)	22	10.4	10.2 (6.6;15.2)	211	97.8 (85.2; 111.6)
2009/10	433196	413	91.2	95.3 (86.5;104.9)	40	8.8	9.2 (6.7;124.5)	453	104.6 (95.3; 114.5)
2011	221277	164	83.2	74.1 (63.4;86.1)	33	16.8	14.9 (10.4;20.7)	197	89.0 (77.23;102.1)
2012	223422	186	87.7	83.3 (71.9;95.9)	26	12,3	11.6 (7.8;16.8)	212	94.9 (82.8;108.3)
2013	224745	193	87.3	85.9 (74.4;98.7)	28	12.7	12.5 (8.4;17.8)	221	98.3 (86.0;112.0)
2011/13	669444	543	86.2	81,1 (74,5;88,2)	87	13.8	13.0 (10.5;16.0)	630	94.1 (87.0;101.7)
2014	234281	175	86.7	74.7 (64.2;86.4)	27	13.4	11.5 (7.8;16.5)	202	86.2 (74.9; 98.8)
2015	237591	167	86.5	70.3 (60.2;81.6)	26	13.5	10.9 (7.3;15.8)	193	81.2 (70.4; 93.3)
2016	219711	156	84.3	71.0 (60.5;82.8)	29	15.7	13.2 (9.0;18.7)	185	84.2 (72.7; 97.0)
2014/16	691583	498	86.0	72.0 (65.9;78.6)	82	14.0	11.9 (9.5;14.6)	580	83.9 (77.3; 90.9)
2017	223415	173	84.4	77.4 (66.5;89.6)	32	15.6	14.3 (10.0;20.0)	205	91.8 (79.8;105.0)
2018	221045	136	78.2	61.5 (51.8;72.5)	38	21.8	17.2 (12.3;23.4)	174	78.7 (67.6;91.1)
2019	208677	149	84.2	71.4 (60.6;83.6)	28	15.8	13.4 (9.0;19.1)	177	84.8 (73.0; 98.0)
2017/19	653137	458	82.4	70.1 (63.9;76.8)	98	17.6	15.0 (12.2;18.2)	556	85.1 (78.3; 92.4)
2020	199550	187	81.7	93.7 (80,9;107.9)	42	18.3	21.0 (15.4;28.2)	229	114.8 (100.6; 130.4)
2021	188989	288	87.3	152.4 (135.5;170.8)	42	12.7	22.2 (16.2;29.8)	330	174.6 (156.5; 194.2)
2020/21	388539	475	85.0	122.3 (111.6;133.6)	84	15.0	21.6 (17.4;26.6)	559	143.9 (132.2; 156.2)

hand, the CMMR in the three-year periods was similar, with the 95%CI overlapping, suggesting stability of the indicator (Table 1).

Figure 1 illustrates the distribution of maternal and late maternal deaths by cause, according to the ICD chapter. Chapter XV predominated in maternal and late maternal deaths. The non-obstetric causes of maternal death were only one in Chapter II (Neoplasms) and one in Chapter V (Mental and Behavioral Disorders; Nutritional and Metabolic Disorders). For late maternal deaths, outside chapter XV, in the last two years, one death occurred due to external causes.

Considering only Chapter XV and applying ICD-MM classification, all mortality ratios (MMR, LMMR, CMMR) are higher for direct than for indirect causes, except in the final two-year period (COVID-19 pandemic), when this relationship is reversed for MMR, LMMR, and CMMR (Figure 2). Non-specific causes (O95) remained relatively stable, higher in the maternal component from 2011 to 2013. Among the CMMR due to direct causes, hypertensive causes and other obstetric complications stand out, and only from 2017 to 2019 did hemorrhages overtake other obstetric complications, which took third place.

The distribution profile of causes, the main groupings and specific causes (up to 4 digits), and the relative differences of the CMMR are presented for: A) the H1N1 period (2009/10) versus interpandemic period (2011/19), and B) the COVID-19 period versus the interpandemic period (2011/19) (Tables 2 and 3).

Hypertensive causes prevailed among direct obstetric causes, mainly due to gestational hypertension with proteinuria (O14), eclampsia (O15), and unspecified maternal hypertension (O16). In the H1N1 pandemic, the CMMR of the O16 category was higher (2.4 times) than in the inter-pandemic period, and, within the group of obstetric complications, the MMR of uterine contraction abnormalities (O62) was double (Table 2). In the COVID-19 period, the CMMR for severe pre-eclampsia (O14.1) almost doubled (1.8 times) the values of the interpandemic period (Table 2).
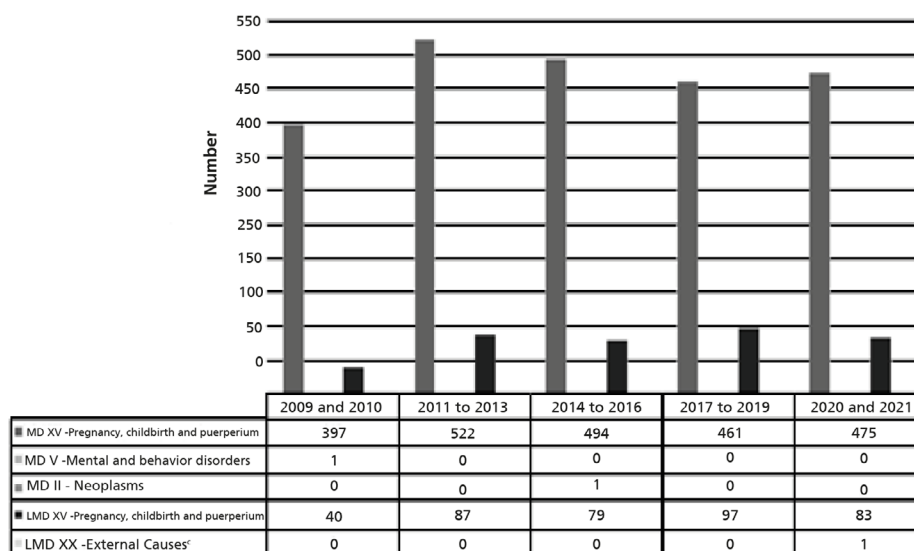
Among indirect causes, the H1N1 pandemic, respiratory system diseases (O99.5) predominated, and the respective CMMR was 3.8 times that of the 2011-2019 period (Table 3). During the COVID-19 pandemic, the CMMR for indirect causes nearly doubled compared to the inter-pandemic period. Notably, this relative difference was approximately 160 for other viral diseases (O98.5), including coronavirus infection. (Table 3).

Discussion

This study, in addition to corroborating the impact of respiratory viruses' pandemics on the magnitude and profile of maternal mortality, highlighted late maternal mortality, which is increasing in the country[12] and the State of Rio de Janeiro, and is also affected by pandemics. The proportional contribution of late deaths reached 17.6% of total deaths in the 2011-2019 period, and there was a rise

Figure 1

Distribution of maternal death (MD)[a] and late maternal deaths (LMD)[b] by causes according to ICD-10 chapter and period in the State of Rio de Janeiro, 2009 to 2021.

|	2009 and 2010	2011 to 2013	2014 to 2016	2017 to 2019	2020 and 2021
MD XV -Pregnancy, childbirth and puerperium	397	522	494	461	475
MD V -Mental and behavior disorders	1	0	0	0	0
MD II - Neoplasms	0	0	1	0	0
LMD XV -Pregnancy, childbirth and puerperium	40	87	79	97	83
LMD XX -External Causes[c]	0	0	0	0	1

[a] Maternal death from pregnancy up to 42nd days after childbirth; [b] Late maternal death - from 43 days up to less than one year after childbirth; [c] One late maternal death due to external causes was not investigated.

Note: All maternal and late maternal deaths by HIV disease (codes B20-B21- Chapter I) were computed as Some Infectious and Parasitic Diseases and HIV disease complicating pregnancy/childbirth/puerperium (code - O98.7 – Chapter XV) in the entire period (2009/2021).

Figure 2

Maternal Mortality Ratio (MMR), Late Maternal Mortality Ratio (LMMR) and Comprehensive Maternal Mortality Ratio (CMMR) per 100,000 live births by obstetric causes and period. Rio de Janeiro, 2009 to 2021.
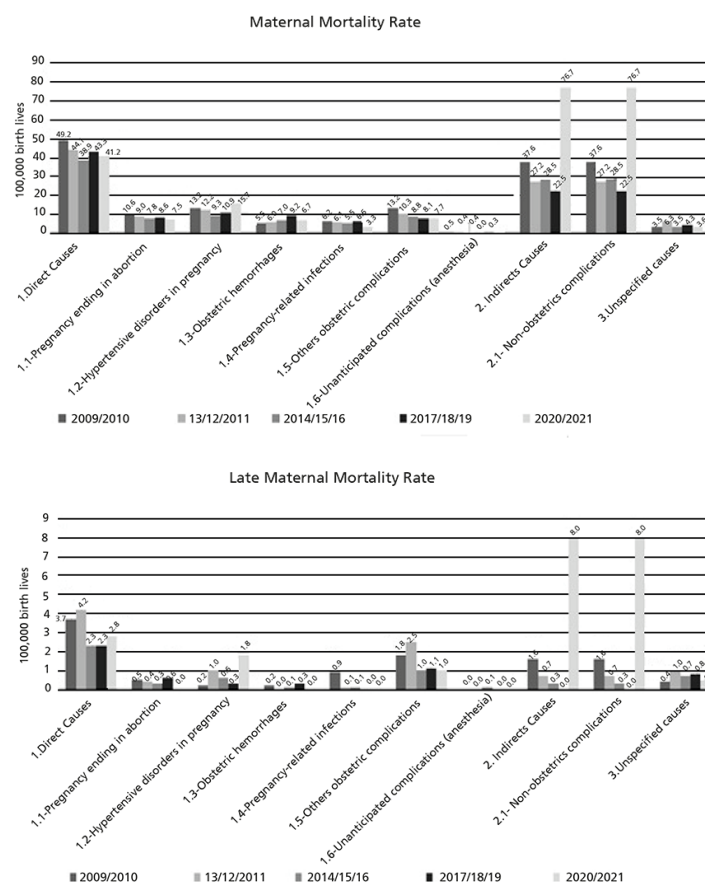
Note: All maternal and late maternal deaths by HIV disease (codes B20-B21- Chapter I) were computed as Some Infectious and Parasitic Diseases and HIV disease complicating pregnancy/childbirth/puerperium (code - O98.7 - Chapter XV) in the entire period (2009/2021).

Table 2

Comprehensive Maternal Mortality Ratio (CMMR) per 100,000 live births according to direct obstetric causes by grouping and main specific causes up to 4 digits, and the CMMR ratio. Rio de Janeiro, 2009 to 2021.

Direct Causes	2009/2010		2011/2019		2020/2021		CMMR Ratio	
	CMMR	95%CI	CMMR	95%CI	CMMR	95%CI	A[a]	B[b]
1- Pregnancy ending in abortion	11.1	8.3;14.6	8.9	4.2;4.8	7.5	5.1;10.6	1.2	0.8
Ectopic pregnancy (O00)	2.5	1.3;4.4	2.4	1.8;3.2	1.5	0.6;3.2	1.0	0.6
- Tubal Pregnancy - O00.1	2.5	1.3;4.4	2.3	1.7;3.1	1.3	0.5;2.9	1.1	0.6
2- Hypertensive disorders	13.4	10.3;17.2	11.4	10.0;13.0	17.5	13.7;22.1	1.2	1.5
Gestational hypertension with proteinuria (O14)	5.1	3.3;7.6	4.7	3.8;5.7	9.0	6.4;12.4	1.1	1.9
- Severe pre-eclampsia - O14.1	1.6	0.7;3.2	2.8	2.1;3.6	4.9	3.0;7.5	0.6	1.8
Eclampsia (O15)	4.4	2.7;6.7	4.3	3.4;5.3	6.2	4.0;9.1	1.0	1.4
- Unspecified eclampsia - O15.9	3.2	1.8;5.3	2.0	1.4;2.7	2.6	1.3;4.6	1.6	1.3
Maternal hypertension NE (O16)	2.8	1.5;4.7	1.1	0.7;1.9	0.5	0.1;1.7	2.4	0.5
3- Obstetric hemorrhages	5.8	3.8;8.4	7.5	6.4;8.8	6.7	4.5;9.7	0.8	0.9
Postpartum hemorrhage (O72)	2.8	1.5;4.7	3.4	2.6;4.3	2.6	1.3;4.6	0.8	0.8
-Other immediate postpartum hemorrhages-O72.1	0.9	0.3;2.2	2.3	1.7;3.0	1.3	0.5;2.9	0.4	0.6
4- Pregnancy-related infections	7.2	4.9;10.0	6.2	5.1;7.3	3.3	1.9;5.6	1.2	0.5
Puerperal Infection (O85)	2.3	1.2;4.1	3.2	2.5;4.1	1.5	0.6;3.2	0.7	0.5
Other Puerperal Infection (O86)	1.8	0.9;3.5	1.4	0.9;2.0	1.3	0.5;2.9	1.3	0.9
5-Other obstetric complications	15.0	11.7;1.9	10.6	9.2;12.1	8.8	6.2;12.1	1.4	0.8
Abnormalities of uterine contraction (O62)	3.5	2.0;5.6	1.7	1.2;2.4	1.5	0.6;3.2	2.0	0.9
- Other forms of uterine inertia - O62.2	3.5	2.0;5.6	1.7	1.2;2.4	1.5	0.6;3.2	2.0	0.9
Obstetric origin embolism (O88)	3.5	2.0;5.6	3.9	3.0;4.8	3.1	1.7;5.2	0.9	0.8
- Obstetric embolism due to blood clot - O88.2	1.6	0.7;3.2	2.0	1.4;2.7	1.5	0.6;3.2	0.8	0.8
Postpartum complications (O90)	5.1	3.3;7.6	3.8	3.0;4.7	3.1	1.7;5.2	1.3	0.8
- Cardiomyopathy - O90.3	4.4	2.7;6.7	3.3	1.2;6.2	2.6	1.3;4.6	1.3	0.8
6 – Unanticipated complications	0.5	0.8;15.3	0.3	0.2;0.7	0.3	0.0;1.2	1.3	1.0
Total	52.9	46.3;60.1	45	23.6;61.6	44	37.8;51.0	1.2	1.0

95%CI= Confidence Interval of 95%; [a] CMMR A (ratio 2009-2010/2011-2019); [b] CMMR B (ratio 2020-2010/2021-2019).

of LMMR, although less intense than for MMR, during the COVID-19 pandemic.

Surveillance and statistical monitoring of late maternal deaths are complex tasks.[2] In Brazil, the systematic investigation of maternal deaths and deaths of women of reproductive age initiated in 2008, revealed an upward trend in late maternal mortality. This behavior was similar to that observed in European countries with established surveillance systems, such as France, the United Kingdom, and the Netherlands, where late maternal deaths have also shown a growing contribution to overall maternal mortality.[15,17,28] Particularly in the State of Rio de Janeiro, this pattern persisted even when the COVID-19 pandemic years were excluded.

According to Diguisto *et al.*,[28] among European countries with enhanced maternal mortality surveillance, only France and the United Kingdom routinely include late maternal deaths in their analyses. However, methodological differences across countries persist, largely due to the limited specificity of ICD-MM guidelines for classifying these deaths, reinforcing the need for greater standardization in international comparisons.[28]

A 2025 study based on Global Burden of Disease estimates for 204 countries showed that, although overall maternal deaths have markedly declined since 1990, the reduction in late maternal deaths has been much smaller, indicating a proportionally greater burden of this component. The analysis also demonstrated an inverse relationship between late maternal deaths and the sociodemographic index (SDI): countries with lower SDI values tend to experience higher rates, but when improvements occur, the decline is proportionally greater.

Table 3

Comprehensive Maternal Mortality Ratio (CMMR) per 100.000 live births by indirect obstetric causes grouped and main specific causes up to 4 digits and non-specific causes and CMMR ratio. Rio de Janeiro, 2009 to 2021.

Causes	2009/2010		2011 - 2019		2020/2021		CMMR Ratio	
	CMMR	95%CI	CMMR	95%CI	CMMR	95%CI	A[a]	B[b]
Indirect Causes	39.2	33.7;45.5	43.0	39.6;46.6	84.7	75.9;94.2	0.9	2.0
7 – Non-obstetric complications	39.2	33.7;45.5	43.0	39.6;46.6	84.7	75.9;94.2	0.9	2.0
1 Maternal infectious and parasitic diseases complicating pregnancy. childbirth and the puerperium (O98)								
- Tuberculosis complicating pregnancy/childbirth/puerperium - O98.0	2.3	1.2;4.1	1.1	0.7;1.6	1.0	0.3;2.5	2.1	0.9
- Viral hepatitis complicating pregnancy/childbirth/puerperium - O98.4	4.6	0.8;15.3	0.0	0.0;0.2	0.3	0.0;1.3	93.0	5.2
- Other viral diseases - O98.5	4.6	0.8;15.3	0.3	0.2;0.7	55.6	48.5;63.4	13.3	160.0
- HIV disease complicating pregnancy/childbirth/puerperium - O98.7	3.2	1.8;5.3	3.6	2.7;4.7	1.8	0.8;3.6	0.9	0.5
- Other maternal infectious diseases - O98.8	9.2	2.9;22.3	2.1	1.5;2.8	8.8	6.2;12.1	4.4	4.2
2 Other maternal diseases complicating pregnancy. childbirth and the puerperium (O99)								
- Diseases of the circulatory system - O99.4	6.9	4.8;9.8	6.5	5.5;7.7	6.4	4.2;9.4	1.1	1.0
- Diseases of the respiratory system - O99.5	14.5	11.3;18.5	3.8	3.0;4.7	2.6	1.3;4.6	3.8	0.7
- Other diseases and nonspecific conditions - O99.8	3.7	1.7;5.0	5.1	4.1;6.1	3.3	1.1;4.2	0.7	0.7
Unspecified causes (O95)	3.9	2.4;6.2	5.5	4.6;6.6	4.1	2.4;6.6	0.7	0.7

95%CI= Confidence Interval of 95%; [a] CMMR A (ratio 2009-2010/2011-2019); [b] CMMR B (ratio 2020-2010/2021-2019).

Note: All maternal and late maternal deaths by HIV disease (codes B20-B21- Chapter I) were computed as Some Infectious and Parasitic Diseases and HIV disease complicating pregnancy/childbirth/puerperium (code - O98.7 – Chapter XV) in the entire period (2009/2021).

In Brazil, the study identified the State of Rio de Janeiro as having one of the highest national ratios of late maternal deaths, consistent with the findings of the present study.[29]

Few countries monitor late maternal deaths, according to the Global Burden of Disease study (GBD).[30] The group of experts on maternal mortality of GBD analyzed late maternal death as both a timing category and as a distinct cause because the underlying causes of late maternal deaths are not specified in most data sources. Only a few countries reliably use ICD-10 to code late maternal deaths, despite understanding its significance.

The assignment of an associated cause of late maternal death as the underlying cause, helped to understand this phenomenon and to subsidize health interventions. Direct causes also prevailed among these deaths, except in the COVID-19 years. While hypertensive disorders predominate in maternal deaths, other obstetric complications are more frequent in late maternal deaths, with cardiomyopathy standing out, as in the pioneer study of Laurenti et al.[2] Only in 2020/2021 were hypertensive disorders in the first position for direct late maternal deaths. In Italy, suicide and malignancies are the main causes of late maternal deaths, followed by cardiovascular diseases;[15,17] in the Netherlands, cardiac diseases predominated;[16] and in France and the United Kingdom, cardiovascular disease and suicide.[27] In these

European countries, suicide is considered a direct cause of maternal death, being one of the most frequent causes for late maternal deaths. In our study, we excluded external causes associated with late death, which may limit the comparability of results.

As we adopted the code O98.7 to maternal and late maternal death related to HIV/aids, practically all deaths were inside Chapter XV and classified by the ICD-MM.

In the GBD study, AIDS-related deaths were found to commonly occur 42 days or more after the end of pregnancy. Therefore, care efforts for HIV-positive mothers should prioritize ensuring uninterrupted antiretroviral treatment.[29]

The use of the adapted ICD-MM classification, extended to include late maternal deaths, proved valuable for describing mortality causes over a long observation period. In the United States, applying this classification clarified the impact of the COVID-19 pandemic, revealing a notable rise in maternal mortality from both direct and indirect obstetric causes—particularly viral, respiratory, and circulatory diseases—as well as hypertensive disorders.[22] Overall, maternal mortality due to obstetric causes, including late deaths, increased substantially during the pandemic. Similar patterns were observed in our study, where both the H1N1 and COVID-19 pandemics affected maternal and late maternal mortality

in comparable ways, consistent with the findings of Thoma *et al.*[23]

The changes of maternal deaths during the COVID-19 pandemic may be related directly to viral or respiratory infection by the coronavirus or indirectly by exacerbation of morbid conditions, such as diabetes and cardiovascular diseases,[23] in addition to worsening of existing care problems, such as difficulty in accessing health services, change in prenatal care services organization, delays in starting prenatal care and in caring for pregnant women with respiratory symptoms.[21-24] The delay in including pregnant and postpartum women in the priority groups for vaccination, as well as the two-month suspension of vaccination in these women with no comorbidities, coincided with the second wave of COVID-19, in which the Gamma variant of SARS-CoV-2 prevailed, with high dissemination, contributing to excess maternal mortality.[24-26] In 2021, the national MMR doubled compared to the previous pandemic year.[3,25]

The importance of hypertensive disorders as a cause of maternal and late deaths is longstanding, despite improvements in prenatal care and childbirth assistance.[2,6,23] In this study, the CMMR due to hypertensive disorders was among the second and third highest risks of death, with pre-eclampsia and eclampsia being the main causes. Furthermore, hypertensive diseases accounted for half of the late deaths during the COVID-19 pandemic in the State of Rio de Janeiro.

This study presents some limitations inherent to the use of secondary data, such as possible inaccuracies in coding and death certificate completion, which may affect the identification of late maternal deaths. Nevertheless, the consistent application of national classification criteria and the reanalysis of cases coded as O96 helped minimize misclassification and strengthen the reliability of the findings.

A major contribution of this study was the reassignment of specific causes to late maternal deaths, qualifying the information traditionally limited by the O96 code. The development and use of a comprehensive maternal mortality indicator, combining deaths occurring during pregnancy and up to one year postpartum, allowed a broader understanding of the maternal health burden and highlighted preventable causes that are often overlooked.

In public health terms, two actions are recommended. First, late maternal deaths should be routinely incorporated into surveillance systems, expanding the scope of existing monitoring frameworks. Second, postpartum care should extend beyond the conventional 42-day period, ensuring clinical follow-up for at least the first three months after delivery, when cardiovascular, hypertensive, and respiratory complications are more frequent. Such measures would enhance prevention and contribute to reducing maternal mortality in Brazil.

Authors' contribution

Belizzi ALM: Conceptualization (Equal); Formal Analysis (Equal); Investigation (Equal); Methodology (Equal); Project Administration (Equal); Writing original draft (Equal); Writing - review & editing (Equal).

Kale PL: Conceptualization (Equal); Formal Analysis (Equal); Data curation (Lead); Investigation (Equal); Methodology (Equal); Supervision (Equal); Validation (Equal); Writing original draft (Equal); Writing - review & editing (Equal).

Fonseca SC: Conceptualization (Equal); Formal Analysis (Equal); Methodology (Equal); Writing original draft (Equal); Writing - review & editing (Equal).

Cascão AM: Conceptualization (Equal); Formal Analysis (Equal); Data curation (Equal); Investigation (Equal); Methodology (Equal); Supervision (Equal); Validation (Equal); Writing original draft (Equal); Writing - review & editing (Equal).

All authors approved the final version of the article and declare no conflict of the interest.

Data availability

All datasets supporting the result of this study are included in the article.

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